



Department of
Primary Industries
Water

Rural floodplain management plans

Water Management Act 2000

Background document to the Floodplain Management
Plan for the Barwon-Darling Valley Floodplain 2017

Appendices

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Abbreviations

ABS	Australian Bureau of Statistics
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
AEP	Annual exceedance probability
AHIMS	Aboriginal Heritage Information Management System
ASDST	Aboriginal Sites Decision Support Tool
COAG	Council of Australian Governments
DEM	Digital Elevation Model
DPIW	NSW Department of Primary Industries, Water
Barwon-Darling Valley FMP	Floodplain Management Plan for the Barwon-Darling Valley Floodplain 2017
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
FM	Flexible Mesh
FMP	floodplain management plan
GVAP	Gross Value of Agricultural Production
IRP	Interagency Regional Panel
IRSAD	Index of Relative Socio-economic Advantage and Disadvantage
LiDAR	Light Detection and Ranging
LPI	Land and Property Information
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MODIS	Moderate Resolution Imaging Spectrometer
MZ A	Management Zone - Major Discharge Areas, Defined Floodways
NDVI	Normalised Difference Vegetation Index
NSW	New South Wales
NSW DPI	NSW Department of Primary Industries
OEH	NSW Office of Environment and Heritage
PCT	Plant Community Type
SDM	Species distribution model
SEIFA	Socio-economic Indexes for Areas
SF	Selection frequency
TAG	Technical Advisory Group
TSC Act	<i>Threatened Species Act 1995</i>
WA 1912	<i>Water Act 1912</i>
WMA 2000	<i>Water Management Act 2000</i>

Appendix 1: Rural floodplain management planning approach under the Water Management Act 2000 (WMA 2000)

Step	Key Inputs/Process	Key Outputs/Outcomes
1 – Define the floodplain boundary	<ul style="list-style-type: none"> Information on the nature and extent of flooding over time Floodplains designated under Part 8 of the <i>Water Act 1912</i> (WA 1912) Other statutory boundaries and infrastructure features (e.g. water sharing plans, roads, floodplain harvesting register of interest areas) 	Map of floodplain boundary to be designated under the WMA 2000
2- identify existing flood works	<ul style="list-style-type: none"> Flood-work licences Area of land protected by flood works identified from spatial data such as flood imagery, LiDAR and aerial photography Local knowledge of DPIW licensing officers 	<ul style="list-style-type: none"> Map of area of land protected by flood works Number of existing approved flood work licences
3 – review existing rural floodplain management arrangements	<ul style="list-style-type: none"> First generation floodplain development guidelines and studies (non-statutory) Second generation rural floodplain management plans (FMPs) (WA 1912) 	Information on and analysis of key aspects of existing rural floodplain management arrangements
4 – determine the floodway network	<ul style="list-style-type: none"> Design floods Flood frequency analysis Hydrological/Hydraulic model input Flood imagery Existing floodway networks (Step 3) Local knowledge 	<ul style="list-style-type: none"> Map of floodway network, including floodways, inundation extent and areas outside the floodway network Better understanding of existing flooding regime
5 – identify and prioritise floodplain assets	<ul style="list-style-type: none"> Identified from peer-reviewed literature, relevant legislation, policies, databases and registers Various spatial data (e.g. plant community type mapping) Optimum watering requirements Conservation significance of assets determined from the Technical Advisory Group and Marxan Cultural assets also identified from Aboriginal Technical Advisory Working Group and community consultation 	<ul style="list-style-type: none"> Definition and maps of ecological and cultural assets Grouping of ecological assets based on optimum watering requirements Understanding of flood-dependency of cultural assets Map of high-priority floodplain assets
6 – prepare a	<ul style="list-style-type: none"> Secondary data sources (Australian Bureau of 	Understanding of the baseline profile

socio-economic profile	<p>Statistics (ABS), ABARES, State departments)</p> <ul style="list-style-type: none"> Local knowledge 	of the floodplain, including stakeholder identification
7 – delineate management zones	<ul style="list-style-type: none"> Hydraulic criteria based on information from Steps 1, 2 and 4 Criteria to ensure appropriate consistency between current and proposed management options based on information from Step 3 Ecological and cultural criteria based on information from Step 5 Analysis to ensure equity based on information from Step 6 Feedback from consultation 	<p>Definition and map of management zones, which will generally result in four zones:</p> <ul style="list-style-type: none"> Major flood discharge Flood storage and secondary flood discharge Flood fringe and existing development Special ecological and cultural protection
8 – determine draft rules	<ul style="list-style-type: none"> Understanding of management zones Existing types of flood works Existing and potential flooding problems Rules from existing rural FMPs Feedback from consultation 	<p>Rules and assessment criteria covering:</p> <ul style="list-style-type: none"> Authorised flood works Acceptable impacts Advertising requirements Existing flood works
9 – consider existing floodplain management arrangements	<p>Information on existing floodplain management arrangements gathered in Step 3 is compared against the draft FMP to determine the extent of change.</p>	<p>Extent of change between existing rural floodplain management arrangements and the proposed FMP is determined</p>
10 – assess socio-economic impacts	<ul style="list-style-type: none"> Economic data Area under irrigated crop Gross margins Prices Hydrology data 	<p>Social and economic impacts assessed against the base case</p>
Consultation and review	<ul style="list-style-type: none"> Draft FMP reviewed by Interagency Regional Panel (IRP) at key stages before targeted consultation, public exhibition and plan commencement Consultation with key stakeholders at targeted consultation and the wider community during public exhibition 	<ul style="list-style-type: none"> IRP provide whole-of-government endorsement of the FMP Key stakeholders and the community's feedback is considered in FMP development Information on community concerns and issues gathered
Plan finalised and commenced	<ul style="list-style-type: none"> Revision of socio-economic assessment if required, and impact mitigation strategies 	<p>Final FMP is implemented and plan outcomes are achieved.</p>

Appendix 2: History of floodplain management in the Barwon-Darling Valley Floodplain

Floodplain management planning in the Barwon-Darling Valley Floodplain is evolving in response to changing community needs; changes to land and water use; an increased awareness of the importance of floodplain ecology and changes to the legislative and policy framework which govern water management. A detailed history of floodplain management in the Barwon-Darling Valley Floodplain is outlined below.

Pre-1970s

Before the 1970s, the NSW Government was not actively involved in managing flood-work developments because agriculture was dominated by low-intensity grazing and there was an absence of earthworks that would affect flooding in the landscape.

In 1912, the NSW Government began to take on a legal responsibility for water management by enacting the *Water Act 1912* (WA 1912). At this time, the legislation did not relate to works on flood-prone land remote from a river or lake. However, Part 2 of this Act did provide for the licensing of works which could affect the distribution of floodwaters flowing in, to or from, or contained in, a river or lake. The enactment of the WA 1912 did not initially change floodplain management in the Barwon-Darling. However, this Act would become the principle driver of floodplain management after amendments were made in subsequent decades in response to changes in flood patterns caused by flood works.

From 1960 to 1970, there was a proliferation of uncoordinated channels and levees over large tracts of natural floodplain due to:

- a major program of large dam construction, which led to expectations of an assured water supply
- the consequential replacement of low intensity grazing by intensive irrigation
- a change in Government policy, which encouraged private irrigation development.

1970 to early 1980s

During the early to mid-1970s, major flood events revealed that uncoordinated flood works were causing major changes in traditional flood patterns in many locations. These changes resulted in heavy crop losses and flood damage was experienced in areas that had previously been relatively flood free.

Primarily in response to the major flood events of the early 1970s, the *Water Resources Commission Act* was enacted in 1976 to investigate, formulate and implement flood mitigation strategies on a valley-wide basis. Under the provisions of this legislation, Guidelines, which were levee/floodway schemes, were prepared for the worst-affected areas. The approach aimed to provide floodways of adequate hydraulic capacity and continuity by restoring or maintaining as far as practical, the natural pattern of flood channels for the effective conveyance of flood flows. Flood protection of developed land was accomplished with the construction of levees bordering the floodways and was funded and implemented by the benefiting landholders. The following two guidelines were produced within the Barwon-Darling Valley Floodplain:

- Guidelines for Flood Plain Development Darling River Little Bogan confluence to Yanda Creek confluence. Water Resources Commission (1986a)
- Guidelines for Flood Plain Development Darling River Yanda Creek confluence to Louth. Water Resources Commission (1986b)

While the Guidelines were developed under this Act, they were non-statutory. The generalised network of proposed floodways for the Barwon-Darling Valley Floodplain were delineated on plans that also identified property boundaries and named the respective landholders. Opportunity was provided for the community to comment on the Guidelines.

The general principles that applied in the development of the Guidelines, and generally in the development of levee/floodway schemes, included:

- any system of floodways should conform as closely as possible to the natural drainage pattern;
- land could be protected only if impacts to other properties could be mitigated;
- floodways should discharge from a holding as closely as practicable to the location of natural floodways;
- the exit of floodwater from floodways should be at rates and depths similar to those which would have been experienced under natural conditions;
- ensure sufficient pondage is retained on the floodplain so that the flood wave is not unduly accelerated to downstream areas and its height increased;
- provision should be made for local drainage from protected areas, but the design of such drainage was the responsibility of individual landholders.

Other issues to consider included:

- the possibility of scour within floodways. Land cleared and ploughed for cultivation may increase susceptibility to scour and erosion. Broad floodways were recommended in these areas so that flows to prevent flow concentration leading to scour. Safeguards against scour were a consideration.
- land use type. Certain land use types may impede flows. For example, dense tall crops such as sorghum may impede flood flows leading to increased flood levels. A more desirable crop for a floodway may be a lower crop such as wheat, or a grazing land use.
- potential adverse impacts of flood works on neighbouring properties.

1984-1985

In 1984, the *Flood Prone Land Policy* was introduced to overcome the potential sterilisation of floodplains resulting from rigorous planning controls introduced in the 1977 Environment and Planning Circular No 15. The policy aims to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible. The policy requires a merit approach to be adopted for all development decisions; for both mainstream and overland flooding to be addressed using strategically generated floodplain risk management plans; flood mitigation works and measures to reduce the impact of flooding; and for action to minimise the potential for flood losses to be balanced by the application of ecologically sensitive planning and development controls.

The WA 1912 was also amended in 1984 to include Part 8, which allowed the Ministerial Corporation to control all private works, on the banks of rivers and lakes and on proclaimed floodplains, which could affect the distribution of floodwaters (referred to as controlled works). Controlled works include earthworks, embankments and levees, as well as access roads, irrigation channels and dams. This provision in the legislation allowed for the designation of floodplains, which are areas where controlled-work approvals must be obtained. The introduction of Part 8 of the WA 1912 heralded the beginning of the NSW Government's involvement in legally controlling flood work development and planning to prevent future flood works from causing or exacerbating flooding problems.

1986

In 1986, the *Floodplain Development Manual* was published to support the NSW Government's *Flood Prone Land Policy*. The manual related to the management of flood liable land in accordance with section 733 of the *Local Government Act 1993* which exempted Councils from liability. The manual applies to urban and rural floodplains across New South Wales.

1990 - 1999

In 1995, a general regulation to Part 8 of the WA 1912 was gazetted that prescribed railways (together with associated bridges and railway works) that are vested in Rail Access Corporation, and roads (together with associated bridges and road works) that are vested in a council or in the Roads and Traffic Authority as exempt from needing a controlled work (flood work) approval.

In 1999, Part 8 of the WA 1912 was amended to allow for more strategic coordination of controlled works through the preparation of statutory rural floodplain management plans for valleys faced with pressure from development, such as the Gwydir, Namoi and Macquarie (s.166a). The amendments made rural floodplain management plans the statutory basis for determining flood control works in order to overcome difficulties with assessment of works on an ad-hoc basis. The amendments also allowed for areas not designated as part of a floodplain to be covered by Part 8 of the WA 1912. This meant that works in these areas were required to be assessed if they potentially affected flood flow into and out of a stream. Section 166C of the WA 1912 provided guidelines for the assessment of such works. It was also required that rural plans be developed in accordance with the provisions and policies of the *NSW Floodplain Development Manual* and *NSW Flood Prone Land Policy*. Up until this point, the floodplain development guidelines produced were non-statutory. The new strategy was developed in response to strong community support for a change in the then current practise. A key objective was to develop the floodplain management plans using community-based floodplain management committees. The process for developing the plans included undertaking:

- flood studies to define the nature and extent of flooding and flood-related issues in technical terms
- floodplain risk management studies to evaluate options in consideration of social, environmental and economic factors to address existing and future flood risk and flood management issues
- rural floodplain management plans to outline strategies to manage flood risk and flood management issues and support the natural functions of the floodplain environment.

To facilitate the revised strategy, a \$5 million program was jointly funded by the Natural Heritage Trust and State funding to develop plans in 18 inland rural areas across 30 000 km². The amendment was to outline a new process to deliver strategic outcomes to manage flood control works on inland floodplains where these works did not require Council consent under rural zonings. Where rural floodplain management plans and development guidelines exist, rural plans replaced the out-dated development guidelines.

The floodplain of the Barwon-Darling River from Walgett to Bourke was one of the areas selected for investigation, and a scoping study was undertaken between Walgett and Bourke (DLWC 2001). The study aimed to:

- collate available data on flood behaviour, existing development, and significant flood dependent ecosystems on the Barwon-Darling Valley Floodplain from Walgett to Bourke;
- describe the flood regime and to identify local issues and concerns; and
- establish priority areas within the study area for future floodplain management studies.

However no further flood studies or planning was followed on from this report at that time.

The approval of controlled works (referred to as flood works for the purpose of the Barwon-Darling Valley FMP and including earthworks, embankments or levees) that were likely to affect the flow of water to or from a lake or river, or prevent land from being flooded, or on a designated floodplain (under Part 8 of the WA 1912) were governed by the predecessors to DPIW. The approval of controlled works in the Barwon-Darling designated floodplain was subject to Part 8 conditions.

2000

In 2000, the *Water Management Act 2000* (WMA 2000) was enacted to replace the WA 1912 and a range of other Acts dealing with water management to achieve sustainable and integrated management for all water-based activities, including water use, drainage, floodplains and groundwater. The WMA 2000 is the culmination of the NSW water reform process driven by the Council of Australian Governments (COAG). The WMA 2000 contains floodplain management provisions that relate closely to existing provisions under the amended Part 8. Section 29 and 30 detail the core and additional provisions to be considered when developing floodplain management plans. The core provisions require the plans to deal with:

- identification of the existing and natural flooding regimes in the area, in terms of the frequency, duration, nature and extent of flooding
- the identification of the ecological benefits of flooding in the area, with regard to wetlands and other floodplain ecosystems and groundwater recharge
- the identification of existing flood works in the area and the way they are managed, their benefits in terms of the protection they give to life and property, and their ecological impacts, including cumulative impacts
- the risk to life and property from the effects of flooding.

The general water management principles of the WMA 2000 also require that the cumulative impacts of water management licenses and approvals, and other activities on water sources and their dependent ecosystems, be considered and minimised.

2001

In 2001, the *Floodplain Development Manual* was revised to make it consistent with a series of improvements to both policy and practice, including the need to:

- consider the full range of flood sizes up to and including the probable maximum flood when developing a floodplain risk management plan
- recognise existing, future and continuing flood risk on a strategic rather than ad hoc individual proposal basis
- support local councils to manage local overland flooding in a similar manner to riverine flooding
- promote the preparation and adoption of local flood plans (prepared under the guidance of State Emergency Service) that address flood readiness, response and recovery.

2005 - 2009

In 2005, the *Floodplain Development Manual* was again updated and gazetted, as the manual relating to the development of flood liable land for the purposes of section 733 of the *Local Government Act 1993*. The updates reflected the significant change in the roles of State agencies and clarified some planning issues which had led to inconsistent interpretations. The manual supports the NSW Government's *Flood Prone Land Policy* in providing for managing human occupation and use of the floodplain considering risk management principles.

On 1 July 2009, following a reorganisation of Government Agencies, the licensing and compliance functions regarding Part 8 were transferred to the newly established Office of Water within the renamed Department of Environment, Climate Change and Water (DECCW). In 2009 the Darling River Floodplain (Bogan River confluence to Louth) Floodplain Management Committee prepared for DECCW a Data Collection and Flood Study (URS 2009). The flood study includes data collection for hydrology, hydraulic and environmental aspects; and defines the nature and extent of flooding, including development of a computer based hydraulic model of flood behaviour. No further risk studies or FMPs were developed at this time.

2012 - 2016

In 2010, work commenced on the *NSW Healthy Floodplains Project*, a NSW government initiative, to reform the management of water on floodplains through the development of floodplain management plans as well as licensing of floodplain harvesting water extractions. In June 2012, Stage 1 of the *Healthy Floodplains Project* was awarded \$36 million by the Commonwealth Government, with additional contributions by the NSW State Government.

Part 8 of the WA 1912 was repealed in 2016 and replaced by the floodplain management provisions of the WMA 2000. The floodplain management provisions under the WMA 2000 enabled the development and commencement of the *Floodplain Management Plan for the Barwon-Darling Valley Floodplain 2017* (Barwon-Darling Valley FMP). The Barwon-Darling Valley FMP supersedes all existing floodplain management arrangements in the Barwon-Darling Valley Floodplain. The designation of the Barwon-Darling Valley Floodplain enables the administration and coordination of flood works in the floodplain.

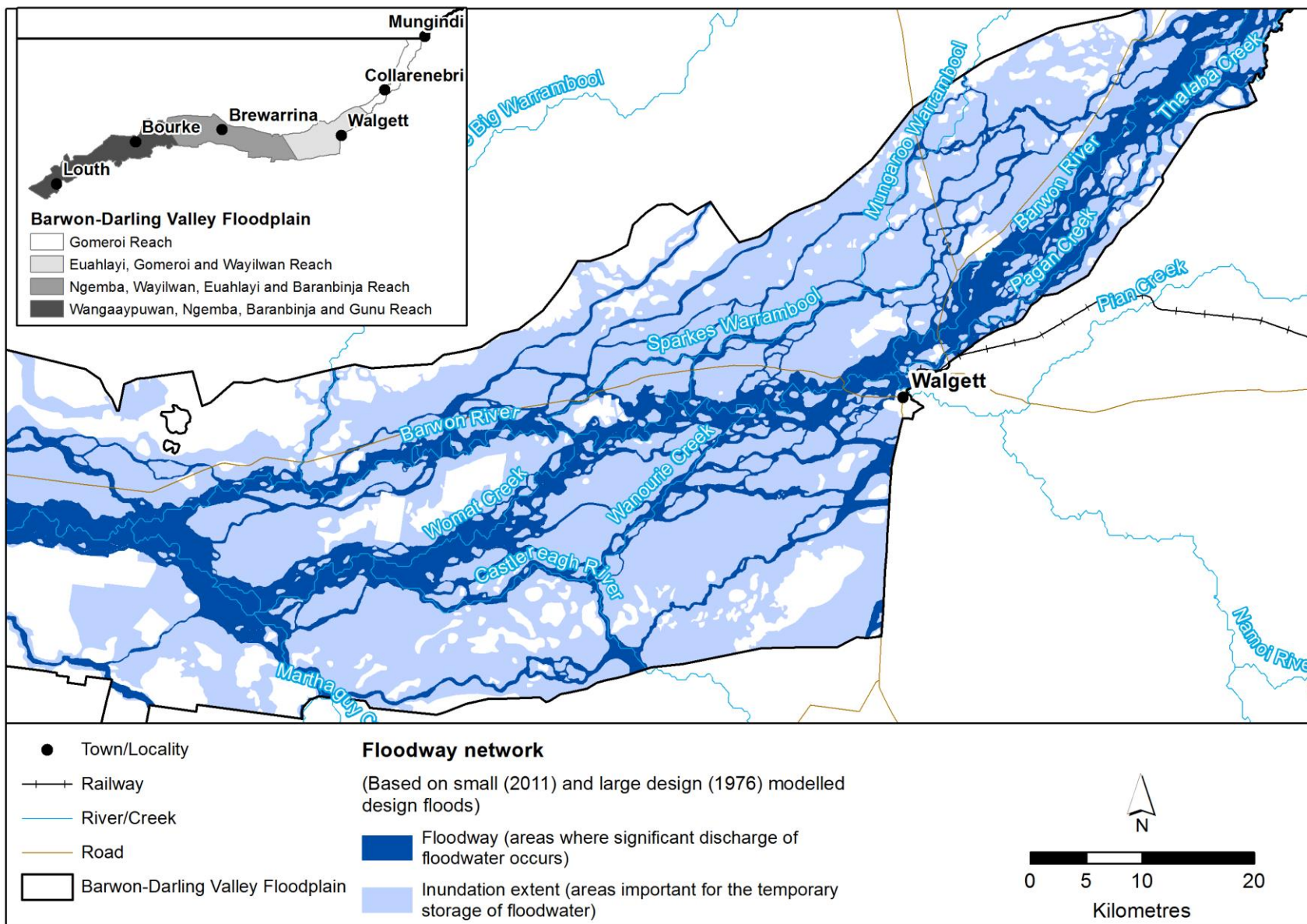


Figure A3.2 Floodway network in Euahlayi, Gomeri and Wayilwan Reach of the Barwon-Darling Valley Floodplain

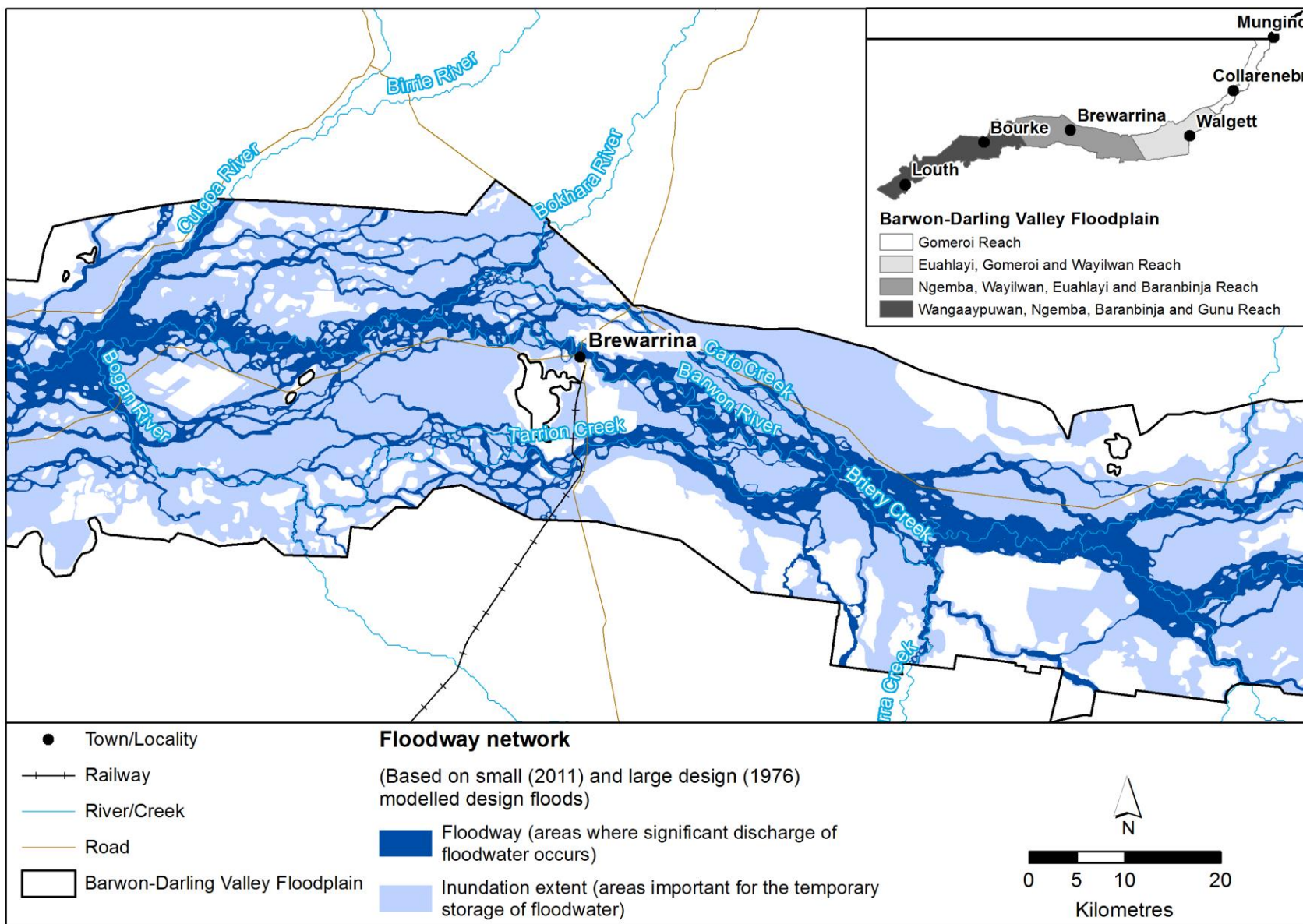


Figure A3.3 Floodway network in Ngemba, Wayilwan, Euahlayi and Baranbinja Reach of the Barwon-Darling Valley Floodplain

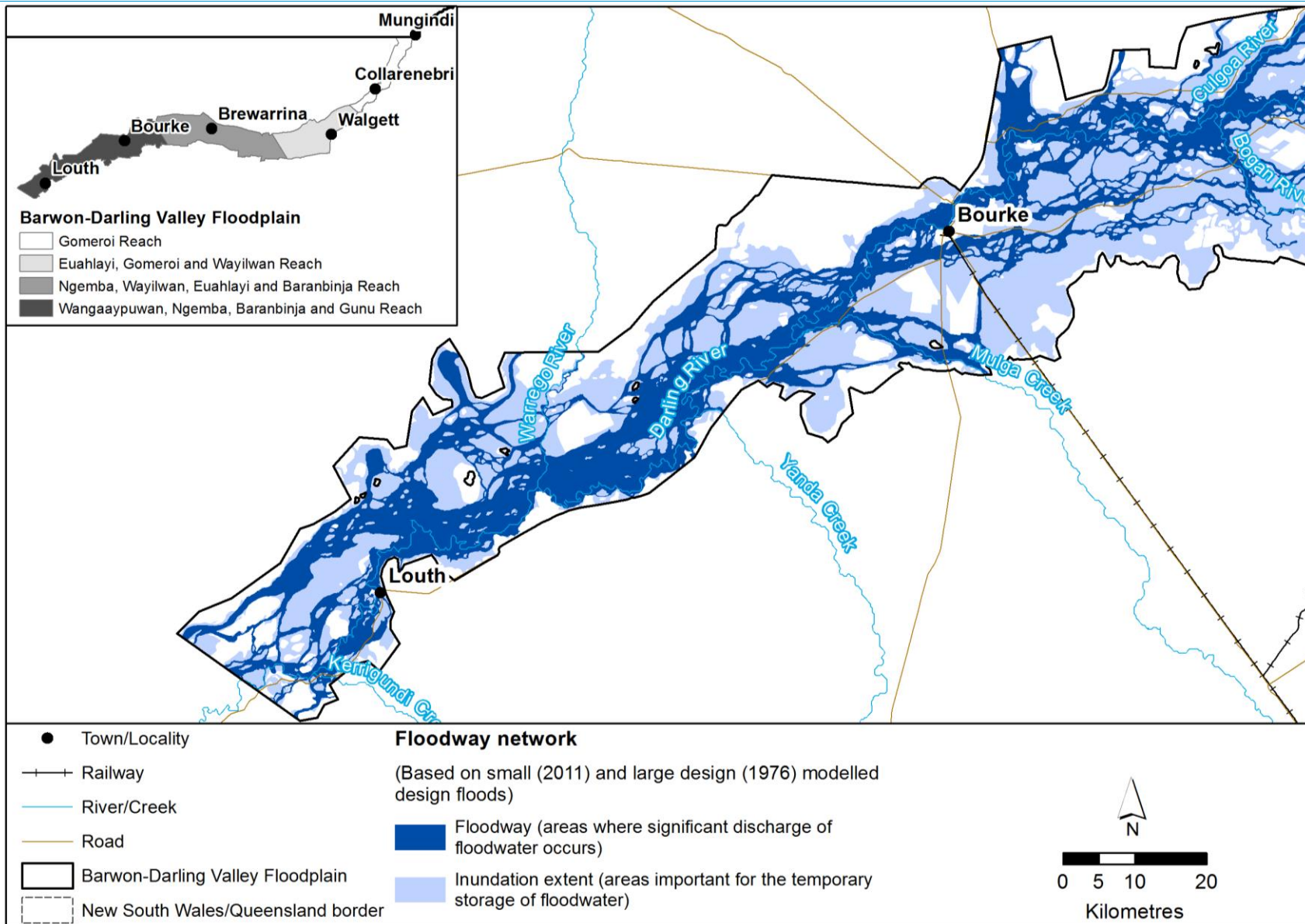


Figure A3.4 Floodway network in Wangaaypuwan, Ngemba, Baranbinja and Gunu Reach of the Barwon-Darling Valley Floodplain

Appendix 4: Design floods

As outlined in Step 4 of the main document, two design floods were selected for the Barwon-Darling Valley FMP:

- large design flood – February 1976 (1.4% Annual Exceedance Probability (AEP) @ Walgett or 1.2% AEP @ Bourke)
- small design flood – November 2011 (17% AEP @ Walgett and Bourke).

The AEPs for the small and large design flood at selected locations within the Barwon-Darling Valley Floodplain in the context of other FMPs design floods are shown on Figure A4.1.

Flood frequency analysis

A flood frequency analysis for gauging stations at six towns throughout the floodplain was undertaken to assist with the selection of design floods for the Barwon-Darling Valley FMP. The technique involved using observed peak flood flow rate ML/d data to calculate statistical information such as mean values, standard deviations, skewness, and recurrence intervals. These statistical data were then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various flows as a function of recurrence interval or exceedance probability.

Annual flood series were used as data inputs because the values will likely be independent and the series can be easily extracted (IEA 1987). The annual flood series comprises the highest instantaneous rate of discharge in each year of record.

Annual flood series were obtained from the six gauging stations situated at Mungindi, Collarenebri, Walgett, Brewarrina, Bourke and Louth (the spacing throughout the Barwon-Darling Valley Floodplain gave a good relatively even distribution throughout the length of the floodplain). These stations were chosen based on their location, length of observed record and the measure of reliability. The annual flow series for each calendar year was extracted from Hydstra, (a hydrologic database administered by DPIW). Gaps within the annual series were filled by first checking the daily flow record of a nearby gauge for a major flow event over the gap period. If no flow event occurred, it was assumed that the highest recorded peak was the highest peak for that year.

A Log-Pearson Type III distribution was fitted to the annual data sets for the six selected locations within the Barwon-Darling Valley Floodplain. The flood frequency analysis software called FLIKE v4.50 (Kuzera 2006) was used to calculate a flood frequency analysis for each of the gauging stations selected. The Log Pearson Type III probability distribution was selected as the appropriate mathematical model of flood frequencies to plot the annual series data following a comparison with a number of probability distributions, in line with the Institute of Engineers Australia's best management practices (refer to Australian Rainfall and Runoff, IEA 1987).

Since the recorded flood peaks are only a small sample of peaks actually occurring over a longer period, an expected probability adjustment was made using the procedure set out in Australian Rainfall and Runoff (IEA 1987). IEA (1987) recommends implementing the expected probability adjustment to remove bias from the estimate. The resulting frequency curves, along with 5 per cent and 95 per cent confidence limits for the six gauging stations within the Barwon-Darling Valley Floodplain are shown in Figure A4.2 to Figure A4.7. The AEPs calculated for various floods at the selected locations within the Barwon-Darling Valley Floodplain using statistical data generated from the flood frequency analyses are shown in Table A4.1.

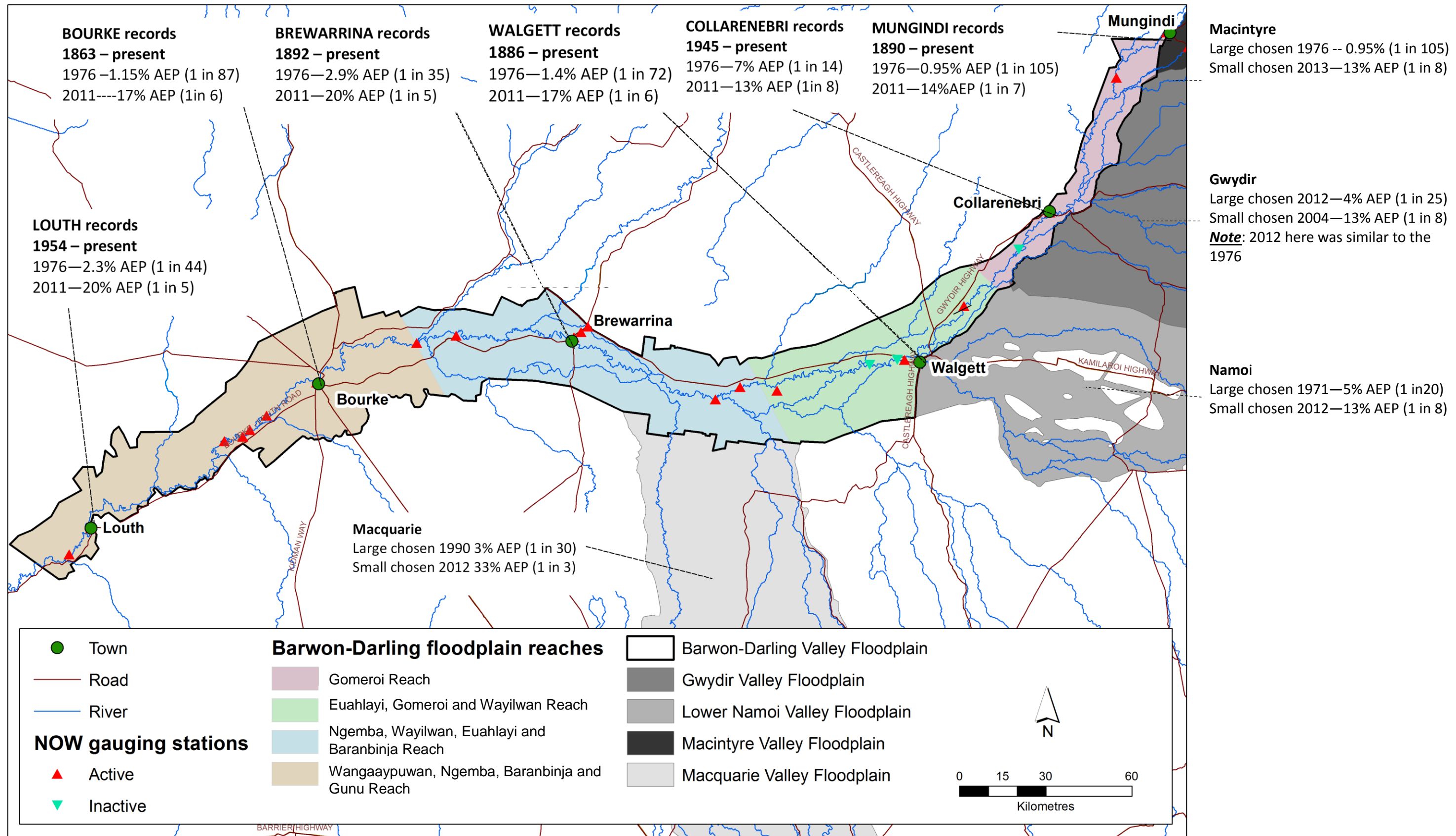


Figure A4.1 Selected design floods, 1976 (large flood) and 2011 (small flood) of the Barwon-Darling Valley Floodplain and large and small design floods for other FMPs

Table A4.1 Annual Exceedance Probability (AEP) for historic flood events at selected locations in the Barwon-Darling Valley Floodplain

Location (Gauging Station number)	Site commenced	Reason for selecting a gauging station for analysis	Flood Event AEP % (1 in Y) and Peak Discharge							
			1890	1974	1976 ML/d	1996	1998	2011 ML/d	2012	2013
Barwon River @ Mungindi (416001)	1890	Long period of record and located at the upstream end of the floodplain (top of Gomeroi Reach)	0.5% (1 in 220)	4% (1 in 28)	1% (1 in 105)	6% (1 in 18)	4.5% (1 in 22)	14% (1 in 7)	25% (1 in 4)	13% (1 in 8)
Barwon River @ Collarenebri (422003)	1945	Located near the centre of Gomeroi Reach	N/A	(10%)* (1 in 10)*	(7%)* (1 in 14)	6%* (1 in 17)*	3%* (1 in 32)*	13% (1 in 8)*	1.7%* (1 in 58)*	25%* (1 in 4)
					180,874			28,212		
					82,250*			62,530		
					152,000					
*Barwon River @ Walgett (422001)	1886	Long period of record and located near the centre of Euahlayi, Gomeroi and Wayilwan Reach	1.3% (1 in 79)	2.1% (1 in 47)	1.4% (1 in 72)	11% (1 in 9)	5.6% (1 in 18)	17% (1 in 6)	4.4% (1 in 23)	33% (1 in 3)
					450,447			100,000		
Barwon River @ Brewarrina (422002)	1892	Long period of record and located in the centre of Ngemba, Wayilwan, Euahlayi and Baranbinja Reach	N/A	3% (1 in 37)	2.9% (1 in 35)	14% (1 in 7)	5.6% (1 in 18)	20% (1 in 5)	6% (1 in 16)	50% (1 in 2)
					170,580			58,939		
Darling River @ Bourke (425003)	1863	Long period of record and located near the upstream end of Wangaaypuwan, Ngemba, Baranbinja and Gunu Reach	0.7% (1 in 142)	1.1% (1 in 90)	1.2% (1 in 87)	20% (1 in 5)	3.6% (1 in 28)	17% (1 in 6)	2.9% (1 in 35)	50% (1 in 2)
					459,403			88,449		
Darling River @ Louth (425004)	1954	located at Louth and near the downstream end of Wangaaypuwan, Ngemba, Baranbinja and Gunu Reach	N/A	2.6% (1 in 39)	2.3% (1 in 44)	25% (1 in 4)	5.6% (1 in 8)	20% (1 in 5)	9.1% (1 in 11)	50% (1 in 2)
					360,836			83,597		

Note: * value being main river flooding and not total flow for Collarenebri

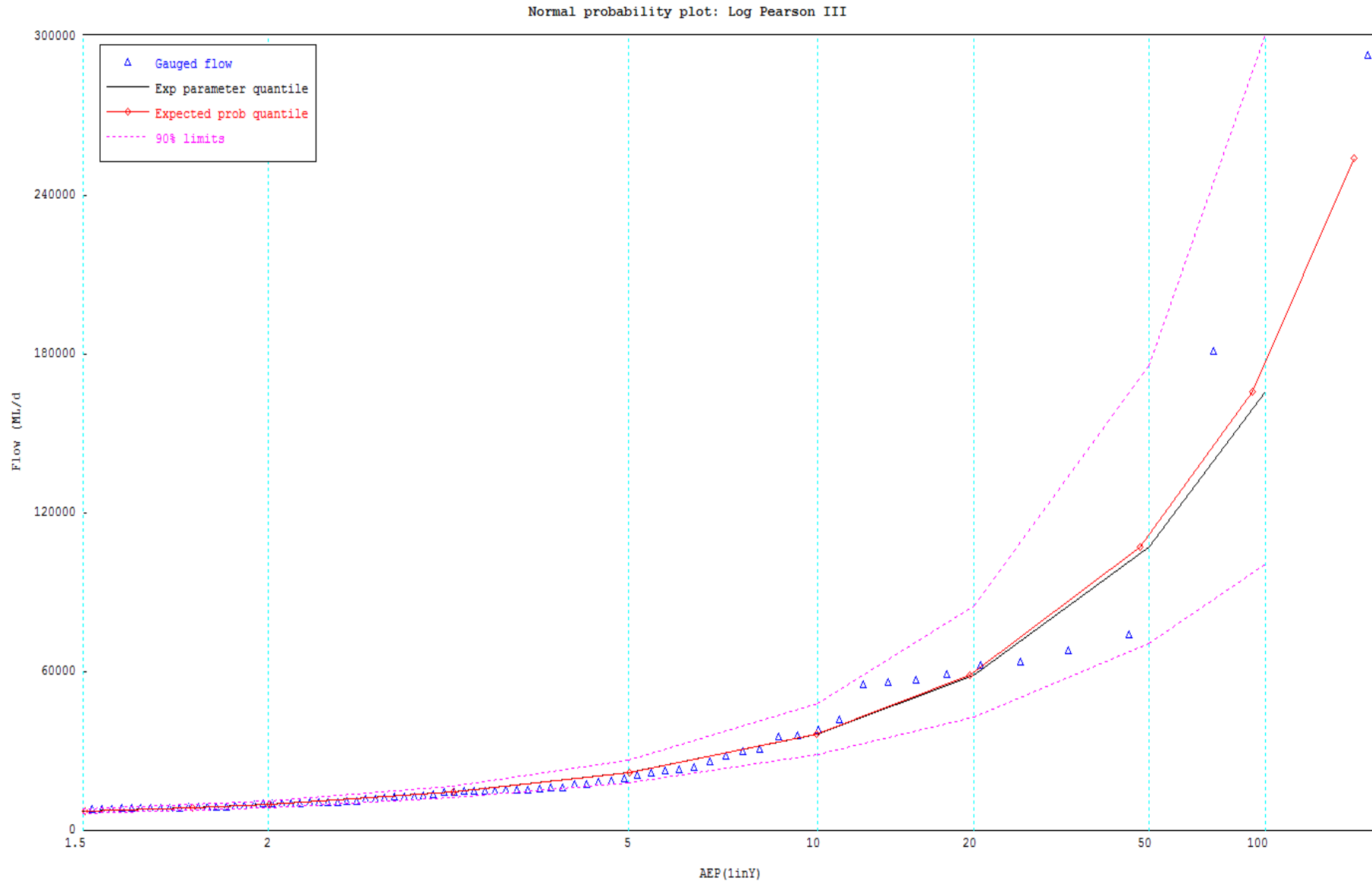


Figure A4.2 Flood frequency curves for Mungindi (416001)

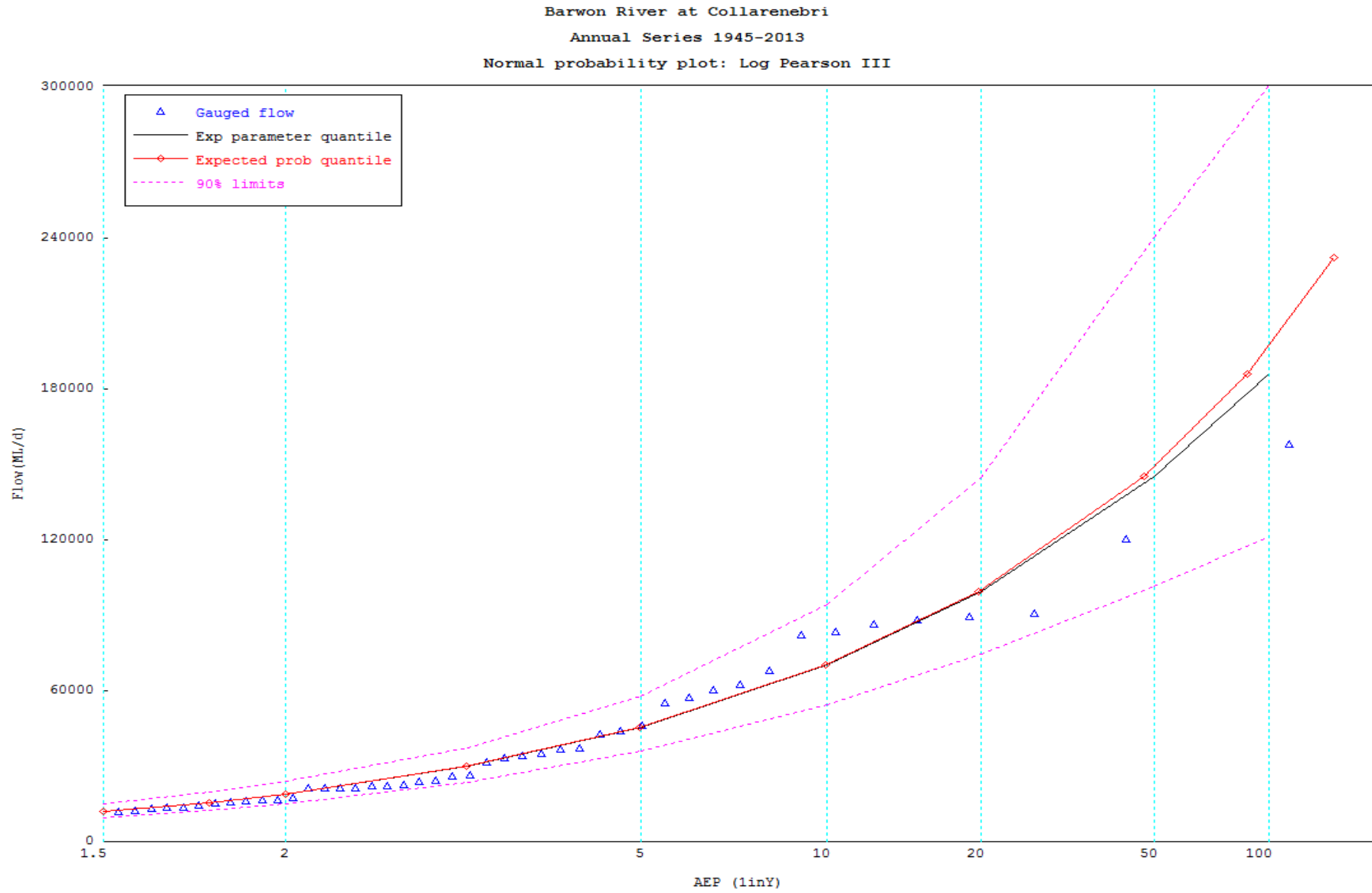


Figure A4.3 Flood frequency analysis for Collarenebri (42203)

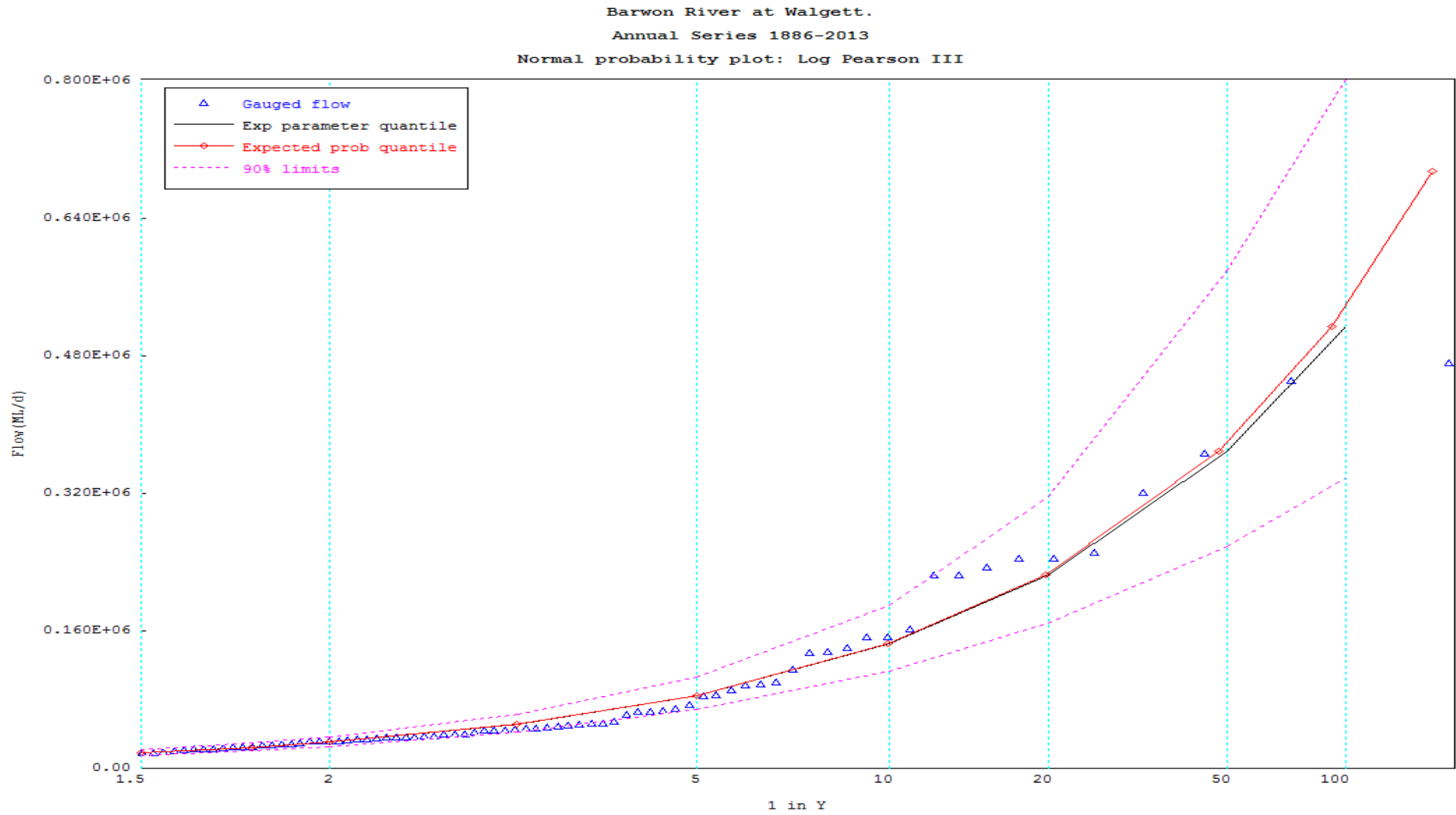


Figure A4.4 Flood frequency curves Walgett (422001)

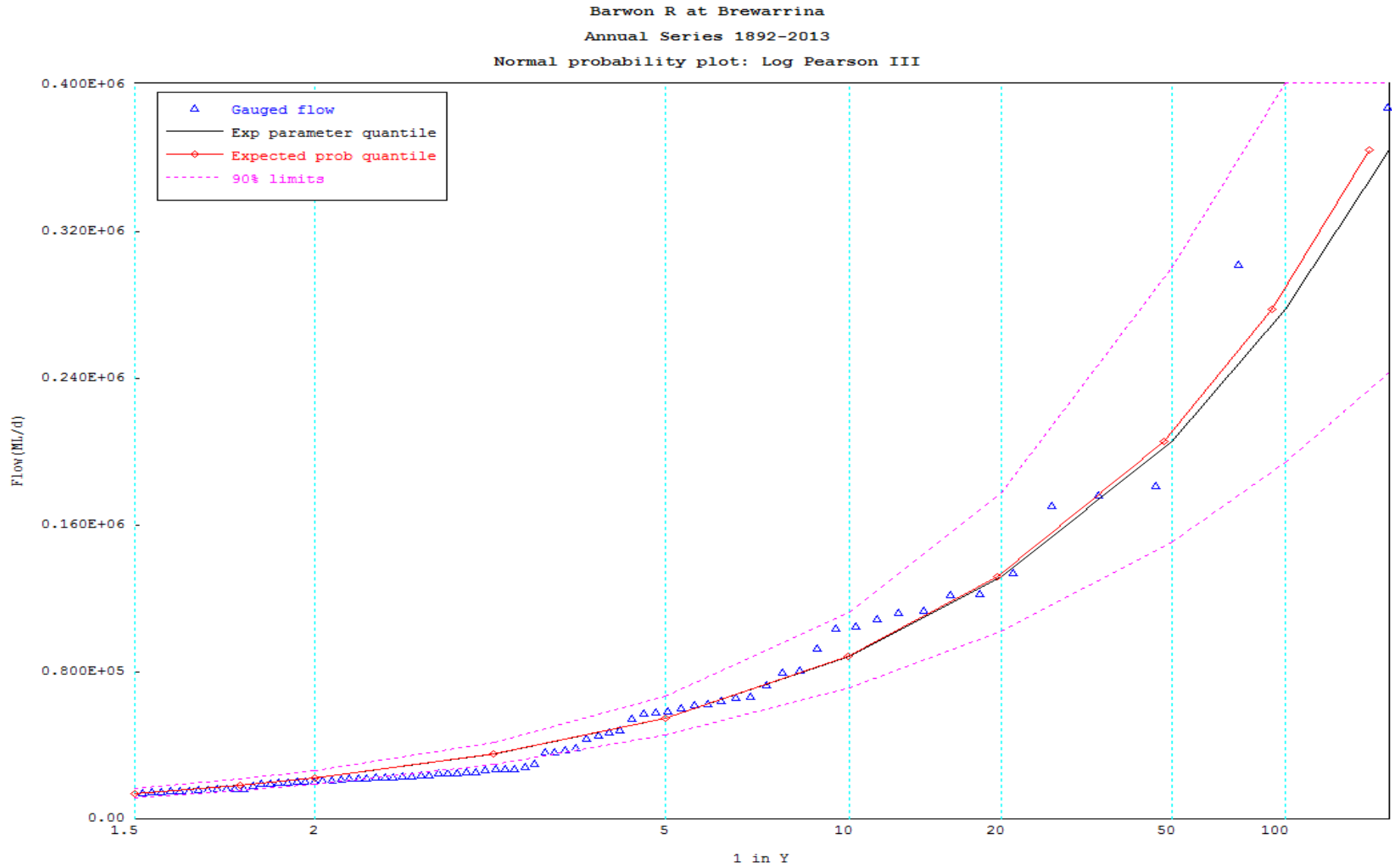


Figure A4.5 Flood frequency curves Brewarrina (422002)

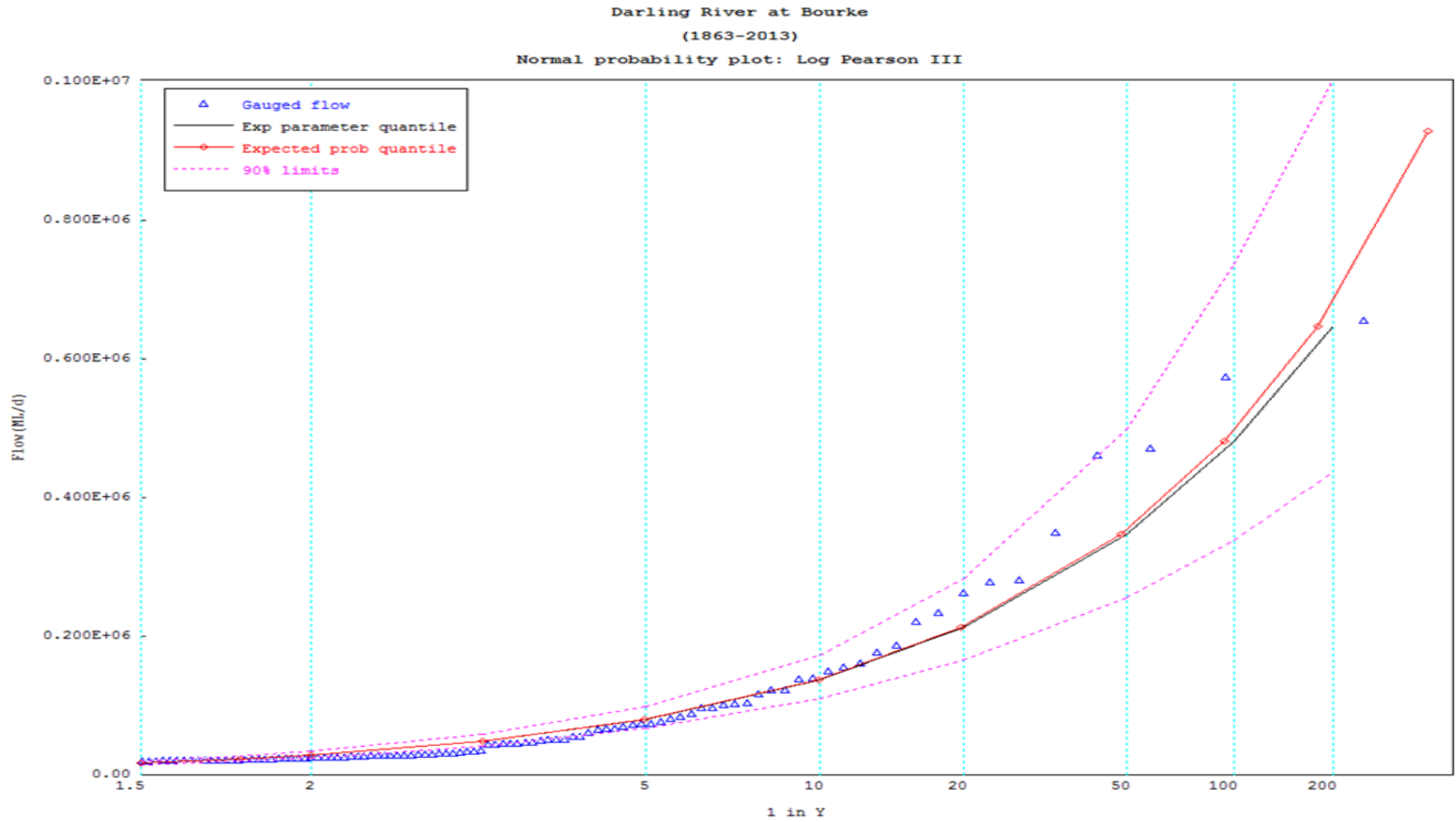


Figure A4.6 Flood frequency curves Bourke (425003)

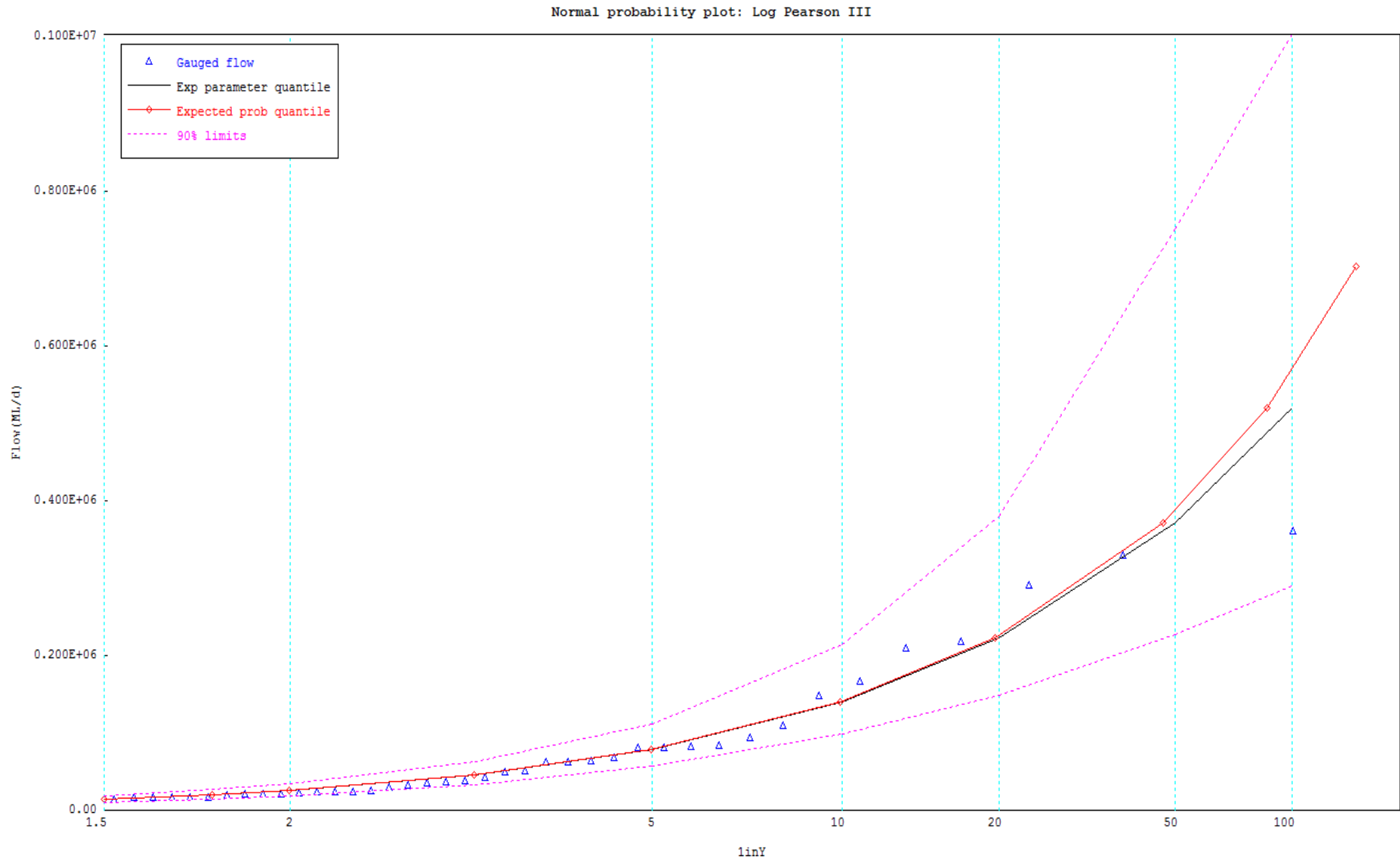


Figure A4.7 Flood frequency curves Louth (425004)

Appendix 5: Further detail on two-dimensional hydraulic modelling

MIKE 21 FM two-dimensional software modelling package was used to model for overland flow. The MIKE 21 FM software uses a 'flexible mesh' computational grid that consists of triangular and quadrilateral elements that can vary in size, to provide greater detail in areas that require it and less detail where it is not required.

Extents and layout

Consideration was given to the following elements in constructing the model:

- topographical data coverage and resolution;
- location of recorded data (e.g. levels/flows for calibration);
- location of controlling features (e.g. dams, levees, bridges);
- desired accuracy to meet the study's objectives; and
- computational limitations.

MIKE 21 FM models were constructed to cover most the floodplain, an area of approximately 11,000 km², extending from just downstream of Mungindi to below Louth. The floodplain computational grid was too large to be run efficiently in one model. Therefore the model was split into four reaches where the flows were passed along each model in series (Figure A4.1). That is, upstream model outflows were applied as downstream model inflows.

Base topography

The ability of the model to provide an accurate representation of the overland flow distribution on the floodplain ultimately depends upon the quality of the underlying topographic model. LiDAR coverage of most the floodplain was acquired from the Barwon-Darling (Bourke) Flood Study, and the Healthy Floodplains Project. Additional topographic data, such as the 5 m ADS DEM and 30 m SRTM DEM was used in areas not covered by the LiDAR to extend the models laterally from the river.

Topographic controls

The Barwon-Darling Valley Floodplain is characterised by flat topography with a large number of linear features elevated above the floodplain. These features include road alignments, levee banks and channels associated with irrigation supply, drainage infrastructure and farming practices. The largest of these features present barriers to flood flows and often have associated cross drainage infrastructure to transfer flows through them. The smaller features act as hydraulic controls, resulting in flood water ponding behind them before spilling over the crest.

To ensure that the extensive network of topographic features is correctly represented within the model, breaklines were created representing elevations along the crests of the embankments from the LiDAR survey. The breaklines were imported into the model to ensure that a continuous crest elevation is represented within the model topography. Water levels in the upstream model cells must exceed the crest of the embankment before spilling into the downstream cells. This approach ensures that the influence of the topographic controls across the floodplain is correctly represented.

Hydraulic roughness

The development of the MIKE 21 FM models required the assignment of 'hydraulic roughness' to different areas within the floodplain. These areas were delineated from aerial photography and land-use data and assigned into roughness categories. Categories proposed for the Barwon-Darling modelling included roads and impervious surfaces, grazing (or grasslands), cropped lands,

forested areas, watercourses and wetlands. The roughness values were varied as part of the calibration process and were initially based on previous model roughness and values of similar areas presented in literature.

Structures

There are a number of bridge and culvert crossings over the main channel alignments and tributaries within the model extents. These structures vary in terms of construction type and configuration, with varying degrees of influence on local hydraulic behaviour. Incorporation of these major hydraulic structures in the models provides for simulation of the hydraulic losses associated with these structures and their influence on peak water levels within the study area.

The structures were modelled as per their geometry by using Level-Width relations within the MIKE 21 FM structures module. The structure geometry was in some cases simplified to effectively implement within the model grid, however this was unlikely to have any impact on the conveyance through the structure or levels or velocities nearby.

Boundary conditions

The model boundary conditions were derived as follows:

- Inflows – There are a large number of inflows into the Barwon-Darling, notably; the Border Rivers, Gwydir, Namoi, Macquarie, Macintyre, Culgoa, Bokhara and overland flow from their floodplains.
- Outflows – These were applied using a constant water level or rating curve that is derived using the downstream cross-section and Manning's equation or using gauge rating curves where appropriate.

Model calibration

The selection of suitable historical events for calibration of computer models is largely dependent on available historical flood information. Ideally the calibration and validation process should cover a range of flood magnitudes to demonstrate the suitability of a model for the range of design event magnitudes to be considered.

The 1976, 2011 and 2012 floods formed the principal calibration events. The 1976 and 2011 events form the large and small design floods, respectively, and it is therefore important to calibrate to these events. However, there has been significant change to the floodplain between 1976 and the time that the LiDAR was flown in 2014. For this reason, the 2012 event was calibrated in addition to the design events.

All three events have a good coverage of gauge peak water levels, flood marks, flood aerial photography and satellite imagery.

Appendix 6: Overview of flood imagery

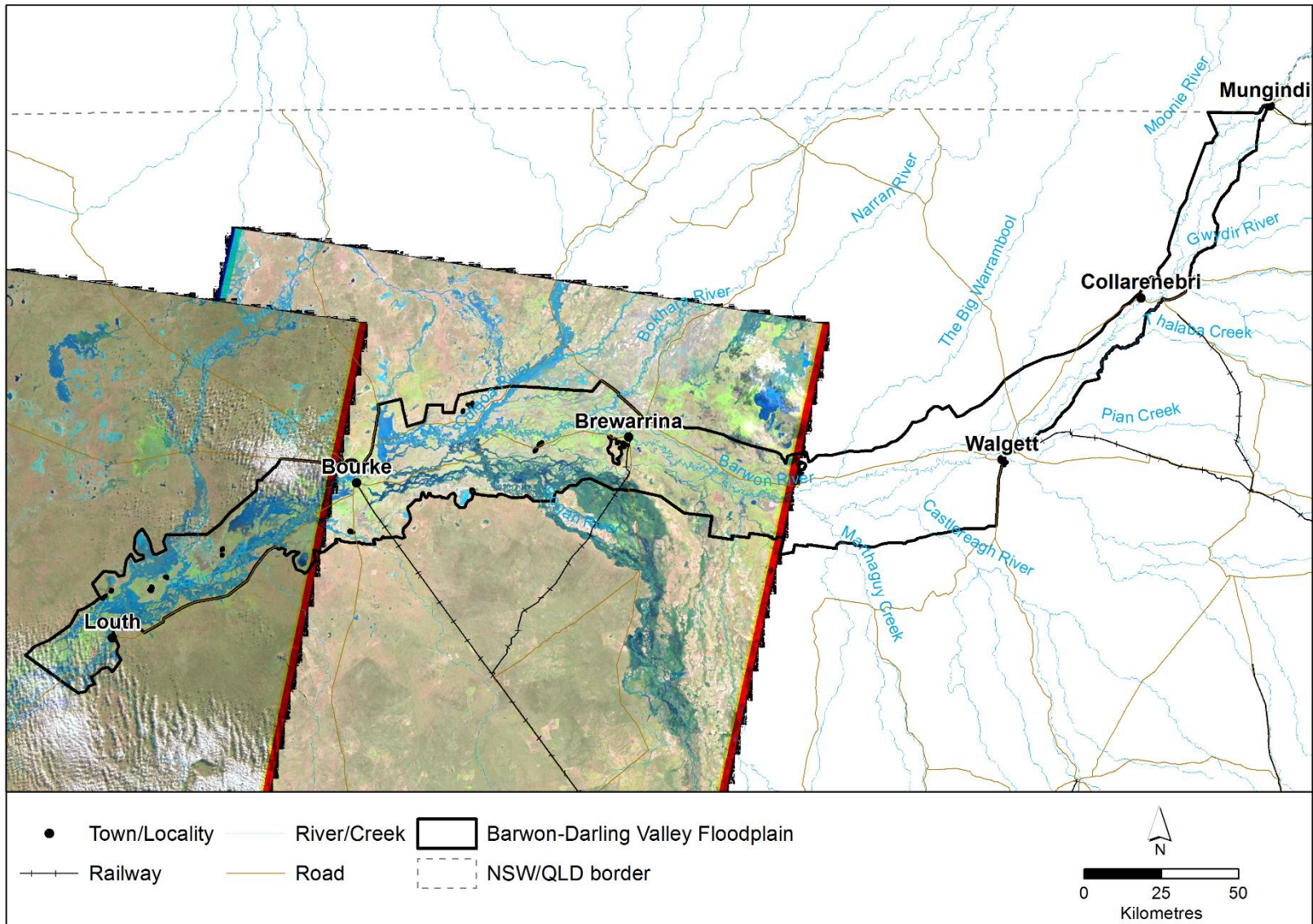


Figure A6.1: Landsat 5 imagery showing flooding in the Bogan, Culgoa, Darling and Warrego rivers, May 1990

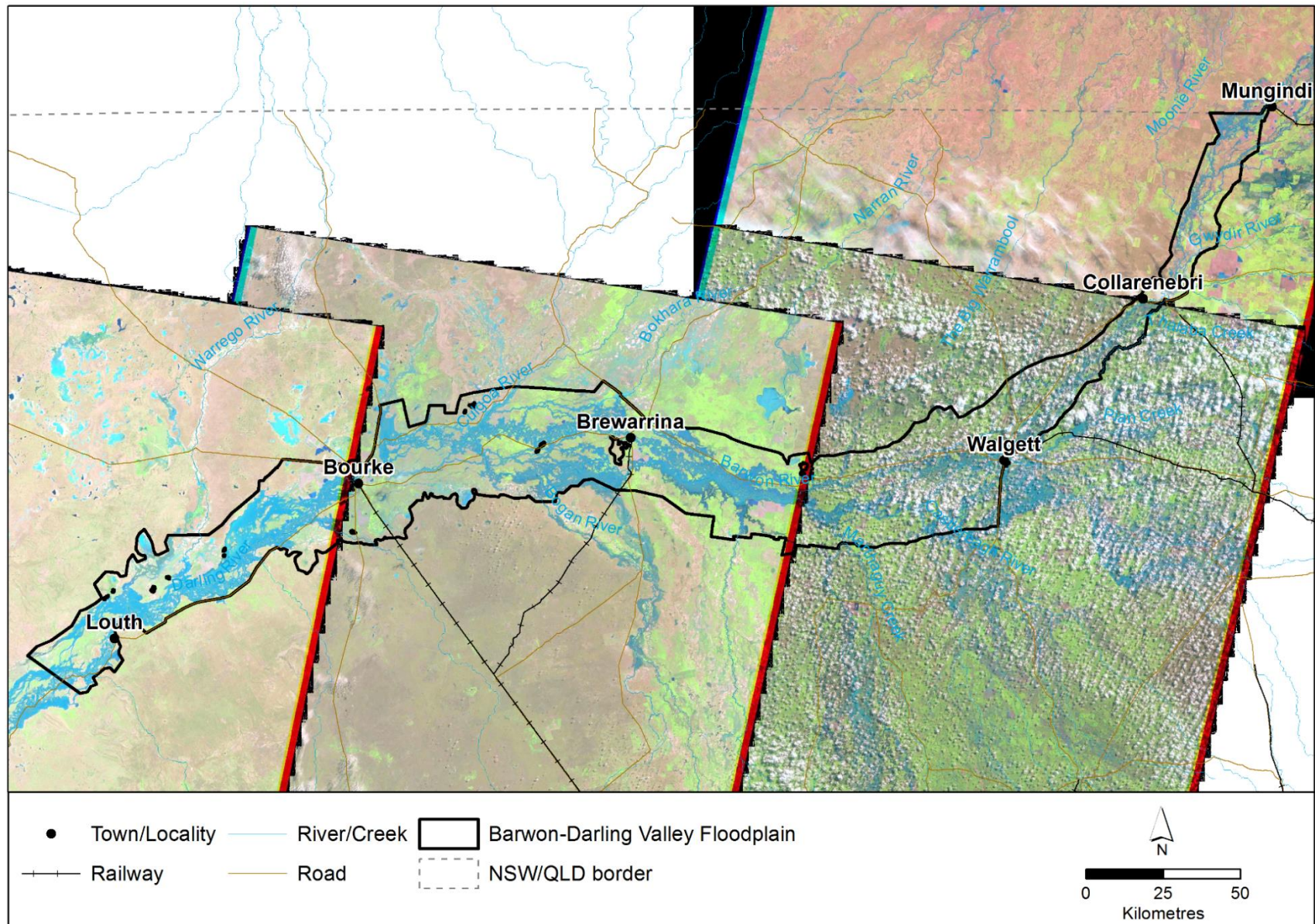


Figure A6.2: Landsat 5 imagery showing flooding in the Barwon-Darling Valley Floodplain from August to October 1998

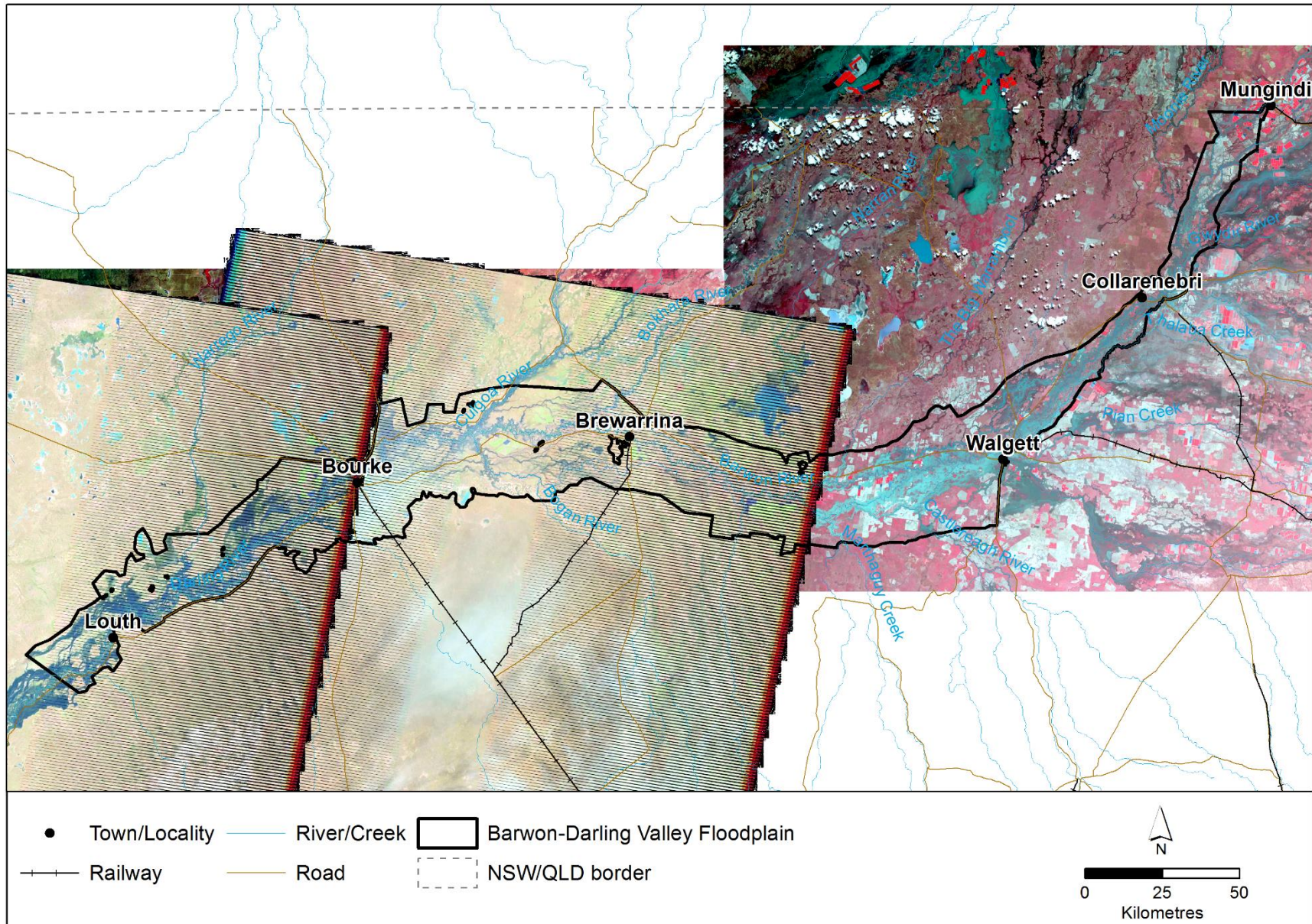


Figure A6.3: Landsat 7 and Deimos imagery showing flooding in the Barwon-Darling Valley Floodplain from February to April 2012

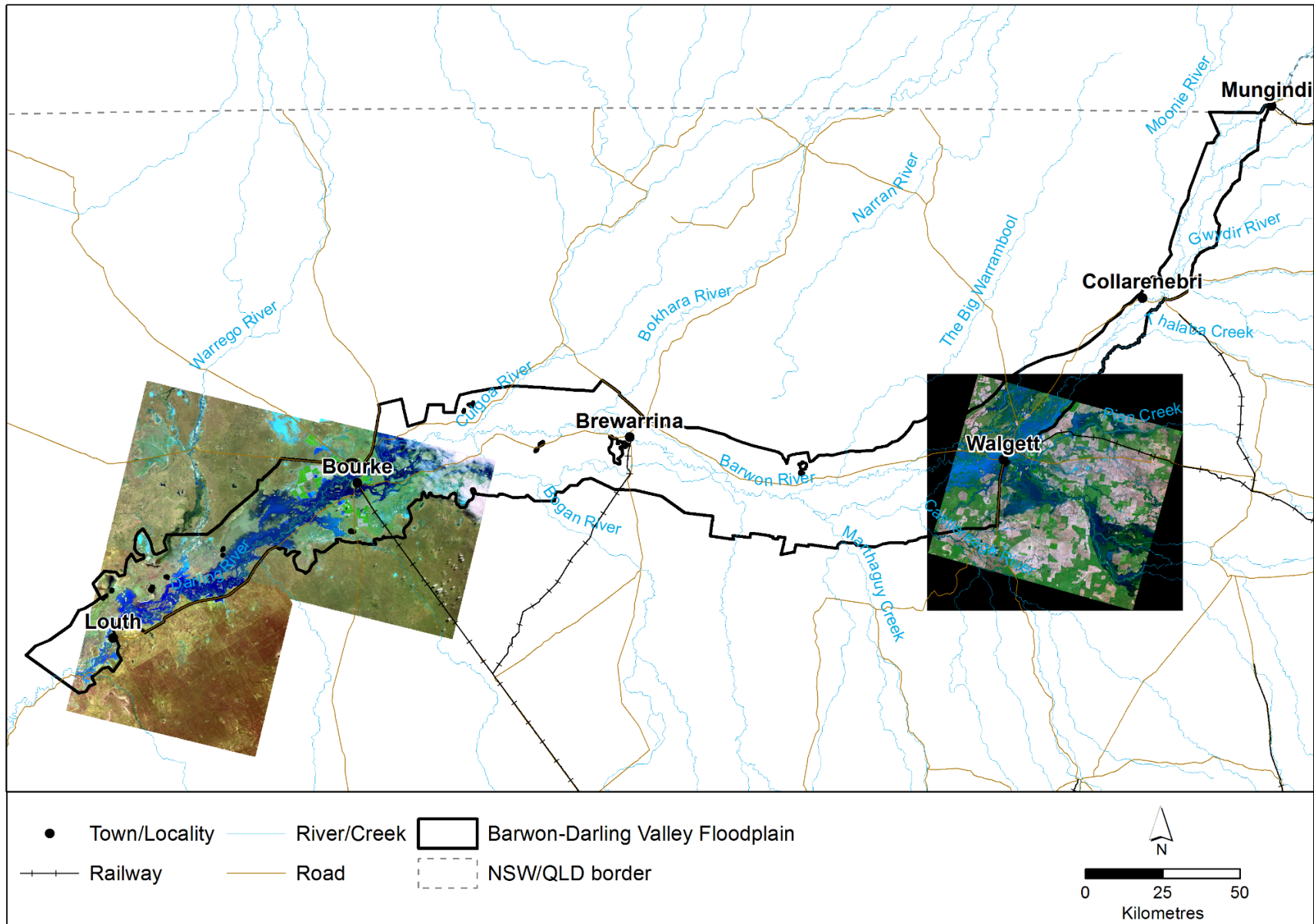


Figure A6.4: Spot imagery showing flooding around Walgett and Bourke in March 2012

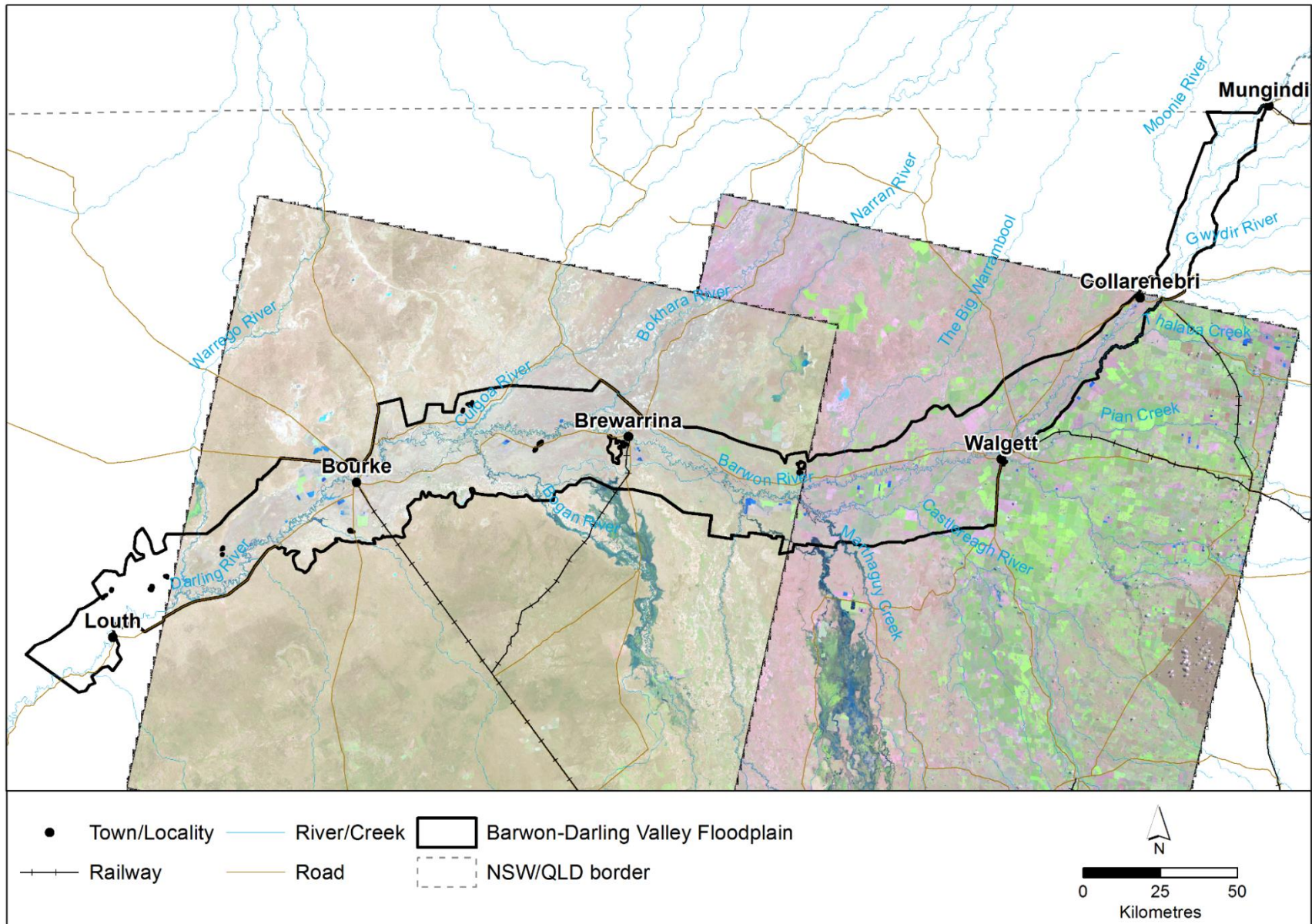


Figure A6.5: Landsat 8 imagery showing flooding in Macquarie and Bogan rivers, September to November 2016

Appendix 7: Marxan prioritisation (planning units)

Planning units are area-based polygons which cover the entire study area. Marxan analysis is an iterative process involving several steps. The first step involves dividing the landscape into 'planning units' which form the basis of the Marxan analysis. Planning units are small parcels of land of a pre-defined shape and size which could potentially be included in (or excluded from) the final Marxan solution. The Barwon-Darling Valley Floodplain was divided into 20 ha hexagonal planning units (n = 56,715) using the Qmarxan plugin (Apropros Information Systems 2014) executed within Quantum GIS Version 1.8.0 software (QGIS Development Team 2013; Figure A7.1 and Figure A7.2). These hexagonal-shaped planning units were selected to be the most appropriate shape and size for the scale of the floodplain management planning exercise and they have been shown to produce more efficient and less-fragmented planning portfolios (Nhancale & Smith 2011) and the consistent sizing of the hexagonal planning units may also reduce area-related bias (Loos 2011).

Marxan planning units partition the floodplain landscape and are the basis upon which data on the abundance of conservation features is compiled within the entire planning region. The amount of each biodiversity feature in each planning unit is calculated using the Qmarxan plugin within Quantum GIS Version 1.8.0 software. The extent of all biodiversity features within each planning unit is assessed to determine the relative importance of individual planning units and this forms the basic Marxan data matrix.

Marxan can be parameterised to 'lock in' (i.e. a planning unit may be forced into the final solution before the algorithm is run) or 'lock out' (i.e. the planning unit may not be considered in the final solution), through the use of status codes. Planning units which intersected the length of the Barwon-Darling, Bogan, Culgoa, Macquarie, Boomi, Namoi, and Warrego Rivers were allocated a status value of 2 to force them into the final solution as the upstream/downstream reaches of these rivers are major discharge areas essential for maintaining floodplain connectivity to support ecological processes and movement requirements of aquatic biodiversity such as native freshwater fish. The entire length of the Barwon-Darling River channel and riparian habitats support a wide variety of ecosystems and diverse range of flood-dependent vegetation, including river red gum, black box, river cooba, coolibah and lignum.

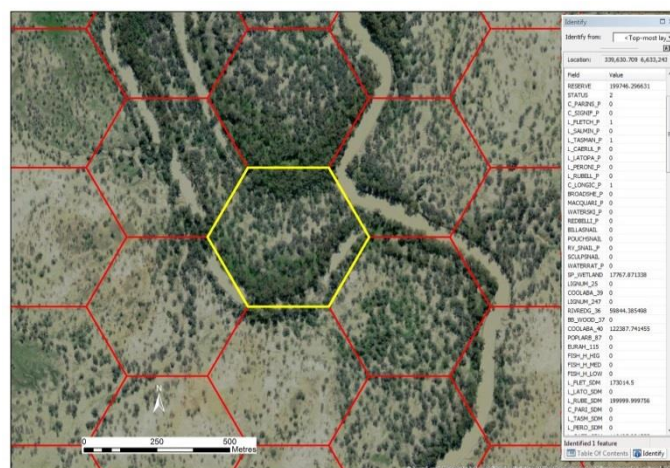


Figure A7.1 The Barwon-Darling Valley Floodplain was partitioned into 20 ha hexagonal planning units. The amount of each flood-dependent surrogate was calculated in each planning unit which formed the Marxan data matrix

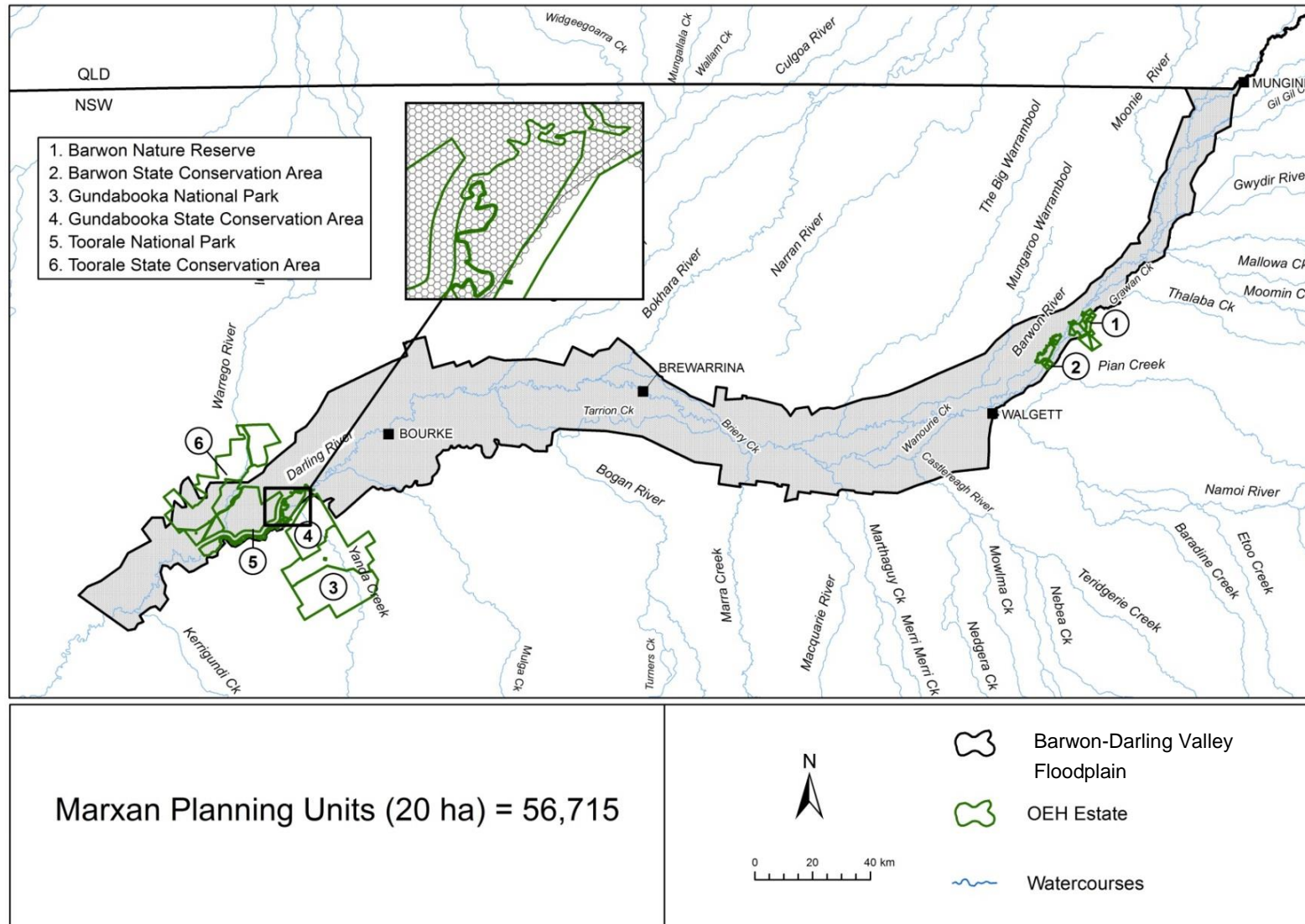


Figure A7.2 Hectare hexagonal planning units (n = 56,715) partitioning the Barwon-Darling Valley Floodplain

Appendix 8: Marxan prioritisation (targets for ecological surrogates)

To represent biodiversity patterns of the Barwon-Darling Valley Floodplain, several key ecological surrogates were chosen for input into the Marxan process to identify priority ecological assets. Surrogates are needed because it is impossible to measure all aspects of biodiversity, so surrogate features are chosen as proxies for biodiversity patterns (Margules, Pressey & Williams 2002). Surrogates were divided into two dataset types; area and point-based data and included sub-sets of taxa, assemblages, and/or environments and environmental variables (Margules & Pressey 2000, Margules et al. 2002).

For each ecological surrogate, targets or conservation objectives, were established. Targets specify the amount of an ecological surrogate that would be needed to be conserved to ensure the persistence of that surrogate (Margules & Pressey 2000). Targets provide a clear purpose for conservation decisions giving them accountability and defensibility (Pressey et al. 2003). Formulation of explicit targets may also be constrained by limited or undocumented information on biodiversity and habitat requirements (Pressey et al. 2003, Possingham et al. 2007). In formulation of conservation targets that address adequacy, a core principle of conservation planning, consideration must also be given to threats to freshwater aquatic ecosystems and their biodiversity components (Linke et al. 2010). Targets were reviewed and selected for each of the ecological surrogates via two TAG sub-group workshops held on 9 September and 6 November 2014 with local experts.

Area-based data sets (mapped vegetation)

Area-based data for vegetation was the primary surrogate for the Marxan prioritisation. Mapped vegetation was chosen as a surrogate if it was dependent on flooding and/or provided habitat to flood-dependent fauna. The area-based data derived from mapped vegetation community types were grouped into the following flood-dependent 'hydro - ecological functional group' surrogate categories:

- Semi-permanent wetlands
- Flood-dependent shrubland wetlands
- Flood-dependent forest/woodland (wetland)
- Flood-dependent woodland

Mapped vegetation was also used as area-based surrogates for floodplain fauna, which included consideration of:

- Spatial extent of flood-dependent vegetation communities which provide breeding and feeding habitat for waterbirds
- Spatial extent of small lagoons, billabongs and anabranches along the length of the Barwon-Darling River which provide breeding and feeding habitat for waterbirds and a range of aquatic species including freshwater native fish, frogs and turtles
- Modelled species distributions

Targets

Targets for area-based vegetation surrogates were developed using previously available information, including where possible, estimates of decline in vegetation communities. There was limited accurate temporal spatial data for variability of vegetation communities over time for the entire Barwon-Darling Valley Floodplain. It was not possible to compare the remaining area of vegetation with a pre-1750 vegetation map for the Barwon-Darling Valley Floodplain to determine estimates of decline for the entire floodplain, as a single pre-1750 vegetation map does not exist for the entire Barwon-Darling Valley Floodplain. Estimation of the extent of change was also constrained by differences in classification and mapping in individual regional vegetation mapping

coverages covering different parts of the floodplain. It was therefore not possible to establish a formal contemporary baseline upon which to establish representation targets for vegetation communities.

Conservation targets for semi-permanent wetlands, flood-dependent shrubland wetlands, flood-dependent forest/woodland (wetland) and flood-dependent woodland were set at 100 per cent. Targets were set at 100 per cent due endangered ecological community status of flood-dependent woodland, decline in geographic distribution of vegetation community types and threats associated with changes to hydrological regimes that alter flooding regimes and/or reduce frequency of flooding (Benson et al. 2006). A description of each of these area-based surrogates is outlined in Table A8.1.

Table A8.1 Area-based flood-dependent vegetation surrogates and their conservation targets for the Barwon-Darling Valley Floodplain Marxan analysis showing hydro-ecological functional groups

Asset type	Asset sub-type	Surrogate	Total area (ha) ^a	Proportion of floodplain (%)	Target (% of area)	NSW Threat category (VIS) [^]	Justification	
Wetlands	Semi-permanent wetlands	Shallow freshwater wetland sedgeland in depressions on floodplains on inland alluvial plains and floodplains (PCT 53)	95	<1	100	Vulnerable	Listed TSC Act, E: Artesian Springs Ecological Community (Part). Altered flooding regimes threaten regularity and degree of flood inundation and ploughing for cropping remains a major threat to shallow wetlands. Provides feeding areas for many waterbird species, habitats and refuges for fauna and flora.	
		Permanent and semi-permanent freshwater lakes wetland of the inland slopes and plains (PCT 238)	894			Near Threatened	Listed TSC Act, E: Artesian Springs Ecological Community (Part). Medium reduction (30-70%) in extent and/or range since European settlement, Water extraction from major rivers has led to altered flooding patterns on floodplain which may negatively affect this vegetation community.	
	Floodplain watercourses	Natural waterbodies, watercourses and named swamps*	3,279			n/a	Provides feeding areas for many waterbird species, habitats and refuges for fauna and flora.	
	Floodplain wetland (flood dependent shrubland wetland)	Canegrass swamp tall grassland wetland of drainage depressions, lakes and pans of the inland plains (PCT 24)	1,387			Least Concern	Listed TSC Act, E: Artesian Springs Ecological Community (Part). Provide shallow water habitat favoured by ground-nesting waterbirds such as stilts, avocets and brolgas. Provides habitat for frogs and other aquatic species when inundated (NFRPC 2004). Major alteration of species composition since European settlement. Some occurrences threatened by changed flooding regimes on floodplains as it requires periodic inundation to stimulate germination.	
		Lignum shrubland wetland on floodplains and depressions of the Mulga Lands Bioregion, Channel Country Bioregion in the arid and semi-arid (hot) climate zones (PCT 25)	19,974			1.7	Least Concern	Disruption of natural flooding regimes and clearing may adversely affect this community.
		Coolibah - river coobah - lignum	17,166			1.4	Endangered	Listed TSC Act, E: Coolibah-Black Box Woodland

Asset type	Asset sub-type	Surrogate	Total area (ha) ^a	Proportion of floodplain (%)	Target (% of area)	NSW Threat category (VIS) [^]	Justification	
		woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39)					in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain and Mulga Lands Bioregion (Part); Listed TSC Act, E: Artesian Springs Ecological Community (Part) Key sites for protection located along Barwon and Darling Rivers. Reduced flooding regimes due to increased irrigation are likely to accelerate the decline of this community.	
		Nitre goosefoot shrubland wetland on clays of the inland floodplains (PCT 160)	317			Least Concern	Listed TSC Act, E: Artesian Springs Ecological Community (Part). Provide habitat for waterbirds such as brolga	
		Lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling Riverine Plains Bioregion (PCT 247)	92	<1		Endangered	Listed TSC Act, E: Artesian Springs Ecological Community (Part). Provides breeding habitat for waterbirds and shelter and refuge for fish, birds, mammals and reptiles. Major reduction (>70%) in extent and/or range, major alteration of species composition since European settlement. May be negatively impacted by altered flooding regimes.	
		Eurah shrubland of inland floodplains (PCT 115)	191			Least Concern	Major reduction (>70%) in extent and/or range, Major alteration of species composition. Occurs in periodically flooded river floodplains and drainage lines providing habitat for brolga.	
	Other Floodplain ecosystems	Flood-dependent forest/woodland (wetlands)	River red gum tall to very tall open forest / woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36)	20,060	1.7		Vulnerable	Listed TSC Act, E: Artesian Springs Ecological Community (Part). Changed flooding regimes due to irrigation draw off are leading to a lack of regeneration of river red gum in some locations. Provides nesting and habitat for both waterbirds and populations of woodland birds. Narrow riparian corridors essential for connectivity. Root masses and limbs provide habitat for in-stream biota during low flows (Sheldon & Walker, 1998).
		Flood-dependent woodlands	Black box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion	194,600	16.8		Vulnerable	Listed TSC Act, E: Coolibah-Black Box Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain and Mulga Lands Bioregion (Part); Listed TSC Act, E: Artesian. Endangered Ecological Community (<i>Environment</i>

Asset type	Asset sub-type	Surrogate	Total area (ha) ^a	Proportion of floodplain (%)	Target (% of area)	NSW Threat category (VIS) [^]	Justification
		(PCT 37).					<i>Protection and Biodiversity Conservation Act 1999 (EPBC Act)</i> . Major reduction (>70%) in extent and/or range, major alteration of species composition since European settlement. Less flooding has led to dieback in some areas and lack of recruitment of trees.
		Coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40)	198,710	17		Endangered	Listed TSC Act, E: Coolibah-Black Box Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Penneplain and Mulga Lands Bioregion (Part); Listed TSC Act, E: Artesian Springs Ecological Community (Part). Endangered Ecological Community (EPBC Act). Major alteration of species composition, major reduction (>70%) in extent and/or range since European settlement. Rate of clearing and lack of flooding are key reasons for listing this community as endangered.
		Poplar box - coolibah floodplain woodland on light clay soil mainly in the Darling Riverine Plains Bioregion (PCT 87)	39,228	3.3		Vulnerable	Listed TSC Act, E: Artesian Springs Ecological Community (Part); Listed TSC Act, E: Brigalow within the Brigalow Belt South, Nandewar and Darling Riverine Plains Bioregions (Part). Major alteration of species composition, Medium reduction (30-70%) in extent and/or range. Alteration of hydrology (drainage) may negatively affect this community. Coolibah component requires occasional flooding for seedling recruitment.

Notes: Data sourced from Bowen and Simpson (2009), Eco Logical Australia (2008), DIPNR (1998a,b,c) Pre-clearing and Existing Vegetation Mapping of Bourke, Pre-clearing and Existing Vegetation Mapping of Walgett Shire, Pre-clearing and Existing Vegetation Mapping of Brewarrina Shire, Gowans et al. (2012), Hunter (2010), Shultz et al. (2014), Peasley and Walsh (1999) Vegetation Mapping- Walgett Shire.

Refer to NSW Vegetation Information System for detailed information regarding characteristic trees (upper stratum species), shrubs/vines/epiphytes (mid stratum species) and groundcover (ground stratum species).

^a Area estimates of Plant Community Types used in the Marxan analysis and calculated by amalgamating multiple regional vegetation mapping coverages. Area estimates are considered to be approximations constrained by compilation of older mapping studies and classifications (which were regarded as less reliable) with more recent mapping data. It is acknowledged by Shultz et al. (2014) that differentiating between PCT 37 and PCT 40 is difficult using aerial imagery.

* Includes natural water surfaces delineated by Shultz et al. 2014, Gowans et al. 2014, Peasley and Walsh (1999), DIPNR (1998a,b,c) Walgett, Bourke and Brewarrina Shires and selected natural waterbodies represented by the Hydro Area feature class from the Digital Topographic Database, Land and Property Information (LPI) (2013).

^ NSW Vegetation Information System threat categories

Area-based data sets (species distribution models)

Species distribution models (SDMs) are numerical tools that combine observations of species occurrence or abundance with environmental estimates. They may be used to gain an understanding of species' ecological requirements and to predict species' distributions across landscapes, sometimes requiring extrapolation in space and time. Correlative SDMs are often used as area-based surrogates to identify priority conservation areas in freshwater river ecosystems (Esselman & Allan 2011; Hermoso et al. 2013a). SDMs aim to estimate the environmental conditions that are suitable for a species by numerically relating known species occurrence records with suites of environmental variables of those locations. The environmental variables used to fit SDMs for the Barwon-Darling Valley Floodplain included topographic and bio-climatic variables, satellite-derived vegetation indices (i.e. Moderate Resolution Imaging Spectrometer (MODIS), Normalized Difference Vegetation Index (NDVI) using species occurrence records but excluded occurrence records associated with human infrastructure (Table A8.2).

SDMs provide a powerful way of overcoming sparseness of point based fauna distribution data by relating them to geographic or environmental predictors (Elith & Leathwick 2009). These predictive SDMs were used as area-based surrogates for Barwon-Darling Valley Floodplain fauna. Maxent v. 3.3.3k (Phillips, Dudik, & Schapire 2010) was used to predict the distribution of eight frog species, three freshwater turtles and one snake species in the NSW Murray Darling Basin (Table A8.3). A common way to set species targets in conservation planning is to use a proportion of species distributions (e.g. Carvalho et al. 2010, Hermoso et al. 2013a, and Hermoso et al. 2013b). Marxan software was used to find an optimal set of planning units that represented at least 50 per cent of each modelled species distribution (Table A8.3).

To evaluate the rigour of the SDM's, receiver operator characteristic calculations were performed. This assesses plot sensitivity (or true positives) against specificity (or false positives) for a range of threshold values, with the area under the curve providing a measure of the ability of the model to discriminate between presences and absences (Wen et al. 2015).

Table A8.2 Environmental variables used to fit SDMs in NSW Murray Darling Basin for the Barwon-Darling Valley Floodplain

Variable	Resolution ¹	Source	Description
Climate	1 km	Bioclim	Annual Mean Temperature
			Mean Diurnal Range (Mean of monthly (max temp - min temp))
			Temperature Isothermality & Seasonality (standard deviation *100)
			Mean Temperature of Wettest Quarter and Driest Quarter
			Precipitation of Driest Month
			Precipitation Seasonality (Coefficient of Variation)
Topography	250 m	Geoscience Australia	Precipitation of Wettest Quarter, Warmest Quarter & Coldest Quarter
			Altitude (mASL)
			Built from the 9 second DEM derived streams database
Vegetation ²	250 m	CSIRO	The amount of upstream area (in number of cells) draining into each cell calculated from the 90 m SRTM elevation data.
			Annual mean NDVI calculated from the monthly MODIS NDVI (2000 – 2012)
			Annual maximum NDVI calculated from the monthly MODIS NDVI (2000 – 2012)
			Standard deviation of annual mean NDVI
			Standard deviation of monthly NDVI (Jan 2000 – Dec 2012)

1. All grids were resampled to 250 m

2. MODIS NDVI. As the MODIS NDVI was available from February 2000, the mean January NDVI (2001 -2012) was used for January 2000.

Table A8.3 Targets for area-based ecological surrogates (fauna species distribution models)

Surrogate	Species	Total area (ha) ^a	Proportion of floodplain (%)	Target (% of area)	Rationale
Frogs	Barking marsh frog (<i>Limnodynastes fletcheri</i>)	263,846	22.8	50	The realised niche is likely to be a subset of the modelled areas. Frogs are an important component of the floodplain which provides important breeding and foraging grounds.
	Broad-palmed frog (<i>Litoria latopalmata</i>)	119,646	10		
	Common green tree frog (<i>Litoria caerulea</i>)	452,827	39		
	Desert tree frog (<i>Litoria rubella</i>)	547,676	47.5		
	Eastern sign-bearing froglet (<i>Crinia parinsignifera</i>)	785	<1		
	Peron's tree frog (<i>Litoria peronii</i>)	91,986	8		
	Salmon striped frog (<i>Limnodynastes salmini</i>)	741,943	64		
Turtles	Spotted grass frog (<i>Limnodynastes tasmaniensis</i>)	74,385	6.4	50	The realised niche is likely to be a subset of the modelled areas. Water-dependent species that may be negatively affected by aquatic barriers, riverine habitat modification, changes in river flows and flood frequency (Bower et al. 2012, Kennett et al. 2009).
	Broad-shelled turtle (<i>Chelodina expansa</i>)	213,604	18.5		
	Eastern snake-necked turtle (<i>Chelodina longicollis</i>)	67,417	5.8		
	Murray turtle (<i>Emydura macquarii</i>)	156,726	13.6		
Snake	Red-bellied black snake (<i>Pseudechis porphyriacus</i>)	5,976	<1		Maintenance of viable populations essential as associated with streams, swamps, lagoons and occupies riparian edge of rivers therefore likely to be an important indicator of overall wetland system health.

Point-based occurrence data (fauna)

Ecological surrogates derived from point-based data for fauna included:

- eleven species of native freshwater fish
- nine species of non-burrowing frogs
- five species of reptiles
- one species of mammal, and
- four species of aquatic snail

These fauna species and assemblages were selected because they have a high dependence on floodwater. A score for presence or absence for the species was assigned to all planning units. If the point record was within a planning unit, the species was considered present. Point-based records of fauna observations were sourced from:

- government agencies (NSW Department of Primary Industries (NSW DPI 2014a)
- Australian Museum Research Institute (30 July 2014)
- scientific literature (Baggiano 2012), Davies et al. (2008, 2012) and Growns and West (2008)
- Institute for Applied Ecology (2014) - University of Canberra Wildlife Tissue and Distribution Database Records.
- on-line databases (BioNet Atlas of NSW Wildlife 2014, <http://www.bionet.nsw.gov.au>)

All point-based occurrence surrogates were given 100 per cent targets (Table A8.4) as the number of records did not cover a large part of the landscape. It was decided that it was important to include the small number of sites where these wetland indicator species were known to occur.

Table A8.4 Point-based fauna surrogates assigned with 100 per cent target and number of occurrences in unique locations

Fauna surrogate	Rationale for selection	Number of unique locations
Native freshwater fish		
Silver perch (<i>Bidyanus bidyanus</i>) [^]	Recorded in 2011 surveys of the Barwon-Darling Valley Floodplain by Davies et al. (2012). Flow dependent specialist (NSW DPI 2013, Baumgartner et al. 2013). Listed critically endangered under the EPBC Act in December 2013 (Department of the Environment 2014). Listed as a vulnerable species in NSW under the FM Act (NSW DPI 2014a) and International Union for the Conservation of Nature (Wager 1996a). Prefers fast-flowing, open waters, especially where there are rapids and races. Modification of natural river flows has led to reduced opportunities for dispersal, spawning and migration (NSW DPI 2005) as this species requires flow pulses or floods for spawning (Boys et al. 2005; Humphries et al. 1999) and major spawning occurs when floodplains are inundated (Rogers & Ralph 2011). Larvae and juveniles drift onto the floodplain after major flooding (Koehn & Crook 2013; Rogers & Ralph 2011). Construction of barriers to migration and recolonisation is also likely to be a cause of its decline (NSW DPI 2014a). Populations in the Barwon-Darling may be negatively affected by targeted, incidental and recreational fishing (NSW DPI 2011). The installation and operation of instream structures and mechanisms that alter natural flow regimes may adversely impact this species as listed in Schedule 6 of the FM Act (NSW DPI 2014b).	28
Olive perchlet (<i>Ambassis agassizii</i>) [^]	Recorded in 2011 surveys of the Barwon-Darling Valley Floodplain by Davies et al. (2012). Floodplain specialist (NSW DPI 2013; Baumgartner et al. 2013) reliant on floodplain habitat to complete essential life history stages. Endangered population under the FM Act (NSW DPI 2014a). Inhabits the vegetated edges of lakes, creeks, swamps, wetlands and rivers, where it is often associated with woody habitat and aquatic vegetation in areas with little or no flow, particularly backwaters (Lintermans 2007). Populations may be negatively affected by river regulatory activities (NSW DPI 2013). Populations in the Barwon-Darling may be negatively affected by targeted, incidental and recreational fishing (NSW DPI 2011). The installation and operation of instream structures and mechanisms that alter natural flow regimes may adversely impact this species as listed in Schedule 6 of the FM Act (NSW DPI 2014b).	9
Un-specked hardyhead (<i>Craterocephalus stercusmuscarum fulvus</i>) [^]	Recorded in 2005 surveys of the Barwon-Darling Valley Floodplain by Davies et al. 2008. Foraging specialist (NSW DPI 2013, Baumgartner et al. 2013). Found around the margins of large, slow-flowing, lowland rivers, and in lakes, backwaters and billabongs (Lintermans 2007). Associated with shallow vegetated areas with sandy or muddy substrate (Ralph et al. 2011). Wetland opportunists as they spawn and recruit in floodplain wetlands (and lakes, anabranches and billabongs) during in-channel flows (Young et al. 2003).	9
Unidentified carp-gudgeon (<i>Hypseleotris spp</i>) [^]	Occurs in slow-flowing or still waters, normally associated with macrophyte beds or other aquatic vegetation (Lintermans 2007). Regarded both as a wetland and low flow opportunist, since it tends to spawn and recruit during low flows and can utilise the main channels, floodplain wetlands and secondary channels during its life cycle (Young et al. 2003).	60
Spangled perch (<i>Leiopotherapon unicolor</i>) [^]	Recorded in the Barwon-Darling Valley Floodplain by Davies et al. (2008), Davies et al. (2012). Foraging specialist (NSW DPI 2013, Baumgartner et al. 2013). Adapted to surviving in diverse environments including rivers, billabongs, lakes and waterholes in intermittent streams (Lintermans 2007). Flooding maximises recruitment, and reduced flooding and access to floodplains likely to disadvantage it (Lintermans 2007).	97

Fauna surrogate	Rationale for selection	Number of unique locations
Murray cod (<i>Maccullochella peelii</i>)^	Long-lived apex predator (NSW DPI 2013; Baumgartner et al. 2013). Listed as a vulnerable species under the EPBC Act. <i>Formerly listed by the</i> International Union for the Conservation of Nature (Wager 1996b) as Critically Endangered. Recorded in the Barwon-Darling strongly associated with large wood (Davies et al. 2008; Davies et al. 2012 and Boys et al. 2005) where it may spawn adhesive eggs onto and within submerged logs (NSW DPI 2011). A species important in Aboriginal mythology associated with deep holes in rivers consisting of instream cover such as rocks, stumps, and fallen trees (Lintermans 2007). Flows are an important factor in the larval survivorship and subsequent recruitment of Murray cod (Cheshire & Ye 2008). Changes such as river modification, clearing riparian vegetation, erosion, reduced river flows and de-snagging rivers have contributed to the decline of available habitat. (Kalatzis & Baker 2010). Appears to be exclusively restricted to riverine habitats across all stages of its life history (Humphries et al. 2002; King 2004; Koehn & Harrington 2005). Overfishing has had a negative impact on populations (NSW DPI 2011).	76
Golden perch (<i>Macquaria ambigua</i>)^	Flow dependent specialist (NSW DPI 2013; Baumgartner et al. 2013). Recorded in the Barwon-Darling strongly associated with large wood (Davies et al. 2008; Davies et al. 2012; Boys et al. 2005, Boys & Thoms 2006). Migratory fish species capable of upstream movements of more than 1000 km (Lintermans 2007). River regulation, including barriers to migration and recolonisation has disrupted migrations and breeding behaviour (Lintermans 2007) as this species requires flow pulses or floods for spawning (Humphries et al. 1999). Commonly spawns in lowland river reaches where large numbers of juveniles then live in nurseries in inundated floodplain and shallow lake habitats before migrating long distance upstream (Gehrke & Harris 2004). Eggs are semi-buoyant and may drift onto the floodplain after major flooding (Koehn & Crook 2013). Increased recruitment recorded during high flows (Boys et al. 2005).	124
Murray-Darling rainbowfish (<i>Melanotaenia fluviatilis</i>)^	Recorded in the Barwon-Darling Valley Floodplain by Davies et al. (2008), Davies et al. (2012). Foraging specialist (NSW DPI 2013; Baumgartner et al. 2013). Prefers areas of instream vegetation in slow moving waters of rivers, billabongs and swamps (NSW DPI 2012; Lintermans 2007). Loss of aquatic vegetation (spawning sites and cover) and cold-water pollution are potential threats (Lintermans 2007). Tends to spawn and recruit during low flows in channels, but it can also use floodplain habitats (Young et al. 2003).	48
Bony herring (<i>Nematalosa erebi</i>)^	Foraging specialist (NSW DPI 2013; Baumgartner et al. 2013). Recorded in the main stem Barwon-Darling more commonly in shallow edgewater patches (Boys et al. 2005; Boys & Thoms 2006; Davies et al. 2008; Davies et al. 2012) in waterways of lowland and slope environments (NSW DPI 2006). River regulation and cold –water pollution has reduced the abundance of the species (Lintermans 2007). A main channel generalist and a wetland specialist since it tends to spawn and recruit in the main channel during high and low-flow stages (Ralph et al. 2011). It also uses anabranches, billabongs and floodplain wetlands during its life-cycle (Young et al. 2003).	131
Australian smelt (<i>Retropinna semoni</i>)^	Recorded in the Barwon-Darling Valley Floodplain by Davies et al. (2008), Davies et al. (2012). Foraging specialist (NSW DPI 2013; Baumgartner et al. 2013). Barriers to fish passage may be fragmenting populations (Lintermans 2007). Require high concentrations of small prey to feed on and develop (Humphries et al. 1999) Larvae and juveniles may benefit from connectivity between the main river and adjacent wetlands, anabranches and still water habitats provided by increased flows (MDBA 2012).	23
Hyrtl's tandan	Recorded in 2008 and 2011 surveys of the Barwon-Darling Valley Floodplain by Davies et al. (2008), Davies et al. (2012). Foraging	10

Fauna surrogate	Rationale for selection	Number of unique locations
<i>(Neosilurus hyrtlii)</i> [^]	specialist (NSW DPI 2013; Baumgartner et al. 2013). Ecology poorly known occurs in a variety of habitats, including flowing waters or still areas such as billabongs and lagoons. Barriers to movement may be detrimental to this species (Lintermans 2007).	
Frogs		
Eastern sign-bearing froglet Froglet (<i>Crinia parinsignifera</i>)	Populations have a strong flood association (Ocock 2013), occurring in rain-fed depressions, semi-permanent wetlands, oxbow lagoons, creeks and rivers and man-made dams and infrastructure (Wassens 2011; Spark 2013).	3
Common eastern froglet (<i>Crinia signifera</i>)	Occurs in rain-fed depressions, semi-permanent wetlands, oxbow lagoons, creeks and rivers and man-made dams and infrastructure (Wassens 2011). Favours water couch habitat and may prefer to breed in deep and permanent pools (Lintermans & Osbourne 2002; OEH 2012).	2
Fletchers frog (<i>Limnodynastes fletcheri</i>)	Small to medium non-burrowing ground frog. Populations have a strong flood association (Ocock 2013; Healy et al. 1997) and may be negatively affected by river regulatory activities (Ocock et al. 2014). Has a strong preference for areas with emergent wetland vegetation, such as spike rush and cumbungi; particularly after flooding (Wassens 2010; Wassens 2011; Croft 2012; Healy et al. 1997; Spark 2013).	20
Spotted marsh frog (<i>Limnodynastes tasmaniensis</i>)	Populations have a strong flood association (Ocock 2013), preferring situations where there is considerable flooded vegetation such as tussocks and sedges (Lintermans & Osbourne 2002). This species will colonise any temporary or permanent pond or grassland soak (Anstis 2013). During drought periods, adults congregate around permanent water (Wassens 2011).	13
Salmon-striped frog (<i>Limnodynastes salmini</i>)	During their breeding season, this species is associated with flooded grasses and dams. The tadpoles prefer warmer, shallow water with vegetation cover (Anstis 2013). Breeds in ephemeral wetlands (Spark 2013).	15
Broad-palmed frog (<i>Litoria latopalmeta</i>)	Populations have a strong flood association (Ocock 2013), restricted to areas near permanent and semi-permanent waters (Anstis 2013). The broad palmed frog occupies a range of habitats, including flood-dependent river red gum and black box (Wassens 2011). Breeds in streams, wetlands and ephemeral ponds (Spark 2013).	5
Red tree frog (<i>Litoria rubella</i>)	Prefers temporary water bodies and is reliant on spring and summer rain/flooding to create pools of water (Wassens 2011; Spark 2013). Males call from tussocks or vegetation near water (Anstis 2013).	35
Green tree frog (<i>Litoria caerulea</i>)	Medium to large arboreal species occurring in a wide variety of habitats. Populations have a moderate association to flooding in wetlands (Ocock 2013) and have been recorded breeding following spring and summer rain/flooding (Wassens 2011; Spark 2013).	31
Peron's tree frog (<i>Litoria peronii</i>)	Arboreal species more abundant in trees and fallen timber in woodland habitats within and around waterbodies (Wassens 2011). Populations have been characterised as moderately flood associated in large inland floodplain wetlands (Ocock 2013). Breeds in ephemeral ponds after heavy rain (Spark 2013).	18

Fauna surrogate	Rationale for selection	Number of unique locations
Reptiles		
Eastern long-necked turtle (<i>Chelodina longicollis</i>)	Occupies a broad range of freshwater aquatic environments, occurring in greatest abundance in shallow, ephemeral wetlands often remote from permanent rivers (Kennett et al. 2009). Riverine habitat modification for agricultural industries, urban development and changes in river flows and flood frequency may threaten populations of this species (Kennett et al. 2009).	4
Broad shelled turtle (<i>Chelodina expansa</i>)	Recent surveys indicate presence in the Barwon-Darling Valley Floodplain where female individuals have been shown to have a reduced propensity for movement throughout their lifecycle (Baggiano 2012; Bower et al. 2012). Male turtles may be negatively influenced by aquatic barriers which impeded movement as the ecological health of the main river channel and backwaters are important to the species (Bower et al. 2012). Prefers lacustrine habitats and slow flowing water bodies and is more frequently represented in permanent lakes and billabongs connected to main river channels (Bower & Hodges 2014).	7
Murray turtle (<i>Emydura macquarii</i>)	Recent surveys indicate presence in the Barwon-Darling Valley Floodplain (Baggiano 2012) and Toorale National Park and State Conservation Area where it is a species of conservation importance (OEH 2014a). Occurs primarily in rivers and waterbodies associated with rivers such as backwaters, oxbows, anabranches and deep, permanent waterholes on the floodplains (Chessman 1988). Rarely seen out of permanent water bodies (Spark 2013).	12
Eastern water skink (<i>Eulamprus quoyii</i>)	Usually found close to or on the shore of slow flowing creeks and estuaries and swampy areas (Spark 2013). The Eastern water skink is often seen basking besides small creeks, larger stream and rivers, but however is not restricted to areas near freshwater (Cogger 2000). Populations may be negatively affected by reductions in water availability as abundance has been correlated with creekside habitats and moist areas (Law & Bradley 1990).	3
Red-bellied black snake (<i>Pseudechis porphyriacus</i>)	Usually associated with streams, swamps and lagoons and occupy riparian edge of rivers (Kingsford et al. 2010; Spark 2013). It mostly feeds on frogs, but reptiles and small mammals are also eaten (Cogger 2000) Predatory reptile that relies on the abundance of prey species in wetland environments (Ayers et al. 2004).	2
Mammals		
Water rat (<i>Hydromys chrysogaster</i>)	Inhabits streams, rivers and wetlands throughout the MDB (Scott & Grant 1997) where it is reliant on crustaceans, aquatic insects, and fish which form the bulk of its diet (CSIRO 2004; Woollard et al. 1978). This species may be found in permanent, swampy or lacustrine habitats associated with major drainages (Dickman 2004). Water rats can occur in high numbers by permanent wetlands and prefer slower moving waters and dense vegetation cover (Scott & Grant 1997; CSIRO 2004). The water rat is often associated with irrigation infrastructure and may be a vagrant at ephemeral waters travelling over three kilometres overland to exploit new resources (Scott & Grant 1997; Dickman 2004). Ecologically very important as predators in freshwater ecosystems (Spark 2013).	2
Snails		

Fauna surrogate	Rationale for selection	Number of unique locations
River snail (<i>Notopala sublineata</i>) [^]	The Barwon-Darling River provides potential habitat for the endangered river snail (NSW DPI 2007a; OEH 2014b) The river snail lives on mud, logs and rocks along river banks, usually in deep water (Cotton 1935; Johnston & Beckwith 1945). The river snail is listed as an endangered species in NSW in Schedule 4 of the FM Act and International Union for the Conservation of Nature (Ponder 1996). Populations may be negatively affected by river regulatory activities (NSW DPI 2007a). The installation and operation of instream structures and mechanisms that alter natural flow regimes may adversely impact this species as listed in Schedule 6 of the FM Act (NSW DPI 2014b).	18
Billabong banded snail (<i>Notopala kingi suprafasciata</i>) [^]	Inhabits billabongs, swamps close to rivers and waterholes in creeks where it is found on mud and leaves and among aquatic plants. The habitat of the billabong banded snail implies that it is dependent on frequent overbank flooding. Populations may be negatively affected by reductions in flood frequencies (Jones 2011).	9
Sculptured snail (<i>Plotiopsis balonnensis</i>) [^]	The sculptured snail lives on rocks and water plants where it grazes on detritus and biofilms (Jones 2011). It is reliant on aquatic habitats and permanent waterholes which provide refuge from droughts (Glaubrecht et al. 2009). The environmental tolerances of this species are poorly known (Jones 2011).	9
Pouch snail (<i>Glyptophysa gibbosa</i>) [^]	Occupies a wide range of habitats and ecological conditions including floodplain wetlands, river littoral zones associated with water plants. Populations may be negatively affected by reductions in flood frequencies (Stevens 2007) or increases in flow velocities that reduces amount of available habitat (Jones 2011).	5

[^] Denotes these native animal species form part of the endangered Lowland Catchment of the Darling River aquatic ecological community. These species are considered aquatic species, under the definition of the FM Act. The listing of the lowland Darling River aquatic ecological community has given all native fish and other aquatic animal life within its boundaries the status of endangered species (NSW DPI 2007b).

Fauna surrogates excluded from the prioritisation

Burrowing species of frog including striped burrowing frog (*Cyclorana alboguttata*), short-footed frog (*Cyclorana brevipes*), water-holding frog (*Cyclorana platycephala*), rough frog (*Cyclorana verrucosa*), ornate burrowing frog (*Platyplectrum ornatum*), sudell's frog (*Neobatrachus sudellae*), crucifix frog (*Notaden bennettii*), and wrinkled toadlet (*Uperoleia rugosa*) are known to occur in the Barwon-Darling Valley Floodplain. These species were excluded from the ecological prioritisation as they are likely to have physiological characteristics which allow them to survive dry conditions (such as burrowing) and their water requirements are very poorly known (Wassens 2011).

Waterbird observations were excluded from the Marxan prioritisation. Waterbirds are not obligate residents, but highly mobile and dispersive species which may require habitat in multiple landscapes and use floodplain landscapes at different temporal scales (Scott 1997; Mackey et al. 2013; Kingsford et al. 2010; Gilmore et al. 2007). There was limited spatial data available for known historical colonial waterbird breeding sites in the Barwon-Darling Valley Floodplain, however, the maintenance of these habitats in the floodplain is important to ensure successful waterbird breeding. An overview of the types of waterbird habitats and the species they support that are known to occur in the Barwon-Darling Valley Floodplain are outlined below.

- Freshwater permanent or ephemeral wetlands with emergent aquatic vegetation such as typha, phragmites and lignum which are important breeding habitat for threatened waterbird species such as freckled duck (*Stictonetta naevosa*), blue-billed duck (*Oxyura australis*) and endangered Australian painted snipe (*Rostratula australis*).
- Floodplain wetlands (swamps, billabongs and watercourses) which are important habitat for threatened black-necked stork (*Ephippiorhynchus asiaticus*) and brolga (*Grus rubicunda*).
- Open water lagoons, billabongs and anabranches provide feeding habitats of ducks and fish-eating (piscivore) waterbird species such as cormorants, grebes, Australasian darter (*Anhinga novaehollandiae*) and Australian pelican (*Pelecanus conspicillatus*) and terns (Scott 1997; Kingsford et al. 2010). Shallow ephemeral waterbodies also provide a food source for many other species of waterbirds such as wading birds, egrets, and some ducks that rely on invertebrates and other small animals as a food resource (Scott 1997).
- Flood-dependent floodplain wetland (flood-dependent shrubland wetlands) and flood-dependent forest/woodland (wetlands) vegetation in low level floodplain regions provide waterbird breeding habitats and/or foraging habitat, such as
 - lignum (*Duma florulenta*), which is important for colonial-nesting species such as straw-necked Ibis (*Threskiornis spinicolis*) and glossy ibis (*Plegadis falcinellus*) providing nesting platforms for these species.
 - river red gum (*Eucalyptus camaldulensis*), black box (*Eucalyptus largiflorens*), coolibah (*Eucalyptus coolabah*), common reed (*Phragmites australis*) and cumbungi (*Typha* spp.) may provide nesting habitat for waterbird species.
 - semi-arid canegrass (*Eragrostis australasica*) swamps which may provide shallow water habitat favoured by ground-nesting waterbirds such as stilts, avocets and brolgas (Roberts & Marston 2011) and other vegetation communities which support grazing waterfowl.

Mapped semi-permanent wetland vegetation habitats were afforded with 100 per cent targets in the Marxan prioritisation to ensure protection of waterbird feeding and breeding habitats in the Barwon-Darling Valley Floodplain. Open water lagoons, billabongs and anabranches were allocated to MZ A to ensure connectivity to these waterbird habitat types. Where there was hydraulic justification, MZ A connections to/through floodplain wetland (flood-dependent shrubland wetlands) and flood-dependent forest/woodland (wetlands) were delineated to include areas of waterbird habitat. Table A8.1 contains the targets for vegetation communities that support waterbird feeding and breeding.

Appendix 9: Marxan prioritisation (constraint surface)

Marxan addresses the minimum-set problem, which is to meet a set of targets at the lowest cost. It minimises an objective function via a process of simulated annealing to select important parts of the landscape from a larger pool of potential areas (or planning units) taking into account planning-unit costs and the locations of the conservation features for protection (Ball, Possingham & Watts 2009). Efficiency is a core objective of Marxan. If efficiency is ignored prioritisation is a simple procedure of conserving everything which may be impractical (Possingham, Grantham & Rondinini 2007). The use of a constraint surface in ecological prioritisation, therefore, allows Marxan to create efficient planning solutions. A cost-efficient network of priority areas is also one that is comprehensive, representative and adequate for the least possible cost and is more likely to be defensible in light of competing interests (Wilson, Cabeza & Klein 2009).

The cost constraint was based on the latest available land use data for the Barwon-Darling Valley Floodplain (OEH 2011a). The land use categories used for computing the Marxan constraint surface were generated by grouping the land use classes identified in detailed land use maps for the Barwon-Darling Valley Floodplain (OEH 2011a). Each land use class was allocated a constraint weighting (scaled from 0 to 1) indicating the potential impacts of that land use may have on aquatic biodiversity and with consideration of the likely impact that land use types may have on hydrological processes on the floodplain (Table A9.1). The land use classes were fitted to the planning unit layer to create the constraint surface. This was done using an area-weighted average value of land capability to give each planning unit a single value using the Geospatial Modelling Environment (Spatial Ecology 2014) Intersect Polygons with Polygons tool (Figure A9.1). Planning units with desirable ecological processes were preferentially weighted lower, while those that were highly modified were weighted higher. For example, existing wetland and riparian areas on the floodplain were allocated a lower constraint weighting compared to areas of cropping, horticultural and intensive animal production. This approach is similar to the freshwater conservation planning work of Rivers-Moore, Goodman and Nel (2011). The Marxan constraint surface only influenced the prioritisation of ecological assets when there was a choice in prioritising one area over another. It did not influence the prioritisation of ecological assets when conservation targets for representation and persistence were very high.

Table A9.1 Land use categories used for computing the Marxan constraint surface and the weights given to each category

Major Land Use Category	Description	Land Use ALUM* Major Category	Land Use ALUM* Detailed description	Constraint
Conservation Area	Crown reserve, Crown reserve - with a woody vegetation cover of woodland, Lands fenced and treated for land degradation problems	Other minimal use	Residual native cover, Rehabilitation	0.45
	Cultural heritage site - aboriginal or European, National park, Protected area managed for conservation of specific natural features.	Nature conservation	Other conserved area, National park	0.45
	Tree lot	Plantation forestry	Environmental forest plantation	0.50
	Wide road reserve or TSR, with some grazing, Wide road reserve or TSR, with some grazing - with a woody vegetation cover of open forest, Wide road reserve or TSR, with some grazing - with a woody vegetation cover of woodland, Wide road reserve or TSR, with some grazing - with more than 30% of ground area having native shrub regeneration, Wide road reserve or TSR, with some grazing - with more than 30% of ground area having regeneration of native tree species	Other minimal use	Stock route	0.50
Cropping	Agricultural industry in a rural location e.g. cotton gin	Manufacturing and industrial	Manufacturing and industrial	
	Cotton – irrigated, Cotton - irrigated; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water, Cotton - irrigated; irrigation practice - sub-surface irrigation, Cropping - continuous or rotation – irrigated, Cropping - continuous or rotation - irrigated; irrigation practice - centre pivot, Cropping - continuous or rotation - irrigated; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water, Cropping - continuous or rotation - irrigated; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water, Cropping of legumes for seed - chickpeas, lupins, vetches, field beans - irrigated; irrigation practice - laser levelled with tail water reticulation and on-farm tail water storage	Irrigated cropping	Irrigated cotton, Irrigated pulses	1.00

Cropping	Cropping - continuous or rotation, Cropping - continuous or rotation - with a woody vegetation cover of woodland, Cropping - with a fixed irrigation system not used at the time of mapping, Cropping within an ephemeral wetland (does not include cropping within an ephemeral lake - see classes 186 & 187), Cropping within bed of an ephemeral lake; lake is not regulated or above regulation level, Fodder crop	Cropping	Cropping, Hay & silage	
	Storage site for agricultural chemicals and products (e.g. fertiliser dumps, cotton bunkers and temporary grain storages)	Manufacturing and industrial	Manufacturing and industrial	
Grazing	Flood runners in western NSW - with a woody vegetation cover of woodland, Flood runners in western NSW - with more than 30% of ground area having regeneration of native tree species, Flood runners in western NSW. (Vegetation is indicative of a more prolonged period of inundation or wetness.)	Grazing native vegetation	Grazing native vegetation	0.10
	Grazing within an ephemeral wetland - with more than 30% of ground area having native shrub regeneration, Grazing within an ephemeral wetland (does not include cropping within an ephemeral lake - see classes 182 & 189), Grazing within bed of an ephemeral lake or watercourse; lake or watercourse are not regulated or above regulation level, Grazing within bed of an ephemeral lake or watercourse; lake or watercourse are not regulated or above regulation level - with a woody vegetation cover of woodland, Grazing within bed of an ephemeral lake or watercourse; lake or watercourse are not regulated or above regulation level with a dense shrub or tree cover, Rangeland grazing within western river outflows (e.g. Paroo & Warrego Rivers)	Grazing native vegetation	Grazing native vegetation	0.25
	Grazing of riparian land, Grazing of riparian land - with a woody vegetation cover of open forest, Grazing of riparian land - with a woody vegetation cover of woodland	Grazing modified pastures	Grazing modified pastures	0.35
	Areas of dense standing dead trees with the ground cover consisting of volunteer species such as bracken, blady grass and tea tree	Other minimal use	Other minimal use	0.50
	Firebreak	Grazing native vegetation, Other minimal use	Grazing native vegetation, Residual native cover	0.50
Flood refuge (constructed features located within flood prone areas)	Land in transition	No defined use	0.50	

<p>Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation, Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with a woody vegetation cover of open forest, Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with a woody vegetation cover of woodland, Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with more than 30% of ground area having native shrub regeneration, Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with more than 30% of ground area having regeneration of native tree species, Rangeland grazing, Rangeland grazing - with a woody vegetation cover of open forest, Rangeland grazing - with a woody vegetation cover of woodland, Rangeland grazing - with more than 30% of ground area having native shrub regeneration, Rangeland grazing - with more than 30% of ground area having regeneration of native tree species</p>	<p>Grazing native vegetation</p>	<p>Grazing native vegetation</p>	<p>0.60</p>
<p>Degraded land (salt site, eroded area)</p>	<p>Land in transition</p>	<p>Degraded land</p>	<p>0.65</p>
<p>Grazing - Residual strips (block or linear feature) of native grassland within cultivated paddock - with a woody vegetation cover of woodland, Grazing - Residual strips (block or linear feature) of native grassland within cultivated paddock. Strips contain scattered to isolated trees only, Grazing of areas with water ponding treatments</p>	<p>Grazing native vegetation</p>	<p>Grazing native vegetation</p>	<p>0.65</p>
<p>Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation, with previous evidence of cultivation</p>	<p>Grazing native vegetation</p>	<p>Grazing native vegetation</p>	<p>0.75</p>
<p>Irrigated pastures; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water, Irrigated pastures; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water, Irrigated pastures; irrigation practice - sprinkler irrigation</p>	<p>Grazing irrigated modified pastures</p>	<p>Grazing irrigated modified pastures</p>	<p>0.85</p>
<p>Recently cleared land (cleared of forest vegetation as yet not covered by crop or pasture), Sown, improved perennial pastures, Volunteer, naturalised, native or improved pastures, Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - contour irrigation, Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - furrow irrigation, Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water, Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used</p>	<p>Grazing modified pastures</p>	<p>Native/exotic pasture mosaic</p>	<p>1.00</p>

	at the time of mapping; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water, Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water, Volunteer, naturalised, native or improved pastures, with previous evidence of cultivation			
	Regeneration within sites cleared under a 'window-pane' pattern	Grazing modified pastures	Grazing modified pastures	1.00
Horticulture	Building associated with horticultural industry (winery, packing shed)	Manufacturing and industrial	Manufacturing and industrial	
	Eucalyptus oil plantation	Perennial horticulture	Perennial horticulture	
	Joboba planting - irrigated; irrigation practice - drip irrigation, Olives – irrigated, Olives - irrigated; irrigation practice - drip irrigation	Irrigated perennial horticulture	Irrigated oleaginous fruits	1.00
	Orchard - tree fruits – irrigated, Orchard - tree fruits - irrigated; irrigation practice - drip irrigation	Irrigated perennial horticulture	Irrigated tree fruits	
	Vegetables - irrigated: irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water	Irrigated seasonal horticulture	Irrigated seasonal vegetables & herbs	
	Vineyard - grape and other vine fruits - irrigated; irrigation practice - drip irrigation	Irrigated perennial horticulture	Irrigated vine fruits	
Intensive Animal Production	Abattoir	Manufacturing and industrial	Abattoirs	
	Effluent ponds from intensive animal industries	Reservoir/dam	Effluent pond	1.00
	Intensive animal production - beef feedlot	Intensive animal husbandry	Cattle feedlots	
	Saleyard	Services	Commercial services	
Mining & Quarrying	Derelict mining land, Gypsum mine and associated processing, Quarry	Land in transition, Mining	Degraded land, Mines, Quarries	1.00
Power Generation	Electricity substation	Utilities	Fuel powered electricity generation	1.00
River & Drainage System	Flood chute (flood runners that are filled with water during and after floods) and designated floodway in irrigation districts, localities, Flood chute and designated floodway in irrigation districts, localities - with a woody vegetation cover of woodland, Lagoon or inland lake, River gravel deposit, River, creek or other incised drainage feature; includes cowals in western NSW	River	River	0.10
	Drainage depression in cropping paddock	Channel/aqueduct	Channel/aqueduct	0.20

	Disposal dam, depression or lake bed for irrigation tail water, Farm dam, Irrigation dam, Irrigation supply channel, Levee bank for urban area, Bore drain (active), Drainage channel (from irrigation system or a channel draining a swamp; base of channel is lined), Drainage or water supply channel - base of channel is not lined	Reservoir/dam, Channel/aqueduct, Services	Reservoir/dam, Supply channel/aqueduct, Evaporation basin Services, Drainage Channel/aqueduct	1.00
	Temporary water storage area (e.g. rice farming - opportunistic storage of water in natural depressions, Water supply pressure reservoir including water filtration plant, Weir	Reservoir/dam	Reservoir/dam	1.00
Special Category	Farm Infrastructure - house, machinery & storage sheds and garden areas, Irrigation farm infrastructure; miscellaneous lands within farms including access roads, bund walls, buildings and services, Irrigation farm infrastructure; miscellaneous lands within farms including access roads, bund walls, buildings and services - with more than 30% of ground area having native shrub regeneration, Irrigation farm infrastructure; miscellaneous lands within farms including access roads, bund walls, buildings and services - with more than 30% of ground area having regeneration of native tree species, Levee for flood protection around house and farm infrastructure	Residential and farm infrastructure	Farm buildings/infrastructure	1.00
Transport & Other Corridors	Aerodrome/airport, Airstrip (local/farmer, grass or bare surface, not sealed), Communications facility, Railway, Railway - track no longer used, Road or road reserve	Transport and communication	Airports/aerodromes, Transport and communication, Navigation and communication, Railways, Roads	1.00
Tree & Shrub Cover	Dense shrub growth - limited to nil grazing capacity, Native forest, Native forest – regeneration, Native woody shrub	Other minimal use, Land in transition	Rehabilitation, Residual native cover, Land under rehabilitation	0.50
	Windbreak or tree corridor	Plantation forestry	Environmental forest plantation	0.50
	Woodland (unmodified native vegetation)	Grazing modified pastures	Native/exotic pasture mosaic	0.50
Urban	Areas irrigated with effluent from sewage disposal ponds, Caravan park or mobile home village, Cemetery, Government and private facilities - gaol, training centre, school, religious institutions & training centres, religious retreats, Industrial/commercial, Landfill (garbage), Rural recreation. Blocks are isolated and not associated with an urban area, Tourist development, University or other tertiary institution, Urban recreation, Sewage disposal ponds	Waste treatment and disposal, Services	Sewage, Recreation and culture, Public services, Landfill	1.00
	Residential, Rural residential	Residential and farm infrastructure	Urban residential, Rural residential with agriculture	1.00
Wetland	Floodplain swamp, Floodplain swamp - back swamp, Floodplain swamp – billabong, Swamp	Marsh/wetland	Marsh/wetland	0.10

* ALUM = Australian Land Use and Management Classification.

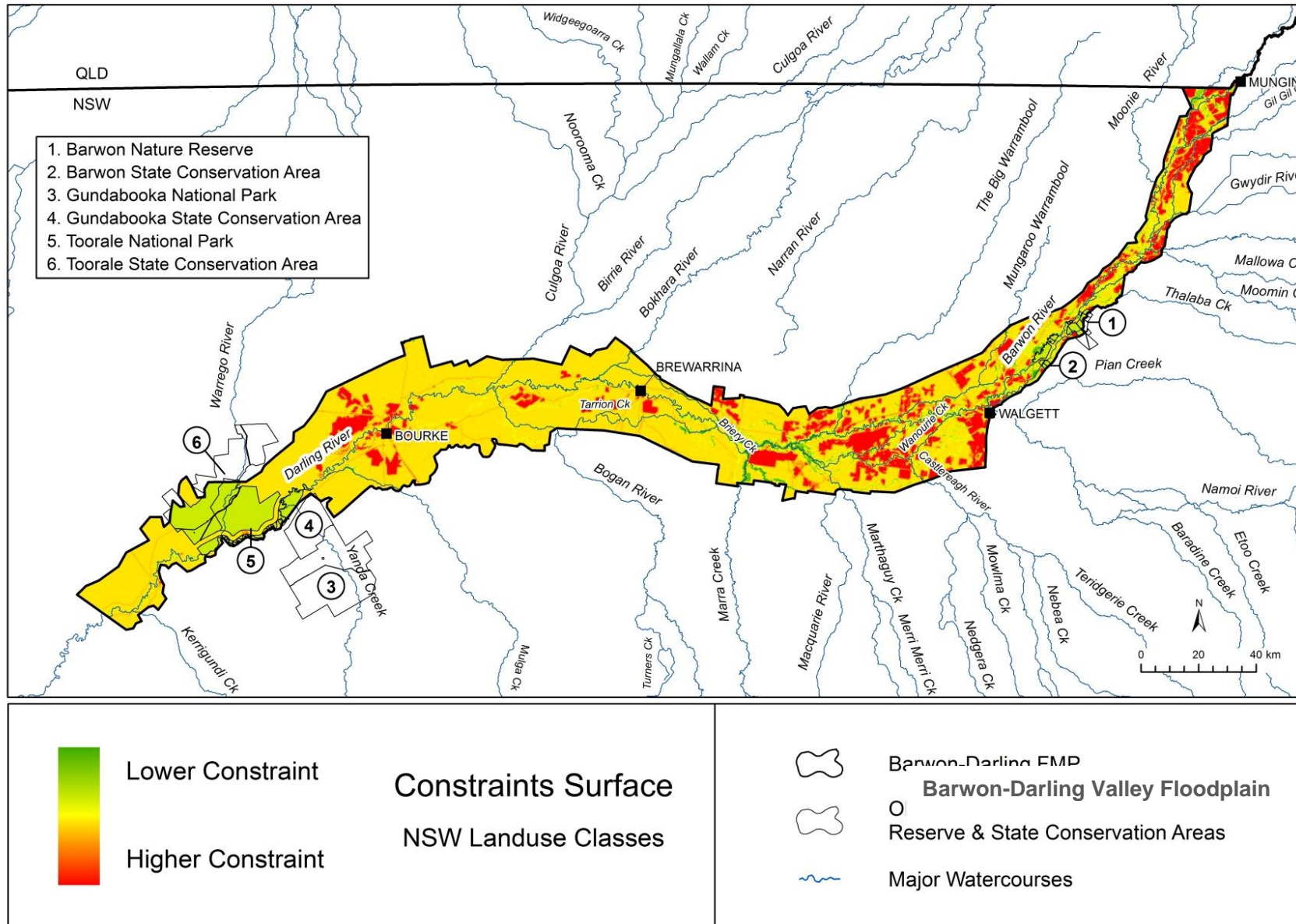


Figure A9.1 Land use based constraints surface derived from detailed land use mapping (OEH 2011a) for the Barwon-Darling Valley Floodplain

Appendix 10: Aboriginal Sites Decision Support Tool

The Aboriginal Sites Decision Support Tool (ASDST) was developed to meet a critical need in regional planning: whole-of-landscape data describing Aboriginal site issues. There are two key components of the ASDST: landscape visualisation through the provision of visual products (GIS layers) that fill in data gaps in the Aboriginal Heritage Information Management System (AHIMS) data; and analysis, by generating information products designed to meet the need of incorporating Aboriginal site heritage information into regional, park, land and natural resource management planning.

The tool is based on and a leader in international best practice in archaeological site predictive modelling and has been successfully applied as part of a variety of projects across NSW (see further information the ASDST website (www.environment.nsw.gov.au/licences/AboriginalSitesDecisionSupportTool.htm)).

Landscape visualisation tool

A suite of state-wide products (GIS layers) of the ASDST have been developed to support regional scale context setting and strategic planning. These layers provide users with landscape context about:

- the original (pre-colonisation) potential distribution of AHIMS features
- the current potential distribution of AHIMS features
- the accumulated impact on AHIMS features across the landscape
- the reliability and validation priority of the ASDST products, and
- a classification of the landscape into areas with similar AHIMS feature profiles.

Analytical tool

The analytical component of the ASDST generates information products (GIS layers, numerical reports and interpretive documents) that can be used to support regional planning for Aboriginal site heritage. The tool utilises modelled information about:

- accumulated impacts
- gap analysis, and
- representativeness.

In turn, this information can be used to report on issues including:

- degree of loss of different AHIMS features in the landscape
- assessment priority and developing survey strategies, and
- conservation priority.

For the Barwon-Darling Valley FMP, the ASDST was used as a context-setting tool, to inform where there may be areas of potential flood-dependent sites, and where there are significant knowledge gaps arising from gaps in the systematic survey for flood-dependent Aboriginal sites. The ASDST data products were used to inform the identification of priority conservation areas for Aboriginal values.

Applicants are required to satisfy due diligence requirements under the *National Parks and Wildlife Service Act 1974*. The ASDST is an important tool that landholders can use prior to submitting a flood-work application to identify areas where there is a high likelihood of cultural asset occurrence. Where there is a high likelihood of cultural asset occurrence it is recommended that a cultural heritage assessment be undertaken prior to submitting a flood-work application to ensure that due diligence requirements are satisfied. More information on landholder due diligence requirements can be obtained from: <http://www.environment.nsw.gov.au/licences/achregulation.htm>

Appendix 11: Socio economic profile

Background

The water management principles of the WMA 2000 require that planning on floodplains considers the socio-economic impacts of proposed flood work management strategies to maximise the social and economic benefits to the community; to avoid and minimise the impacts of flood works on other water users; and to minimise the existing and future flood risk to human life and property arising from occupation of floodplains.

The Barwon-Darling Valley FMP contains management zones and rules that provide an equitable and consistent approach to controlling development on the floodplain. The management zones and rules are designed to minimise the impact that flood work development may have on neighbouring properties, which will help to minimise the risk to life and property from the effects of flooding.

A socio-economic profile of the floodplain area was required so that the social and economic impact of development controls in the floodplain and flood risk to life and property from the effects of flooding can be effectively considered.

In addition, it is important that, before options about future water resource management can be developed, the floodplain area is understood and the ability of the community to absorb change is appreciated.

The objective of the profile of socio-economic factors is to assemble existing key socio-economic data to provide a general picture of the socio-economic and demographic structures of the catchment.

Developing the profile, or 'snapshot', involves documenting the biophysical, social and economic conditions of the valley to help understand the floodplain. The main types of socio-economic information that inform the baseline profile include:

- geographies that are relevant to the socio-economic discussion of the floodplain,
- demographic profiles,
- household income statistics,
- employment statistics,
- economic wellbeing indicators, and
- agricultural production statistics.

The socio-economic profile analysis informs Steps 7, 8 and 10 of the preparation of the Barwon-Darling Valley FMP. Information from this profile informed the development of management zones and rules (Steps 7 and 8). Information from this profile was also drawn upon in the socio-economic impact analysis (Step 10) that identifies and considers the potential socio-economic impacts associated with the implementation of the FMP. The socio-economic impact analysis was undertaken in coordination with the development of management zones and rules.

Study area geography

There are several geographies that are relevant to the socio-economic discussion of flood management within the Barwon-Darling Valley Floodplain covering 1.1 million hectares. The three areas examined were the Barwon-Darling Valley Floodplain economy, rural floodplain and the urban floodplain.

The Barwon-Darling Valley Floodplain economy (Figure A11.1) area includes the Barwon-Darling rural and urban floodplains as well as the adjacent areas in the Barwon and Bogan River catchments that engage with the economy of the region. This area (8 million hectares) is located between the regional centres of Moree, Dubbo and Broken Hill and the

Queensland border. Most goods and services consumed in the Barwon-Darling Valley Floodplain economy area are sourced from the regional centres of Bourke, Brewarrina, Collarenebri, Lightening Ridge and Walgett or other small townships in this area.

The Barwon-Darling rural floodplain is the area downstream of Mungindi along the Barwon and Darling Rivers to Weir 21 approximately 25 km downstream of Louth. The Barwon-Darling Valley Floodplain is bounded by the Border Rivers, Gwydir and Namoi Valley floodplains in the east and the Macquarie Valley floodplain in the south. The Barwon-Darling rural floodplain area, of 4.8 million hectares, will be directly impacted by the Barwon-Darling Valley FMP (Figure A11.2). The community residents who live and work in this area are predominantly agricultural based, but the community does include people who live in small rural towns. There are limited community services and infrastructure in this area; most of the required farm inputs and human services are provided from the local towns and the regional centres.

The Barwon-Darling urban floodplain incorporates the townships of Bourke, Brewarrina, Collarenebri and Walgett. While this area is situated on or adjacent to the floodplain, and may be affected by Barwon-Darling Valley FMP flood water, flood water management in urban areas of NSW is provided under the Local Government Act 1993. The communities that live in these towns are reliant upon the surrounding rural floodplain areas both as a source of employment and as a consumer of services.

Data sources

Demographic data for the Barwon-Darling Valley Floodplain economy, the Barwon-Darling rural floodplain, and the Barwon-Darling urban floodplain; on population including the Aboriginal community, on sex and age ratios; on household weekly incomes; and on labour participation rates and employment by industry sector; is drawn from the ABS Census of Population and Housing 2011 Statistical Area level 1 (SA1) data (ABS 2011a). The SA1 areas are the smallest unit for release of Census data. The SA1 boundaries combine to form the boundary of the Barwon-Darling Valley Floodplain economy and the urban floodplain areas. The rural floodplain area is defined as parts of 5 SA1 areas. Regional population trends for local government areas have been drawn from the ABS Regional Population Growth 2013 data (ABS 2013).

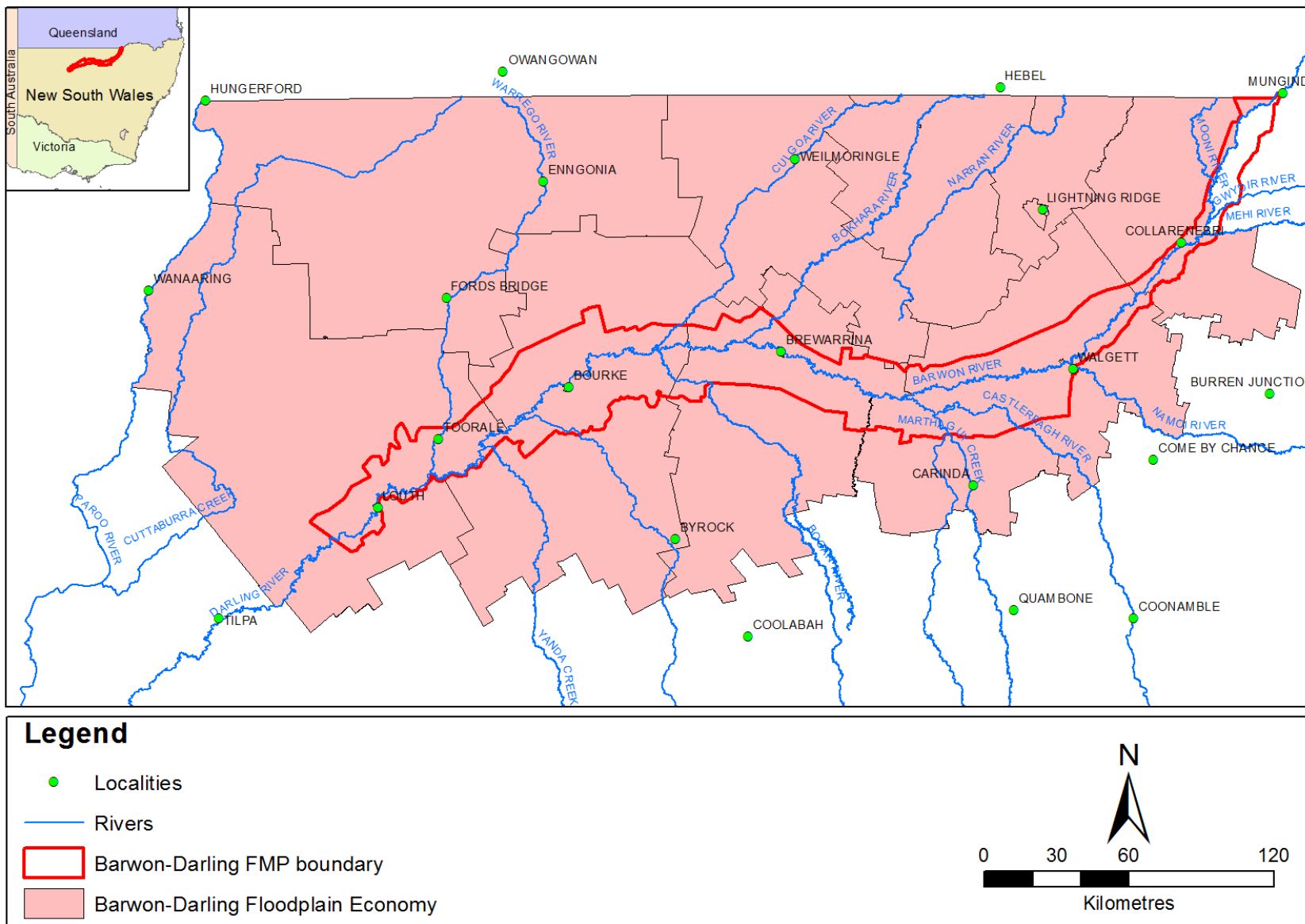


Figure A11.1 Barwon-Darling Valley FMP and Barwon-Darling Floodplain economy area

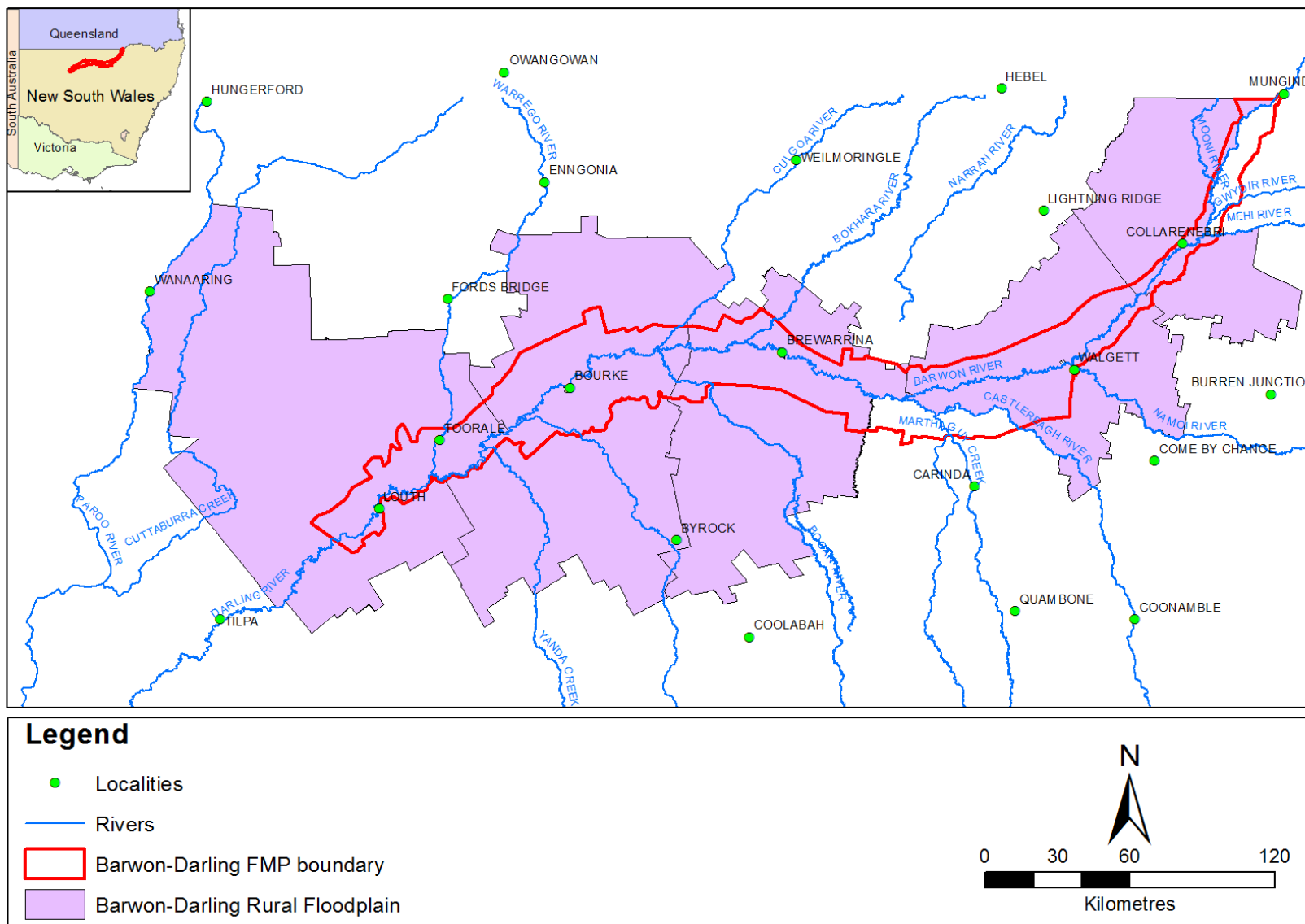


Figure A11.2 Barwon-Darling Valley FMP and Barwon-Darling rural floodplain area

Information on the relative socio-economic advantage and disadvantage rankings for the LGA and SA1 areas is drawn from the ABS Census of Population and Housing 2011 Socio-economic Indexes for Areas (SEIFA) (ABS 2011b).

Agricultural production is a significant component of the floodplain economy. The ABS Agricultural Census 2011 (ABS 2011c) provides comprehensive data on both dry land and irrigated agricultural production at the Statistical Area level 2 (SA2). SA2 areas are a general-purpose medium sized area built from whole SA1s. The SA2 communities of the floodplain economy include parts of the SA2 regions of Bourke – Brewarrina, Walgett – Lightning Ridge and Moree Region.

Demographic profiles

In general, regional populations have experienced gradual decline, however the populations of the 3 Local Government Areas of the Barwon-Darling region have stabilised over recent years. Regional population trends for the 3 relevant Local Government Areas are presented in Figure A11.3.

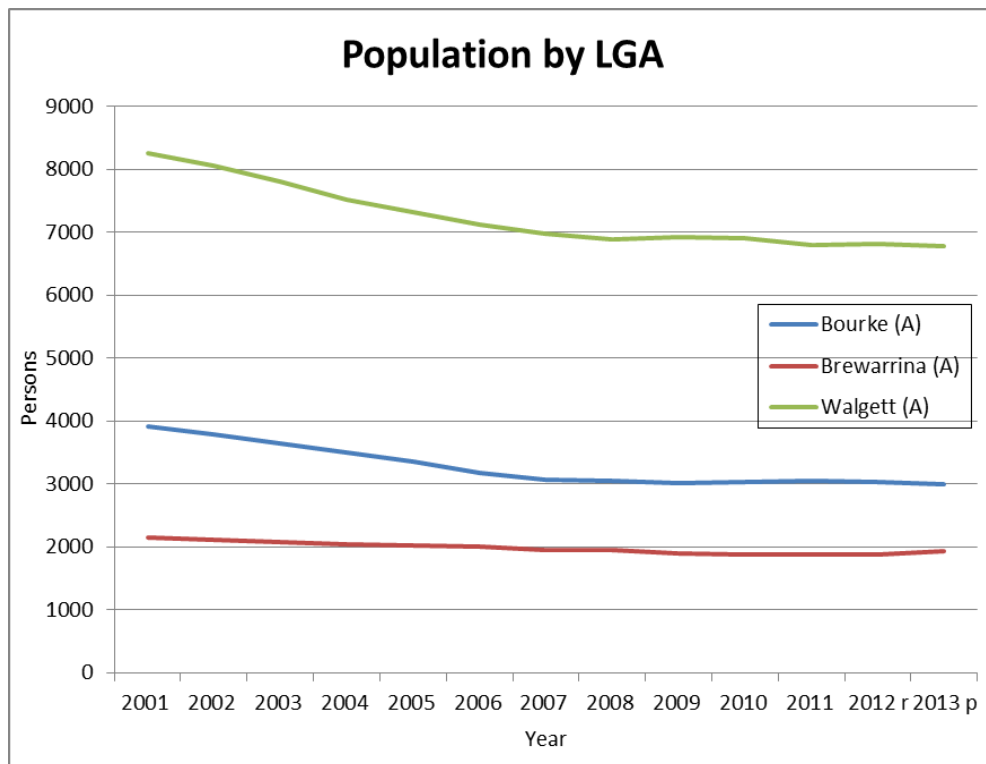


Figure A11.3 Barwon-Darling regional population trend by LGA 2001 - 2013

Barwon-Darling Valley Floodplain economy

The economy of the Barwon-Darling Valley Floodplain is interwoven with the economy of the adjacent community, drawing inputs from, passing outputs through and using services from the same business centres as the adjacent community. It is appropriate therefore to consider the socio-economic profile of the wider Barwon-Darling Valley Floodplain economy (Figure A11.1).

The population of the Barwon-Darling Valley Floodplain economy area (Figure A11.3) is estimated to be 10,690 people, of whom 72 per cent live in towns. The major towns of this area are: Bourke, Brewarrina, Collarenebri, Lightning Ridge and Walgett. The overall Barwon-Darling Valley Floodplain economy total population is greater than the total of the Barwon-Darling rural and urban floodplain populations as the boundary of the Barwon-

Darling Valley Floodplain economy area includes areas in addition to the rural and urban floodplain areas (see Figure A11.1 and A11.2).

The Aboriginal community makes up 34.5 per cent of the Barwon-Darling Valley Floodplain economy population, which is substantially higher than the NSW state proportion of 2.5 per cent.

There were more males than females living in the Barwon-Darling Valley Floodplain economy area; the sex ratio (the number of males per 100 females) is 110.

The dependency ratio of the Barwon-Darling Valley Floodplain economy is 59, a measure of the proportion of the population that is not of working age per 100 persons of working age (aged 15-64). This dependency ratio should be read with the understanding that there are a considerable number of farmers over the age of 64 years continue to work in the agricultural sector. The 'actual' dependency ratio is likely to be closer to the NSW state ratio of 52. The age by sex distribution of this community reveals an under representation in the 15 to 45 age groups, as compared to the under 15 and over 45 age groups of the NSW population. This under representation is demonstrated to a greater extent in the Barwon-Darling rural floodplain.

The age by sex distribution of the Barwon-Darling Valley Floodplain economy is presented in Figure A11.4. The age by sex distribution of the NSW population is presented in Figure A11.5.

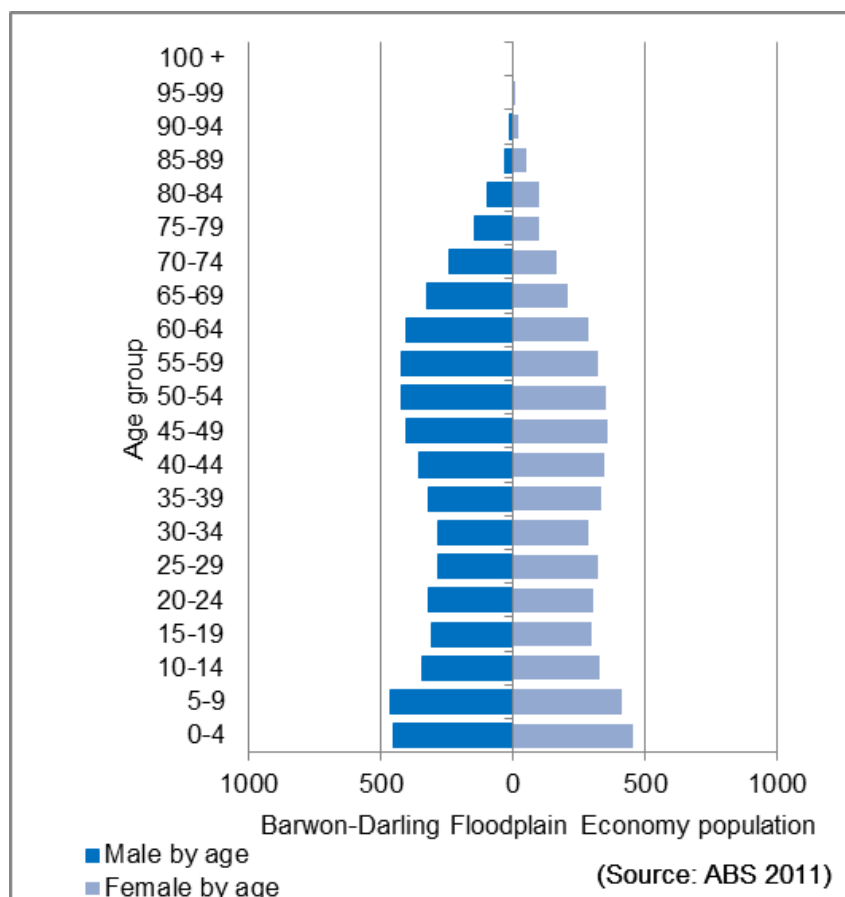


Figure A11.4 Barwon-Darling Valley Floodplain economy by age group and sex 2011

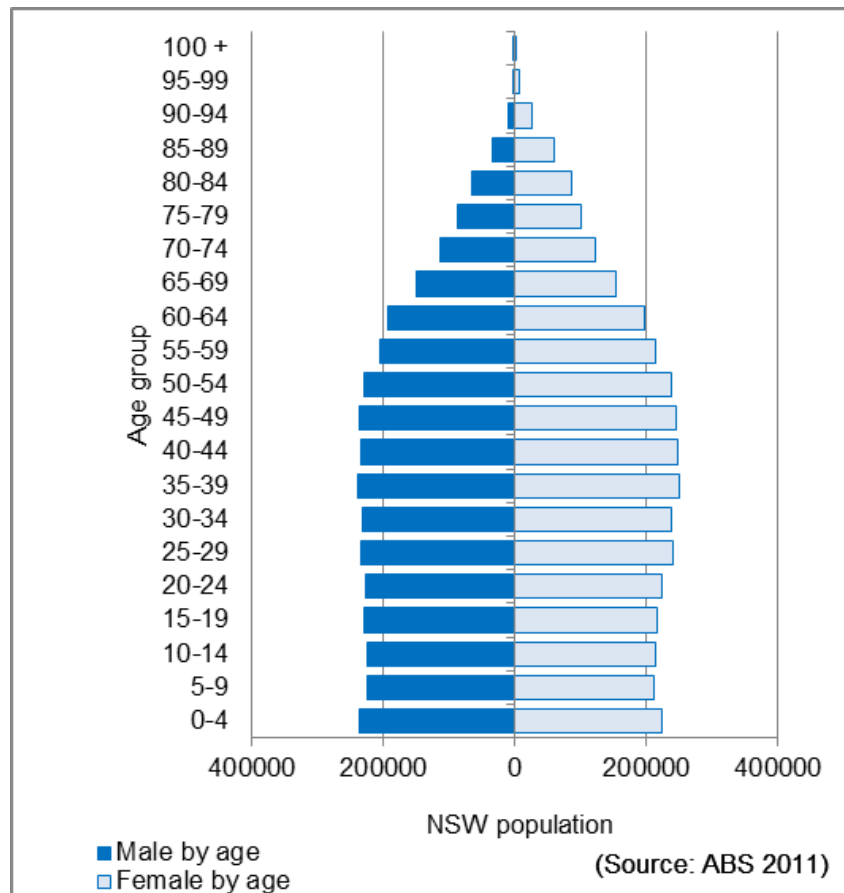


Figure A11.5 NSW by age group and sex 2011

The Barwon-Darling rural floodplain

The estimated population of the Barwon-Darling rural floodplain, calculated on the area of 4.8 million hectares, is 1,800 people. The population density of the rural floodplain is estimated to be 3.8 people per 100 km².

The Aboriginal proportion of the Barwon-Darling rural floodplain community is 15.6 per cent, which is more than six times that of the NSW community at 2.5 per cent.

There are more males than females in the Barwon-Darling rural floodplain population, with the sex ratio of 119 higher than the NSW state sex ratio of 97.

The dependency ratio of the Barwon-Darling rural floodplain, at 53, is close to the NSW state dependency ratio of 52. As discussed regarding the dependency ratio calculated for the Barwon-Darling Valley Floodplain economy, a considerable number of farmers over the age of 64 years continue to work in the Agricultural sector. The 'actual' dependency ratio is likely to be lower than the NSW state ratio.

The population pyramid (age by sex) indicates a lower than expected proportion of the population in the 15 to 45 age groups. This is likely to be related to the inaccessibility of secondary and tertiary education opportunities, and associated employment, in this area. The age by sex distribution of the Barwon-Darling rural floodplain is presented in Figure A11.6.

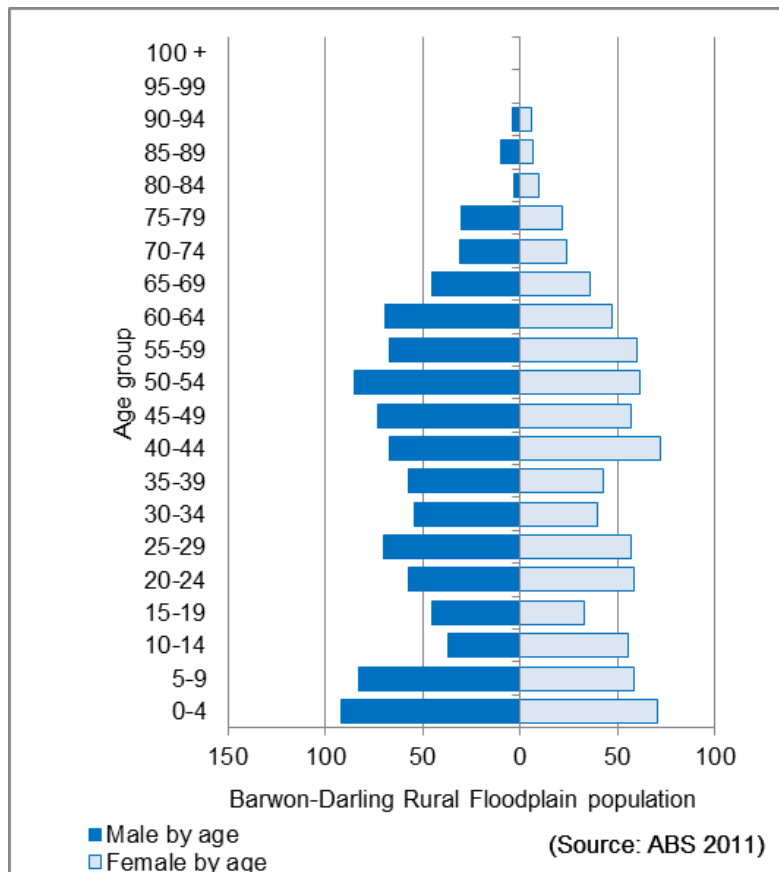


Figure A11.6 Barwon-Darling Rural Floodplain population by age group and sex 2011

The Barwon-Darling urban floodplain

The Barwon-Darling urban floodplain population of 5,150 people includes the urban centres of Bourke with a population of 2,050, Brewarrina with 930, Collarenebri with 390 and Walgett with 1,790 people.

The Aboriginal community constitutes 49.3 per cent of the Barwon-Darling urban floodplain community, which is substantially above the Barwon-Darling rural floodplain proportion of 15.6 per cent and the NSW proportion of 2.5 per cent.

The sex ratio of the Barwon-Darling urban floodplain is 98, which is lower than the Barwon-Darling rural floodplain sex ratio of 119 and close to the NSW state sex ratio of 97.

The dependency ratio of the Barwon-Darling urban floodplain is 57, higher than the adjacent Barwon-Darling rural floodplain community dependency ratio of 53 and the NSW state dependency ratio of 52.

The demographic statistics are presented in Table A11.1 and the age by sex distribution is presented in Figure A11.7. It is interesting to note that the Barwon-Darling urban floodplain community does not reflect the under representation in the 15 to 45 age groups observed in the rural floodplain community.

Household Income

Barwon-Darling Valley Floodplain economy

The proportion of low income households (with weekly incomes of \$599 or below) in the Barwon-Darling Valley Floodplain economy, at 38 per cent, is well above the NSW state proportion of 23 per cent. The proportion of medium income households (with weekly incomes of \$600 to \$2,499 per week) in the Barwon-Darling Valley Floodplain economy, at

53 per cent, is close to the NSW proportion of 56 per cent. Consequently, the high income household proportion of 9 per cent is well below the NSW state proportion of 21 per cent.

The weekly household income proportions for NSW, and for the Barwon-Darling Valley Floodplain economy, rural floodplain and urban floodplain, are presented in Figure A11.8.

Table A11.1 NSW and Qld Barwon-Darling urban floodplain demographic statistics

Town	Area (ha)	Total population	Aboriginal population	Aboriginal proportion (%)	Dependency ratio
Bourke	653	2,050	760	37.0	55
Brewarrina	295	930	610	65.5	59
Collarenebri	111	390	190	48.1	61
Walgett	838	1,790	990	55.3	56
Total Barwon-Darling urban Floodplain	1,897	5,160	2,550	49.4	57
NSW Total		6,917,700	172,600	2.5	52

Source: ABS 2011a

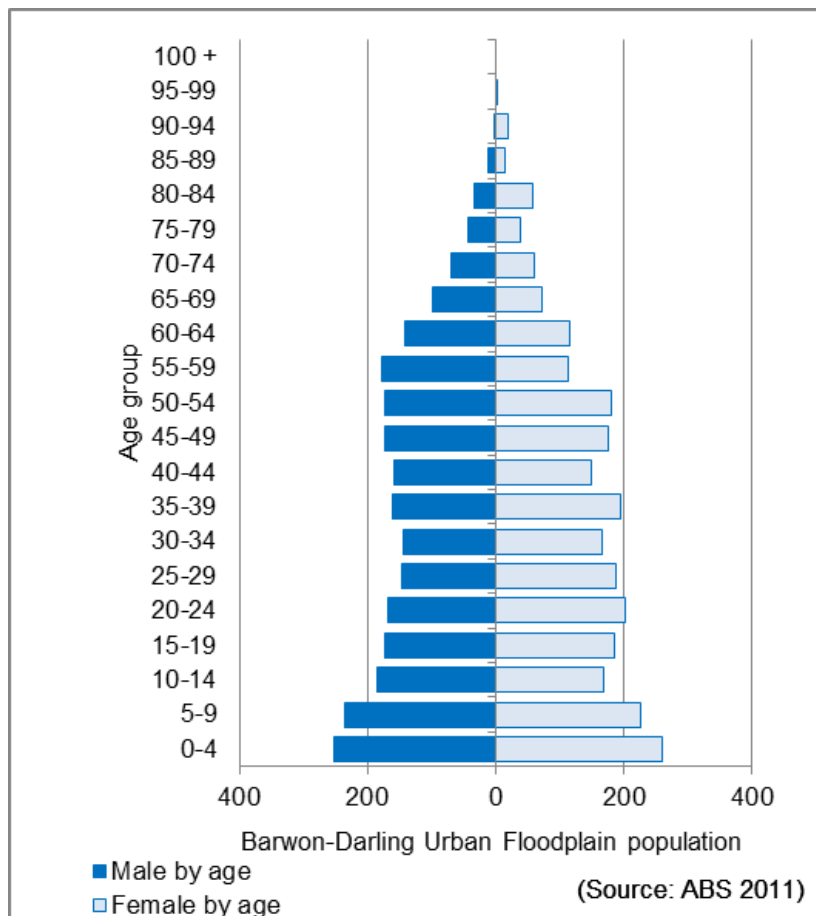


Figure A11.7 Barwon-Darling urban floodplain population by age group and sex 2011

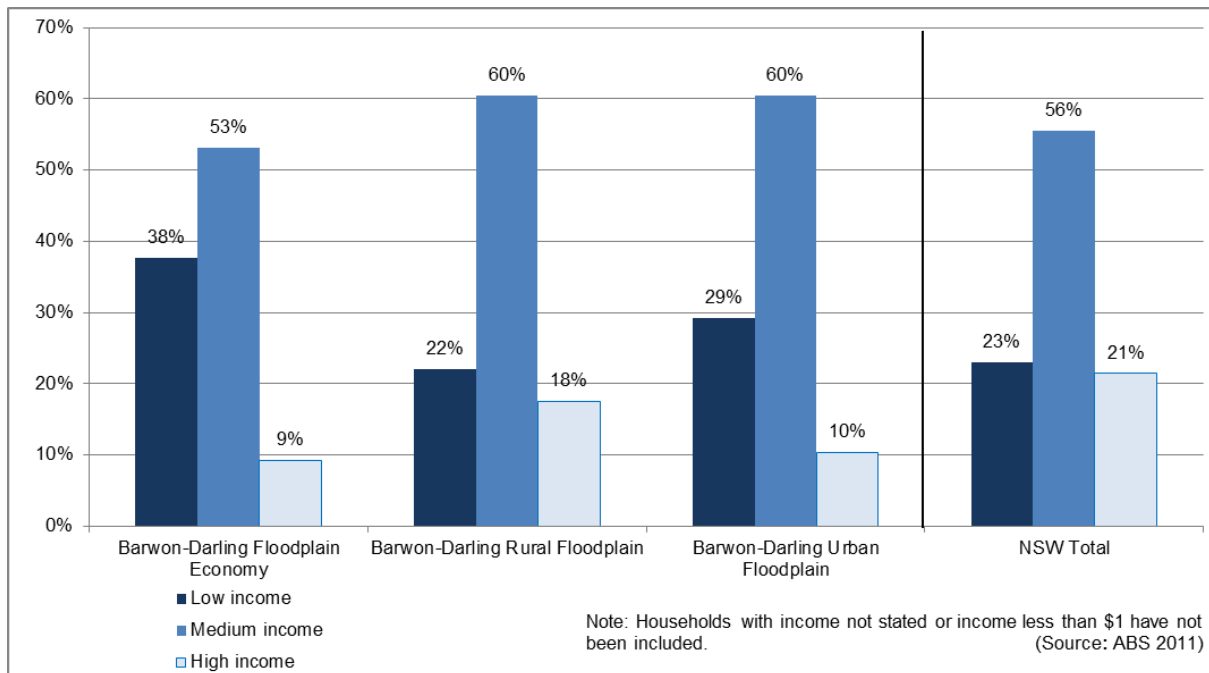


Figure A11.8 Distribution of households in low, medium, and high income categories (%)

Barwon-Darling rural floodplain

The Barwon-Darling rural floodplain households in 2011 are equally as prosperous as their NSW state counterparts, with a similar proportion of households in the low income category at 22 per cent, as the NSW state proportion of 23 per cent. The proportion of households in the medium income range, at 60 per cent, is greater than the NSW state proportion of 56 per cent. The high income proportion of 18 per cent is less than the state proportion of 21 per cent.

Barwon-Darling urban floodplain

The Barwon-Darling urban floodplain community has a greater proportion of low income households than the NSW state, at 29 per cent. The proportion of medium income households, at 60 per cent, is above the NSW state proportion. The proportion of high income households, at 10 per cent, is about half that of the NSW state proportion of 21 per cent. The medium weekly household income in the Barwon-Darling Valley Floodplain economy correlates with that of the Barwon-Darling urban floodplain, with 72 per cent of the population living in the townships, however, there are more low income and less high income households in the Barwon-Darling urban floodplain.

Employment

Barwon-Darling Valley Floodplain economy

The labour force of the Barwon-Darling Valley Floodplain economy is 3,900 persons. The number of persons 15 years and above is 8,230. The labour force participation rate, which is the number of persons in the labour force as a percentage of persons aged 15 years and over, at 47 per cent is below the NSW participation rate of 56 per cent.

Employment in the Barwon-Darling Valley Floodplain economy is predominantly within the agricultural, forestry and fishing sector with 23.5 per cent of employment (920 persons, with this number including employment in a large agricultural area that is not on the rural floodplain). In contrast, the NSW state agriculture sector engages 2.2 per cent of the workforce. The next most significant employment sectors are health care and social assistance, education and training and public administration and safety, with 13.8 per cent,

12.7 per cent, and 11.6 per cent of employment, respectively. There is a relatively even distribution of the remaining 38.4 per cent of employment amongst the other sectors. Barwon-Darling Valley Floodplain economy employment by sector, organised in order of the top 10 sectors in the Barwon-Darling rural floodplain, is presented in Figure A11.9. Total employment for NSW is presented in Figure A11.10.

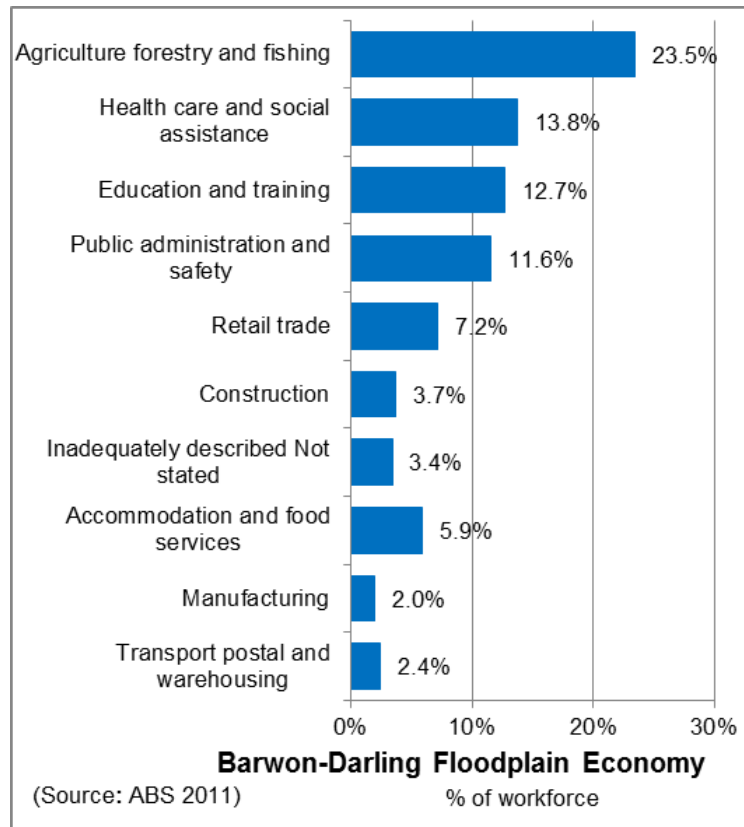


Figure A11.9 Barwon-Darling Valley Floodplain economy employment by industry sector

Barwon-Darling rural floodplain

The labour force of the Barwon-Darling rural floodplain is 910 persons. The population 15 years and above is 1,400 persons. The labour force participation rate is 65 per cent, markedly higher than the NSW participation rate of 56 per cent.

Employment in the Barwon-Darling rural floodplain is dominated by the agriculture, forestry and fishing sector, with 55.4 per cent of the workforce or 510 persons, working in the agricultural industry. This is in sharp contrast to the NSW state agriculture sector which engages only 2.2 per cent of the workforce. The next most significant employment sectors of the Barwon-Darling rural floodplain are health care and social assistance with 8.1 per cent, education and training with 7.9 per cent of the workforce and public administration and safety with 4.2 per cent. Employment by sector for the top 10 sectors in the rural floodplain is presented in Figure A11.11

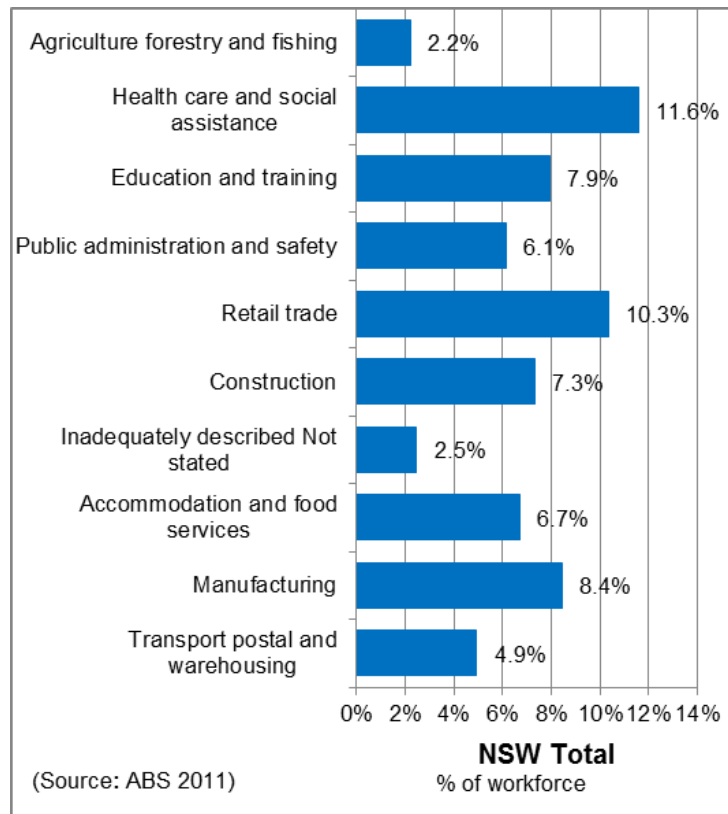


Figure A11.10 NSW total employment by industry sector

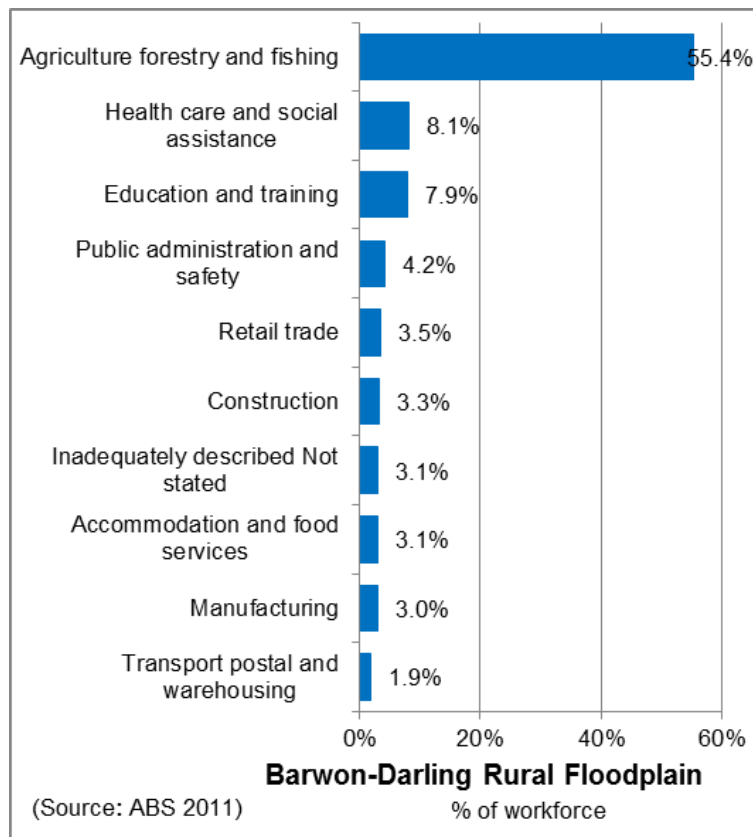


Figure A11.11 Barwon-Darling rural floodplain employment by industry sector

Barwon-Darling urban floodplain

The labour force of the Barwon-Darling urban floodplain is 1,840 persons. The population of 15 years and above is 3,820 persons. The labour force participation rate is 48 per cent, about the same participation rate as in the Barwon-Darling Valley Floodplain economy but lower than the in NSW, and substantially lower than the participation rate in the Barwon-Darling rural floodplain.

In contrast with the surrounding rural community, employment in the Barwon-Darling urban floodplain is reasonably evenly distributed across sectors. A significant proportion of the workforce is employed in the service sectors. The public administration and safety sector is the most significant employer with 19.2 per cent of the workforce (350 persons), closely followed by health care and social assistance with 18.4 per cent, and then by education and training with 15.6 per cent. Barwon-Darling urban floodplain employment by sector, organised in order of the top 10 sectors in the Barwon-Darling rural floodplain, is presented in Figure A11.12.

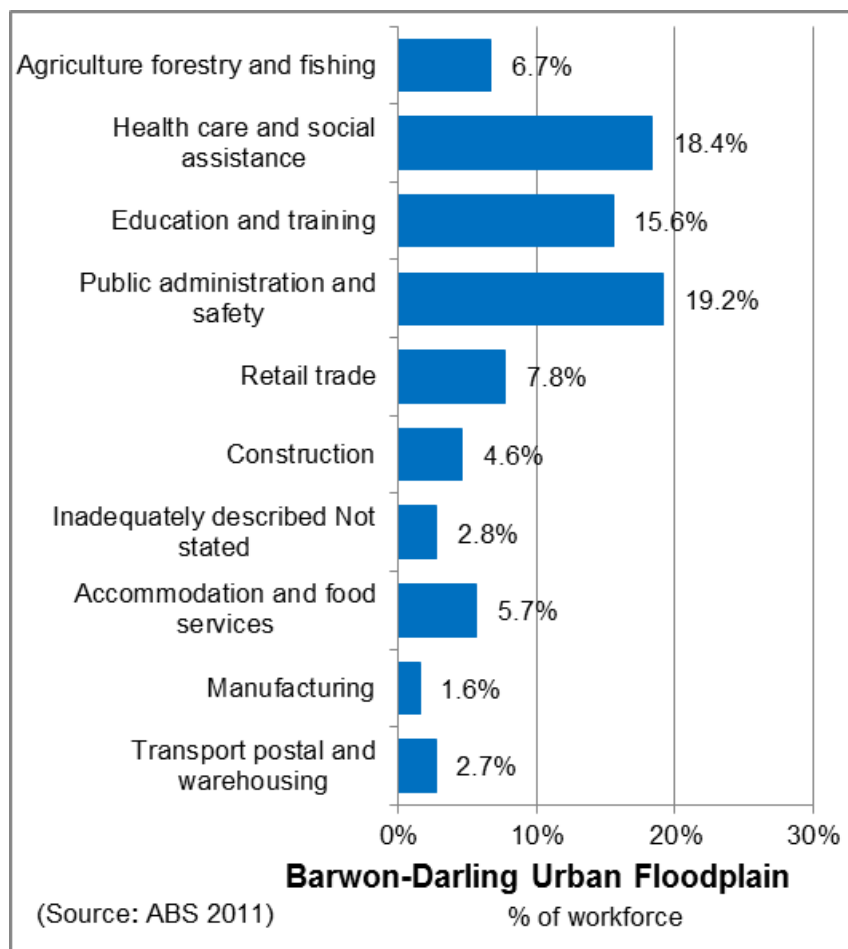


Figure A11.12 Barwon-Darling urban floodplain employment by industry sector

Estimated employment in the Barwon-Darling Valley Floodplain

The urban residents employed in the agricultural sector combined with the rural residents employed in the agriculture sector make up the employment that could be directly impacted by the Barwon-Darling Valley FMP. Given the location of the townships, it is assumed that about 25 per cent of the Barwon-Darling urban floodplain agricultural sector employees and 50 per cent of the Barwon-Darling rural agricultural sector employees make up the agriculture sector work in the Barwon-Darling Valley Floodplain. The estimated total

employment in the agricultural sector potentially impacted by the Barwon-Darling Valley FMP is 280 persons.

Wellbeing indicators

Socio-Economic Indexes for Areas (SEIFA) is a product developed by the ABS that ranks areas in Australia according to relative socio-economic advantage and disadvantage (ABS 2011b). The indexes are based on information from the five-yearly Census. The index scores are on an arbitrary numerical scale; the scores do not represent some quantity of advantage or disadvantage. As measures of socio-economic level, the indexes are best interpreted as ordinal measures. They can be used to rank (order) areas and illustrate the distribution of socio-economic conditions across different areas.

The Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) summarises 25 variables that indicate either relative advantage or disadvantage. This index ranks areas on a continuum from most disadvantaged to most advantaged. An area with a low score on this index has a relatively high incidence of disadvantage and a relatively low incidence of advantage.

The IRSAD scores for the whole of the Local Government Area of Bourke (A) is in the 3rd decile, Moree Plains (A) is in the 2nd decile while the local government areas of Brewarrina (A) and Walgett (A) are in the 1st decile of NSW, demonstrating distinct relative disadvantage that these areas are facing at a large scale.

At the SA1 level, the lowest area IRSAD score is 750 (ranked 342, decile 1 in the state), is in the township of Brewarrina. The highest scoring area has a score of 1,058 (decile 7 in the state) which is the agricultural area surrounding the township of Walgett.

The range and distribution of the IRSAD scores for the floodplain area are presented in Figure A11.13. The dark green areas have a score that is amongst the lowest 10 per cent of scores for the state, being the relatively more disadvantaged. The red areas indicate areas of advantage while the yellow areas indicate areas that are relatively neither advantaged nor disadvantaged. The IRSAD scores for the smaller SA1 areas representing the townships of Bourke, Brewarrina, Collarenebri and Walgett (see insert in Figure A11.13) are mostly shaded green indicating that they are relatively disadvantaged (being within deciles 1 to 3), excepting one SA1 on the south Bourke (decile 4) and two SA1s on the east of Walgett (decile 4 and 6). The Barwon-Darling rural floodplain areas are generally shaded light green to orange (being within deciles 4 to 7) indicating that they are neither advantaged nor disadvantaged, or are relatively marginally advantaged, excepting the SA1 surrounding Brewarrina (decile 1) which is substantially disadvantaged.

Agricultural production

Agricultural production is the significant economic activity of the region's economy, occupying 86 per cent of the farm holdings in the Barwon-Darling Valley Floodplain. The Gross Value of Agricultural Production (GVAP) is predominantly from cropping, which is equally shared between wheat and cotton. Irrigated production area on the Barwon-Darling rural floodplain is dominated by cotton production. The regional economy is structured to provide the inputs and services and the handling of outputs of these industries and to provide the services they require. The performance of the regional economy responds in large part to the fortunes of the wheat and cotton industries.

The ABS Agricultural Census 2011 provides agricultural production statistics for the 3 SA2 areas that cover the Barwon-Darling Valley Floodplain (ABS 2011c) (Figure A11.14).

In the Barwon-Darling Valley Floodplain, broad acre cropping and livestock production are the predominant products but they are not evenly distributed across the SA2 area. The value

and area used for these products in the Barwon-Darling Valley Floodplain were estimated based on the following assumptions:

- value and area of agricultural cropping, horticulture and grazing production was distributed within the SA2 areas according to the proportion of each that occurred within the Barwon-Darling Valley Floodplain, based on land-use data;
- the estimated percentages of each ABS SA2 area in the Barwon-Darling Valley Floodplain;
 - Cropping: Bourke – Brewarrina 61 per cent, Walgett – Lightning Ridge 14 per cent and Moree Region 2 per cent,
 - Horticulture: Bourke – Brewarrina 100 per cent, Walgett – Lightning Ridge 47 per cent and Moree Region 0 per cent, and
 - Grazing: Bourke – Brewarrina 12 per cent, Walgett – Lightning Ridge 13 per cent and Moree Region 4 per cent;
- the estimated area and value of agricultural production of individual crops and products for the Barwon-Darling Valley Floodplain are the sum of the proportional estimates for the SA2 areas listed above.

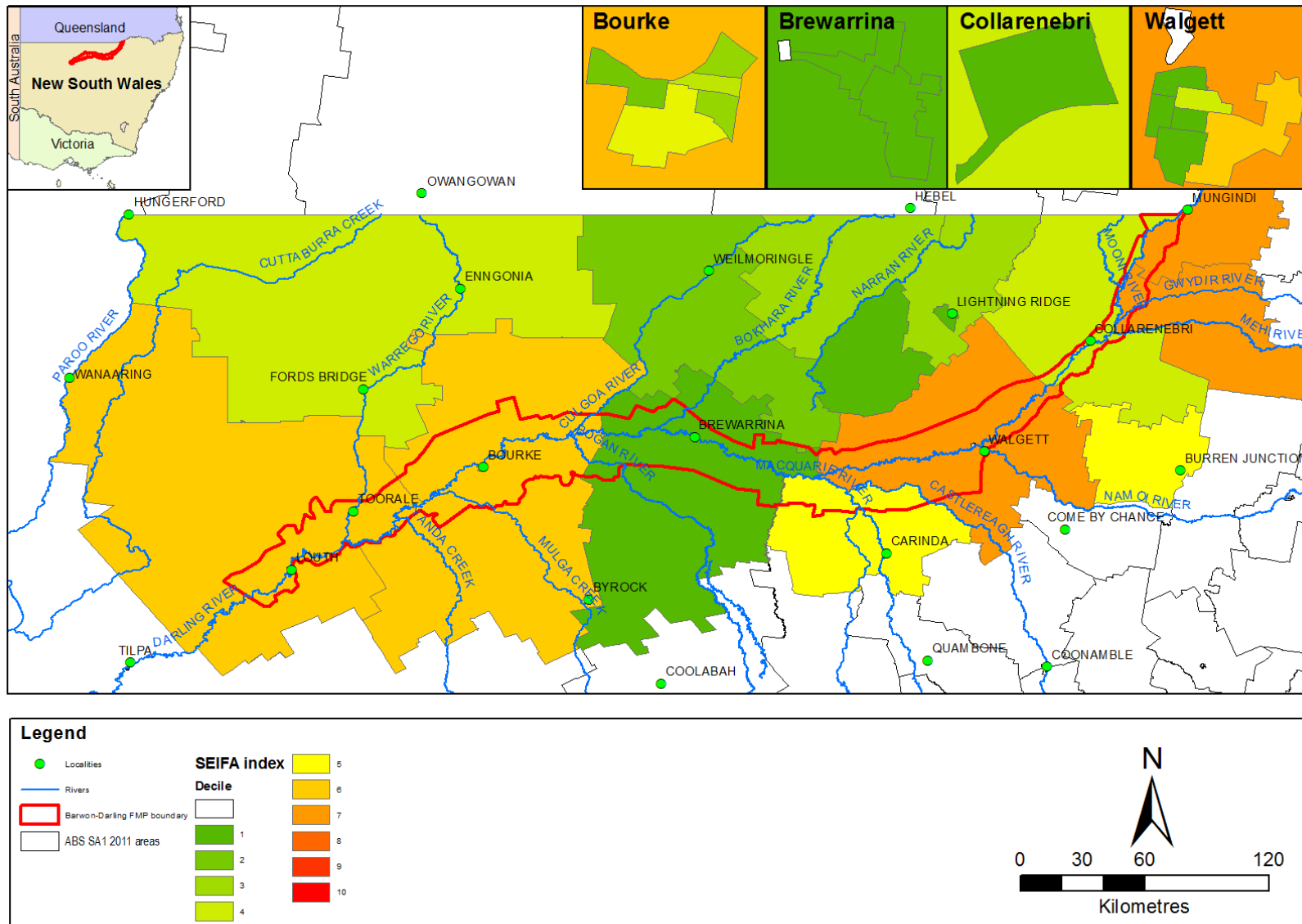


Figure A11.13 Index of relative socio-economic advantage and disadvantage, state decile

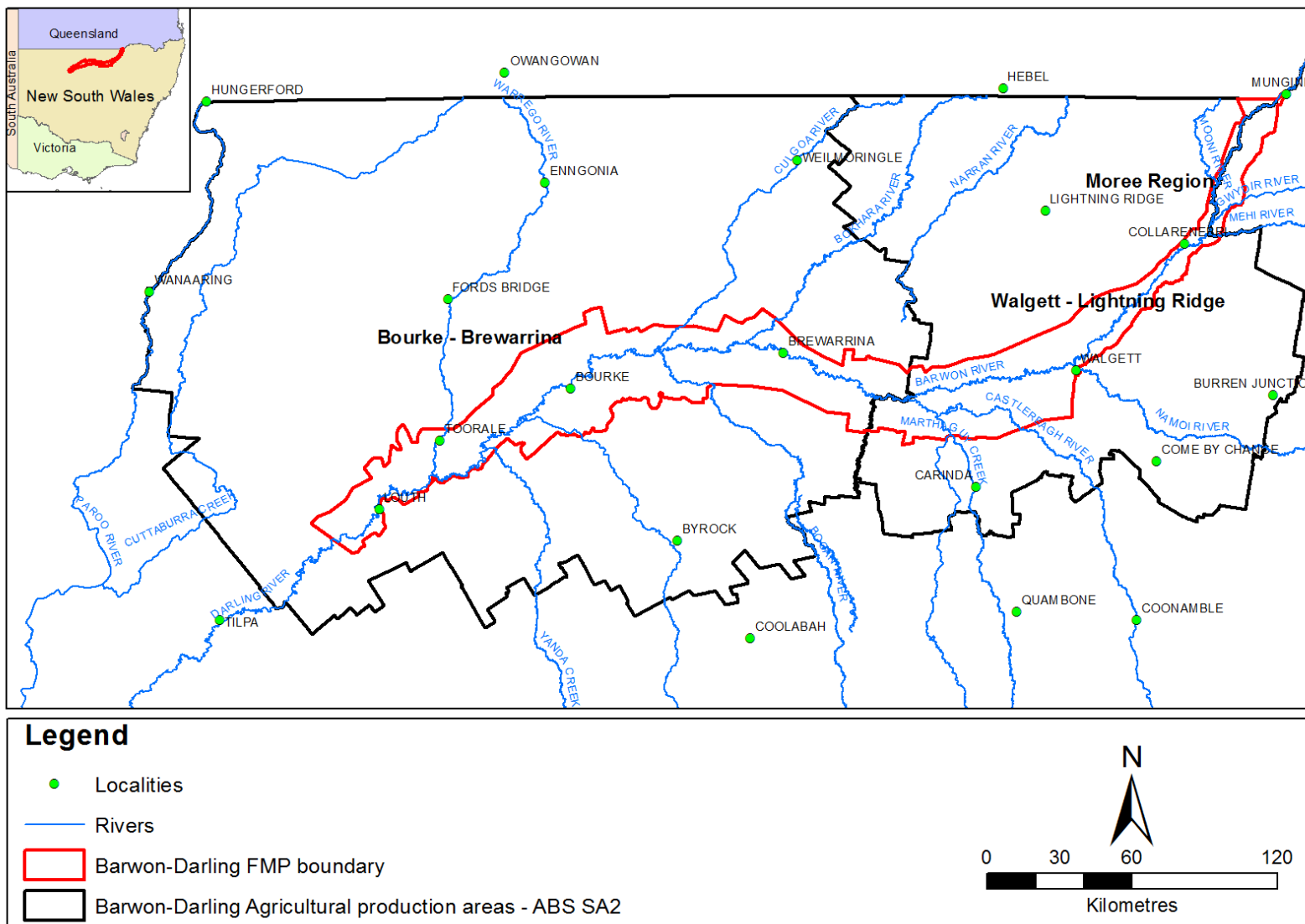


Figure A11.14 Barwon-Darling Valley Floodplain and agricultural data area

As agricultural production is not evenly distributed across the area of these regions, the values derived and presented below provide estimates (only) of the value of production and the area of holding in the Barwon-Darling Valley Floodplain (Figure A11.14). Pigs, goats and poultry production are not included in the estimated totals because their production is not conventionally undertaken in the floodplain area.

The GVAP in 2010-2011 in the Barwon-Darling Valley Floodplain, using a farm holding area of 946,200 ha, is estimated to be \$122 million or 1.1 per cent of total NSW GVAP. The gross value of broadacre cropping, estimated at \$105 million, constitutes 86 per cent of the GVAP of the Barwon-Darling Valley Floodplain production using 138,800 ha or 15 per cent of the area (Table A11.2). The highest value producing individual broadacre crops are wheat yielding \$36 million and cotton yielding \$55 million or 30 per cent and 45 per cent of the total FMP area GVAP, respectively. Livestock and livestock products yield \$15 million, accounting for 12 per cent of GVAP while using 85 per cent of the area. Data for GVAP and area of holding is presented in Table A11.2 and Table A11.3.

Irrigated agricultural production

The ABS Agricultural Census 2011 identifies the area watered and the quantity of water used by irrigated agricultural production for the 3 SA2 areas of the region in 2010-2011 (ABS 2011c).

The total area watered and the total quantity of water used in the Barwon-Darling Valley FMP area was estimated based on the following assumptions:

- the estimated percentages of irrigated agriculture of each ABS SA2 area within the Barwon-Darling Valley Floodplain are: Bourke – Brewarrina 100 per cent, Walgett – Lightning Ridge 25 per cent and Moree Region 1 per cent, and
- the total area watered and the total quantity of water used in the Barwon-Darling Valley Floodplain are the sum of the proportional estimates for the SA2 areas listed above.

There was an estimated total of 18,200 ha of irrigated land in the Barwon-Darling Valley Floodplain in 2010-2011. This area of irrigated land constitutes approximately 1.6 per cent of the Barwon-Darling Valley Floodplain farm holding area.

It is estimated that 92,000 megalitres of water was extracted for agricultural irrigation across the regions in 2010-2011. Most the irrigation water used in 2010-2011 was applied to cotton, using 84,500 megalitres or 92 per cent, at an estimated average rate of 5.6 megalitres per hectare. Irrigation for cotton used an estimated 15,000 ha or 83 per cent of the estimated Barwon-Darling rural floodplain irrigated area. Data for irrigation activity is presented in Table A11.3 and Table A11.4.

Table A11.2 Gross value of agricultural production (GVAP) 2011 (\$M)

Gross Value of Agricultural Production (\$M)	Bourke-Brewarrina	Walgett-Lightning Ridge	Moree Region	Estimated Barwon-Darling Valley Floodplain	New South Wales
Cropping weight	61%	14%	2%		
Horticulture weight	100%	47%	0%		
Grazing weight	12%	13%	4%		
Broadacre crops					
– Cereals and wheat for grain	6	192	206	36	2,511
– Cereals for grain (excl. wheat)	0	24	117	6	998
– Legumes for grain	0	40	52	7	237
– Oilseeds	-	4	10	1	438
– Hay	-	2	2	0	284
– Cotton	51	103	442	55	1,126
– Other crops (exclude. Cotton)	-	0	1	0	97
Total Broadacre crops	58	364	829	105	5,690
Horticulture					
– Fruit	2	-	6	2	631
– Nurseries, cut flowers and cultivated turf	na	na	na	na	na
Total Horticulture	2	-	6	2	631
Livestock products					
– Whole milk	-	-	-	-	505
- Cattle and calves	17	22	30	6	1,616
– Wool	19	21	7	5	853
- Sheep and lambs	17	14	5	4	610
- Pigs	na	na	na	na	na
- Goats	na	na	na	na	na
– Eggs	na	na	na	na	na
– Poultry	na	na	na	na	na
Total livestock products	53	57	41	15	3,583
Agriculture – total value (\$M)	111	421	877	122	9,274

'na' means that this crop is unlikely to occupy floodplain land. Source: Based on ABS Agricultural Census 2011 data

Table A11.3 Land mainly used for agricultural production 2010-2011

Area	Bourke- Brewarrina	Walgett- Lightning Ridge	Moree Region	Estimated Barwon- Darling Valley Floodplain	New South Wales
Cropping weight	61%	14%	2%		
Horticulture weight	100%	47%	0%		
Grazing weight	12%	13%	4%		
Broadacre crops					
– cereals wheat for grain (ha)	19,114	354,100	334,725	69,634	3,814,726
– cereals - other than wheat for grain (ha)	1,203	64,472	192,613	13,976	1,637,949
– non-cereal - cotton (ha)	9,748	31,569	133,447	13,192	329,665
– non-cereal – except cotton (ha)	673	133,505	185,742	23,504	1,262,087
Land mainly used for agriculture – Crops (ha)	45,852	637,406	921,706	138,777	9,209,190
Horticulture					
- Orchard fruit and nut trees (ha)	350	-	1,183	350	47,483
- Grapevines for wine production (ha)	na	na	na	na	na
- Nurseries, cut flowers and cultivated turf (ha)	na	na	na	na	na
Hay and silage - hay (ha)	15	4,620	4,092	778	312,513
Pasture seed production - Clean pasture seed produced (ha)	-	-	-	-	18,280
Land mainly used for agriculture - total grazing (ha)	4,969,425	1,475,390	586,493	802,599	46,419,229
Land mainly used for agriculture - other agricultural purposes (ha)	-	53	410	23	29,377
Land mainly used for agriculture – forestry plantation (ha)	313	-	9	37	112,489
Area of holding - total area of holding (ha)	5,110,778	2,160,269	1,508,618	946,160	58,326,346

'na' means that this crop is unlikely to occupy floodplain land. Source: Based on ABS Agricultural Census 2011 data

Table A11.4 Area of irrigated agricultural production 2010-2011

Area watered	Bourke- Brewarrina	Walgett- Lightning Ridge	Moree Region	Estimated Barwon- Darling Valley Floodplain	New South Wales
Weights	100%	25%	1%		
Cereal crops for grain or seed (e.g. wheat, oats, maize) (ha)	2,241	1,159	57	2,531	109,676
Other crops - broadacre (e.g. canola, field beans, lupins, sunflowers, poppies) (ha)	-	1,035	269	261	96,129
Other crops - cotton (ha)	9,748	19,051	68,378	15,035	196,233
Cereal crops cut for hay (incl. wheat, oats, sorghum) (ha)	1	-	57	1	6,809
Fruit and nut trees, plantation or berry fruits (excl. grapes) (ha)	350	-	1184	359	49,842
Grapevines (ha)	na	na	na	na	na
Nurseries, cut flowers, cultivated turf (ha)	na	na	na	na	na
Pasture - cut for hay (ha)	-	-	57	0	25,420
Pasture - for grazing (ha)	25	26	120	33	130,380
Pasture - for seed (ha)	-	-	83	1	3,092
Total area watered (ha)	12,221	21,310	69,021	18,221	674,064

'na' means that this crop is unlikely to occupy floodplain land. Source: Based on ABS Agricultural Census 2011 data

Table A11.5 Water used for irrigated agricultural production 2010-2011

Water for agricultural production	Bourke-Brewarrina	Walgett-Lightning Ridge	Moree Region	Estimated Barwon-Darling Valley Floodplain	New South Wales
Weights	100%	25%	1%		0.0%
Cereal crops cut for hay (incl. wheat, oats, sorghum) (ML)	1	-	51	1	13,989
Cereal crops for grain or seed (e.g. wheat, oats, maize) (ML)	2,801	3,987	3,027	3,822	203,841
Other crops - Broadacre (ML)	-	5,594	1,001	1,408	809,027
Other crops - cotton - volume applied (ML)	54,655	106,920	403,198	84,473	1,073,849
Fruit and nut trees, plantation or berry fruits (excl. grapes) (ML)	2,156	-	8,134	2,218	94,237
Grapevines (ML)	na	na	na	na	na
Nurseries, cut flowers, cultivated turf (ML)	na	na	na	-	na
Pasture cut for hay (ML)	-	-	277	2	78,406
Pasture for grazing (ML)	35	42	15	46	232,629
Pasture for seed (ML)	-	-	34	0	6,281
Total area watered (ML)	59,754	116,652	407,604	91,971	2,745,896

'na' means that this crop is unlikely to occupy floodplain land. Source: Based on ABS Agricultural Census 2011 data

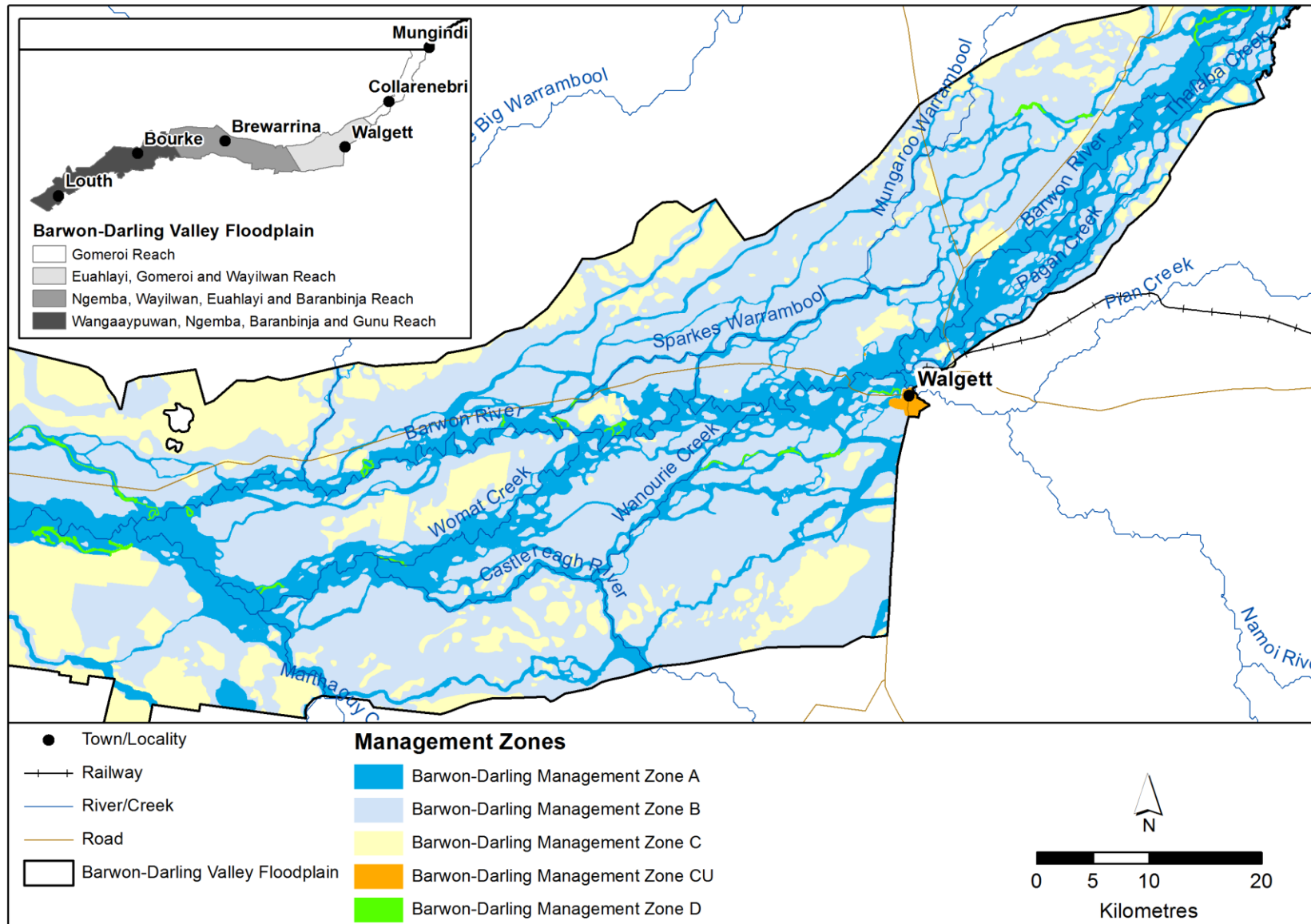


Figure A12.2. Management zones in Euahlayi, Gomeri and Wayilwan Reach of the Barwon-Darling Valley Floodplain

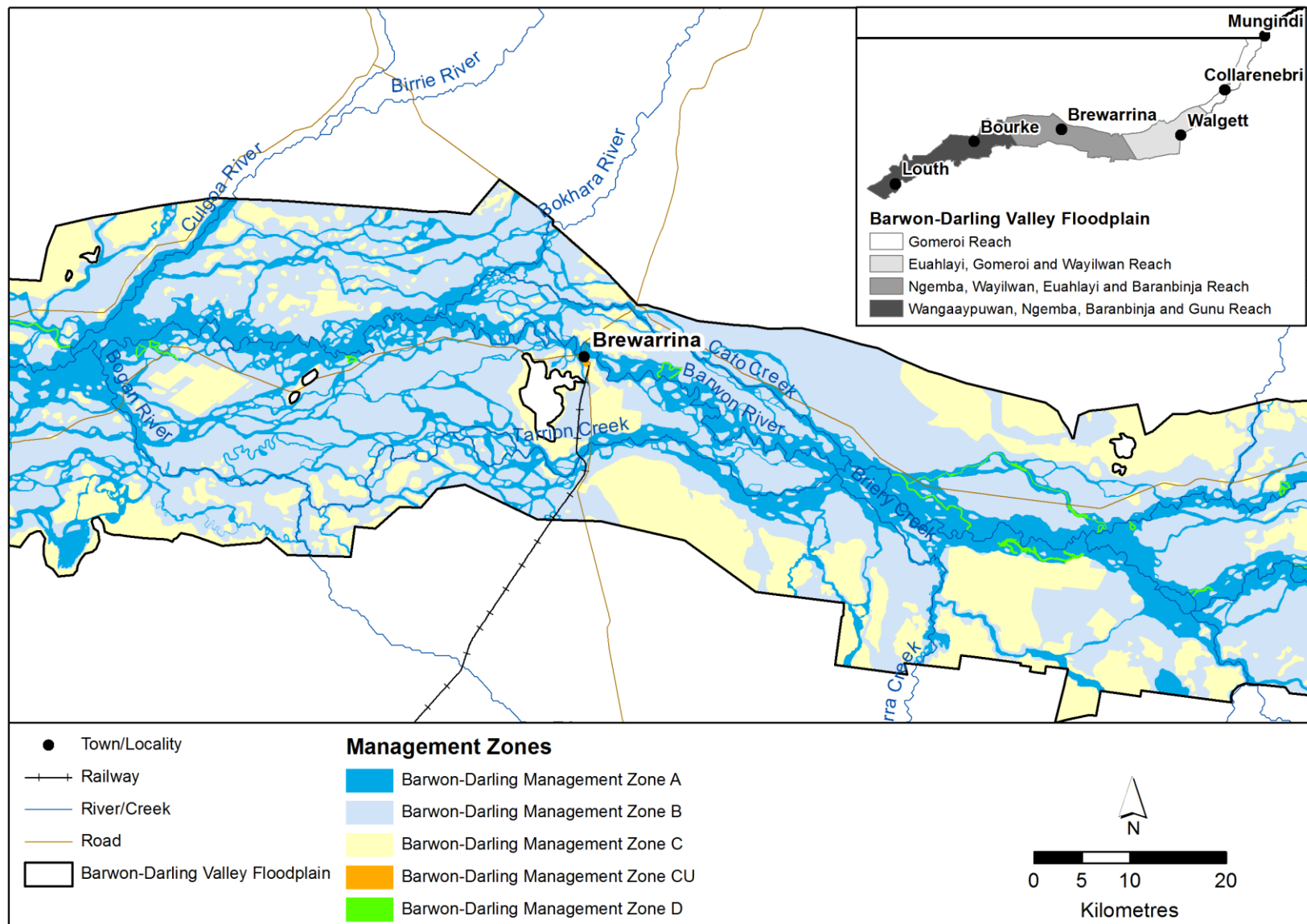


Figure A12.3. Management zones in Ngemba, Wayilwan, Euahlayi and Baranbinja Reach of the Barwon-Darling Valley Floodplain

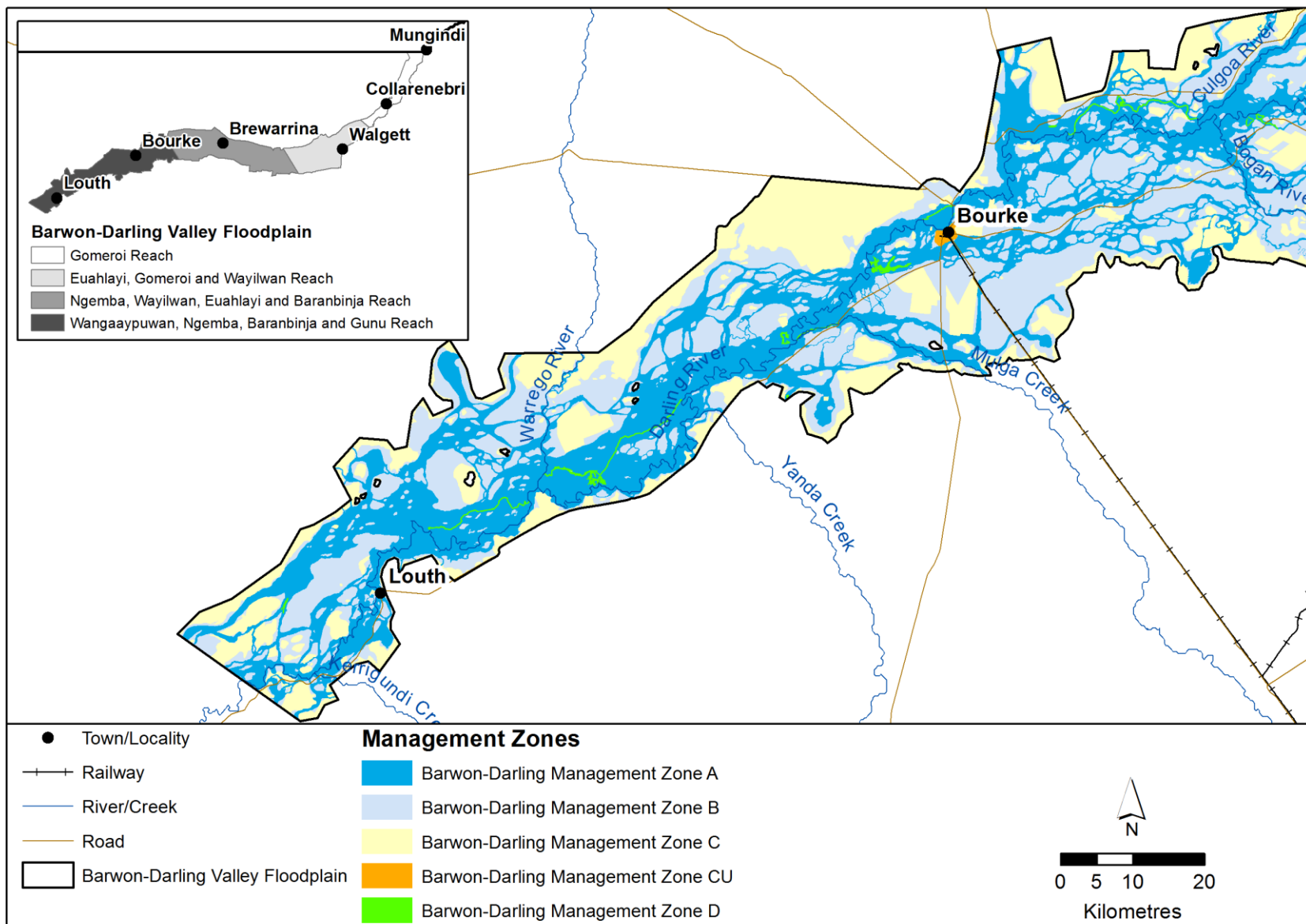


Figure A12.4. Management zones in Wangaaypuwan, Ngemba, Baranbinja and Gunu Reach of the Barwon-Darling Valley Floodplain

Appendix 13: Management Zone D assets

Table A13.1 Description of Management Zone D assets

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
1	Brewarrina Fish Traps	Significant meeting place for Aboriginal people with connections to the area. The Brewarrina fish traps continue to be visible and used in the Darling River today and were included in the National Heritage List on 3 June 2005.	3	Yes	486013	6685860	National Heritage List, Australian Government Department of the Environment.
2	Briery Anabranh	Large open water pool/anabranh adjacent to the Barwon River, fringed with black box – coolibah (Peasley & Walsh 1999). Key environmental asset in the Barwon-Darling region (MDBA 2010).	417	Yes	533823	6665290	MDBA (2010) and named anabranh on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
3	Briery Water	Floodplain watercourse (Water – DIPNR 1998b), fringed with black box / coolibah (DIPNR 1998b). Key environmental asset in the Barwon-Darling region (MDBA 2010).	227	No	522808	6670460	MDBA (2010) and named landscape feature on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
4	Broadsheet Lagoon on Wombat Creek	Large open water lagoon on Wombat Creek fringed with river red gum – coolibah (Peasley & Walsh 1999). Key environmental asset in the Barwon-Darling region (MDBA 2010).	49	No	561584	6663570	MDBA (2010) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
5	Bundabina Falls	Natural weir, ephemeral water flow. Important cultural area in the Barwon River region (Hudson & Bacon 2009).	11	No	644864	6722380	Hudson & Bacon (2009)

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
6	Butti Lagoon	Open water lagoon adjacent to Barwon River fringed by flood-dependent vegetation (OEH 2015) including Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39). Important cultural area in the Barwon River region (Hudson & Bacon 2009).	18	No	665700	6742260	Brennan et al. (2002), Hudson & Bacon (2009), NSW DPI (2012)
7	Canary Lagoon	Large open water lagoon adjacent to Barwon River (Sparkes Warrambool) fringed with black box / coolibah (DIPNR 1998c). Key environmental asset in the Barwon-Darling region (MDBA 2010).	65	No	576526	6675920	Brennan et al. (2002), Cooney (1994), MDBA (2010), NSW DPI (2012) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
8	Cemetery Billabong	Highly ephemeral billabong. Important cultural area in the Barwon River region (Hudson & Bacon 2009).	9	No	657333	6730410	Hudson & Bacon (2009)
9	Collymungle Lagoon	Large open water lagoon on Gwydir River, fringed with flood-dependent vegetation (OEH 2015) including River Red Gum tall to very tall open forest / woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36) and Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37).	67	Yes	667408	6742760	Brennan et al. (2002), Hudson & Bacon (2009) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
10	Comilaroy Billabong 1	Ephemeral billabong. The area contains historic homestead ruins and has been identified as an	11	No	682372	6785600	Hudson & Bacon (2009)

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
		important cultural area in the Barwon River region (Hudson & Bacon 2009).					
11	Duck Egg Swamp	Open water swamp fringed with Mitchell Grass grassland - chenopod low open shrubland on floodplains in the semi-arid (hot) and arid zones (PCT 43) (Shultz, Gowans & Westbrooke 2014).	16	No	375896	6647940	Brennan et al. (2002), NSW DPI (2012) and named swamp on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
12	Eight Mile Lagoon	Large open water lagoon adjacent to Darling River, fringed with flood-dependent Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39) and Coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40) (Shultz et al. 2014).	466	Yes	389888	6666120	URS (2008) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
13	Elephant Waterhole	Large waterhole at confluence of the Castlereagh and Macquarie River's fringed with river red gum – coolibah (Peasley & Walsh 1999).	68	No	550712	6661140	Named waterhole on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
14	Euromlin Lagoon	Open water lagoon on Euromlin Creek, fringed with flood-dependent vegetation (OEH 2015) including Lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling Riverine Plains Bioregion (PCT 247) and Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains	63	No	596958	6673250	Claus et al. (2011) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
		mainly in the Darling Riverine Plains Bioregion (PCT 39).					
15	Eurool Wetland	Highly ephemeral chain of ponds. Important cultural area in the Barwon River region (Hudson & Bacon 2009).	7	No	643406	6722270	Hudson & Bacon (2009)
16	First Lagoon	Open water lagoon on Gwydir River, fringed with flood-dependent vegetation (OEH 2015) including Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37) and River Red Gum tall to very tall open forest / woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36).	13	Yes	666292	6740750	Named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
17	Fish Holes Lagoons	Open water lagoons fringed with coolibah / belah and black box / coolibah (DIPNR 1998c).	203	No	636001	6712220	Brennan et al. (2002) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
18	Gidgin Lagoon	Open water lagoon at confluence of Wanourie and Euromlin Creek's, fringed with flood-dependent vegetation (OEH 2015) including Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39) and Lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling	38	No	590041	6672120	Claus et al. (2011) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
Riverine Plains Bioregion (PCT 247).							
19	Gil Gil Creek Waterhole	Semi-permanent waterhole identified as an important cultural area in the Barwon River region (Hudson & Bacon 2009).	12	No	684285	6773970	Hudson & Bacon (2009)
20	Half Moon Lagoon	Open water lagoon on Euromlin Creek, fringed with flood-dependent vegetation (OEH 2015) including Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37), Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39) and Lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling Riverine Plains Bioregion (PCT 247).	32	No	593343	6672720	Named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
21	Herding Yard Lagoon	Large open water lagoon adjacent to Barwon River (Sparkes Warrambool) fringed with black box / coolibah (DIPNR 1998c).	22	No	577733	6677530	Brennan et al. (2002), NSW DPI (2012) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
22	Horseshoe Lagoon (A)	Large open water horse shoe shaped lagoon adjacent to Warraweena Lagoon with coolibah / other (DIPNR 1998a). Key environmental asset in the Barwon-Darling region (MDBA 2010).	79	No	422284	6689030	MDBA (2010) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
23	Horseshoe Lagoon (B)	Open water horse shoe shaped lagoon adjacent to Barwon River, fringed with River Red Gum tall to very tall open forest / woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion, Lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling Riverine Plains Bioregion (PCT 247), and Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39). Key environmental asset in the Barwon-Darling region (MDBA 2010).	38	No	543506	6667940	MDBA (2010) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
24	Kier Lagoon	Large open water lagoon adjacent to Barwon River fringed with black box / coolibah (DIPNR 1998c). Key environmental asset in the Barwon-Darling region (MDBA 2010).	87	Yes	559370	6671820	MDBA (2010) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
25	Louth Waterhole	Large open water lagoon on Monday Creek fringed with flood dependent vegetation (Shultz et al. 2014) including Coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40) and Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39).	61	No	305872	6618820	Named waterhole on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
26	Meeki Creek Billabong	Ephemeral billabong. Important cultural area in the Barwon River region (Hudson & Bacon 2009).	48	Yes	651862	6726600	Hudson & Bacon (2009)

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
27	Ngemba Old Mission Billabong	Large billabong forming part of the Brewarrina Ngemba Billabong Aboriginal Protected Area recognised for both its ecological and cultural features (IUCN Category V: protected landscape; Category VI: protected area with sustainable use of natural resources) fringed with coolibah just upstream of Brewarrina adjacent to the Barwon River providing habitat for a variety of species including ibis, broilgas, ducks, fish, turtles and amphibians (Maclean, Bark, Moggridge, Jackson & Pollino 2012).	115	No	495326	6684170	Maclean et al. (2012)
28	Orange Tree Lagoon	Large open water lagoon adjacent to Darling River, fringed with coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40) (Shultz et al. 2014).	118	Yes	375524	6656050	Brennan et al. (2002) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
29	Piano Creek Lagoon (A)	Lagoons adjacent to Barwon River and Piano Creek fringed with River Red Gum tall to very tall open forest / woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36) and Coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40) (Shultz et al. 2014).	113	Yes	442551	6686280	Brennan et al. (2002), NSW DPI (2012)
30	Piano Creek Lagoon (B)	Lagoons adjacent to Barwon River and Piano Creek fringed with River Red Gum tall to very tall open forest / woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion	50	No	440301	6686210	Brennan et al. (2002), NSW DPI (2012)

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
		(PCT 36) and Coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40) (Shultz et al. 2014).					
31	Polygonum Swamp	Large open water billabong, North Bourke, providing habitat for waterbirds, including brolga (<i>Grus rubicunda</i>) – mating pair, shags, ducks, black swans (<i>Cygnus atratus</i>), Australian pelicans (<i>Pelecanus conspicillatus</i>).	24	No	399396	6673540	Brennan et al. (2002), Cooney (1994), URS (2008), NSW DPI (2012) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
32	Ross Billabong	Open water billabong adjacent to Darling River, fringed with Coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40) (Shultz et al. 2014). Key environmental asset in the Barwon-Darling region (MDBA 2010).	816	Yes	351067	6640280	Brennan et al. (2002), DLWC (2001), Cooney (1994), Cox, Thomas and Lu (2012), NSW DPI (2012), Gowans, Milne, Westbrooke and Palmer (2012), MDBA (2010) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
33	Ryan's Lagoon on Mulga Creek	Open water lagoon on Mulga Creek, adjacent to Darling River, fringed with Coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40) (Shultz et al. 2014). Mulga Creek listed as key environmental	123	Yes	379939	6657040	Brennan et al. (2002), MDBA (2010) and named lagoon on Land and Property Information – SIX Maps/Topographic Map

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
		asset in the Barwon-Darling region (MDBA 2010).					(LPI 2013)
34	Second Lagoon	Open water lagoon adjacent to Gwydir River, fringed with flood-dependent vegetation (OEH 2015) including Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37) and River Red Gum tall to very tall open forest / woodland wetland on rivers on floodplains mainly in the Darling Riverine Plains Bioregion (PCT 36).	30	Yes	665914	6741190	Named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
35	Sparkes Warrambool	Large open water lagoons on Sparkes Warrambool, surrounded by standing dead timber (DIPNR 1998c).	166	Yes	620135	6703510	Brennan et al. (2002) and named warrambool on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
36	Talowla Billabong	Open water billabong fringed with Coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40) (Gowans et al. 2012). Key environmental asset in the Barwon-Darling region (MDBA 2010).	343	Yes	333095	6631670	Brennan et al. (2002), MDBA (2010) and named billabong on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
37	The Big Billabong	Large open water billabong, north of Bourke fringed with Coolibah open woodland wetland with chenopod/grassy ground cover on grey and brown clay floodplains (PCT 40). Key environmental asset in the Barwon-Darling region (MDBA 2010).	99	Yes	396767	6673540	Brennan et al. (2002), DLWC (2001), NSW DPI (2012), MDBA (2010), URS (2008 and named billabong on Land and Property Information – SIX

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
							Maps/Topographic Map (LPI 2013)
38	Toothia Billabong	Large open water billabong adjacent to Barwon River fringed with black box / coolibah (DIPNR 1998c).	22	No	571449	6676000	Brennan et al. (2002), NSW DPI (2012)
39	Turee Lake	Large open water swamp, adjacent to Darling River, fringed with coolibah/other (DIPNR 1998c).	30	No	412835	6685530	Brennan et al. (2002), NSW DPI (2012)
40	Two (2) Mile Creek Lagoon	Ephemeral billabong. Important cultural area in the Barwon River region (Hudson & Bacon 2009).	6	Yes	656098	6729180	Hudson & Bacon (2009)
41	Ulah Lagoon	Large open water lagoon adjacent to Barwon River, fringed with black box / coolibah (DIPNR 1998c).	80	Yes	581514	6675360	Brennan et al. (2002), Cooney (1994), NSW DPI (2012) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
42	Unnamed lagoon 1	Open water lagoon located upstream of Banarway Creek surrounded by black box woodland wetland. The lagoon periodically receives water flow from Ballone Creek.	3	No	669953	6751040	Unnamed lagoon listed in Schedule 4 of the Water Sharing Plan for the Gwydir Unregulated and Alluvial Water Sources 2012
43	Unnamed lagoon 2	Open water lagoon located on the Barwon River surrounded by black box woodland wetland and to a lesser extent fringed with river red gum tall to very tall open forest.	3	No	666131	6754390	Unnamed lagoon listed in Schedule 4 of the Water Sharing Plan for the Gwydir Unregulated and Alluvial Water Sources 2012

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
44	Unnamed lagoon 3	Open water lagoon located on an unnamed watercourse in the Barwon Nature Reserve. The lagoon is surrounded by coolibah, river coobah, lignum woodland wetland and fringed with black box woodland wetland and coolibah open woodland wetland.	19	No	640027	6712910	Unnamed lagoon listed in Schedule 4 of the Water Sharing Plan for the Gwydir Unregulated and Alluvial Water Sources 2012
45	Unnamed lagoon 4	Open water lagoon located adjacent to the Barwon River surrounded by coolibah, river coobah, lignum woodland wetland, river red gum tall to very tall open forest and black box woodland wetland.	15	No	665203	6742800	Unnamed lagoon listed in Schedule 4 of the Water Sharing Plan for the Gwydir Unregulated and Alluvial Water Sources 2012
46	Unnamed lagoon 5	Large open water lagoon located on the Barwon River, surrounded by black box woodland wetland.	31	Yes	665967	6750470	Unnamed lagoon listed in Schedule 4 of the Water Sharing Plan for the Gwydir Unregulated and Alluvial Water Sources 2012
47	Unnamed lagoon 6	Open water lagoon surrounded by black box woodland wetland.	21	No	643457	6715820	Unnamed lagoon listed in Schedule 4 of the Water Sharing Plan for the Gwydir Unregulated and Alluvial Water Sources 2012
48	Unnamed lagoon 7	Open water lagoon located on an unnamed watercourse that anabranches from the Barwon River, surrounded by coolibah, river coobah, lignum woodland wetland and black box woodland wetland.	6	No	672345	6767220	Unnamed lagoon listed in Schedule 4 of the Water Sharing Plan for the Gwydir Unregulated and Alluvial Water Sources 2012

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
49	Unnamed lagoon 8	Large open water lagoon located on an unnamed watercourse that anabranches from the Barwon River, surrounded by black box woodland wetland.	24	No	671544	6765900	Unnamed lagoon listed in Schedule 4 of the Water Sharing Plan for the Gwydir Unregulated and Alluvial Water Sources 2012
50	Unnamed lagoon 9 (on Grawan Creek)	Large open water lagoon located adjacent to Grawan Creek, surrounded by coolibah, river coobah, lignum woodland wetland and black box woodland wetland.	21	No	643340	6717560	Unnamed lagoon listed in Schedule 4 of the Water Sharing Plan for the Gwydir Unregulated and Alluvial Water Sources 2012
51	Walgett Lagoon	Open water lagoon, adjacent to Barwon River, just west of Walgett, fringed by flood-dependent vegetation (OEH 2015) including Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39) and Lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling Riverine Plains Bioregion (PCT 247).	56	Yes	605554	6678620	Named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
52	Wali Billabong	Highly ephemeral billabong. Important cultural area in the Barwon River region (Hudson & Bacon 2009).	9	Yes	652647	6729650	Hudson & Bacon (2009)
53	Warraweena Lagoon	Large open water lagoon fringed with coolibah / other (DIPNR 1998a). The Lagoon provides a diverse habitat, including open water, lignum swamps and overhanging river red gums and is utilised by a wide range of waterfowl (URS 2008). Key environmental asset in the Barwon-Darling	485	No	423935	6687260	Brennan et al. (2002), DLWC (2001), NSW DPI (2012), URS (2008), MDBA (2010) and named lagoon on Land and Property Information – SIX

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
		region (MDBA 2010).					Maps/Topographic Map (LPI 2013)
54	Waterholes at Big Waterhole Creek	Large waterholes just south of Grawan Creek, fringed with Black Box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37) and Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39) (OEH 2015).	40	No	648890	6721060	Named waterholes on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
55	Weerabilla Lagoon	Large open water lagoon, near Wombian Station (Brennan et al. 2002) fringed with black box / coolibah (DIPNR 1998c).	26	Yes	661149	6736620	Brennan et al. (2002), NSW DPI (2012)
56	Wigelroy Lagoon	Open water lagoon, on Euromlin Creek, fringed by flood-dependent vegetation (OEH 2015) including Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion (PCT 39) and Lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling Riverine Plains Bioregion (PCT 247).	60	No	600812	6673090	Claus et al. (2011) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)
57	Yambacuna Lagoon	Open water lagoon adjacent to Barwon River fringed with coolibah / other (DIPNR 1998b).	59	No	462212	6685350	Brennan et al. (2002), NSW DPI (2012) and named lagoon on Land and Property Information – SIX Maps/Topographic Map

No.	Asset name	Cultural/Ecological significance	Size (ha)	Asset hydrologically modified*	Easting	Northing	Reference
							(LPI 2013)
58	Yambie Swamp and Lagoon	Large open water lagoon adjacent to Barwon River, fringed with black box / coolibah and poplar box / coolibah (DIPNR 1998b).	404	Yes	531576	6671540	Brennan et al. (2002), NSW DPI (2012) and named lagoon on Land and Property Information – SIX Maps/Topographic Map (LPI 2013)

Note. Coordinates were calculated using GDA 1994 MGA 55

* Hydrologic modification of an asset was determined using LiDAR captured in 2014 and included any earthen works within the asset or immediately upstream or downstream of the asset.

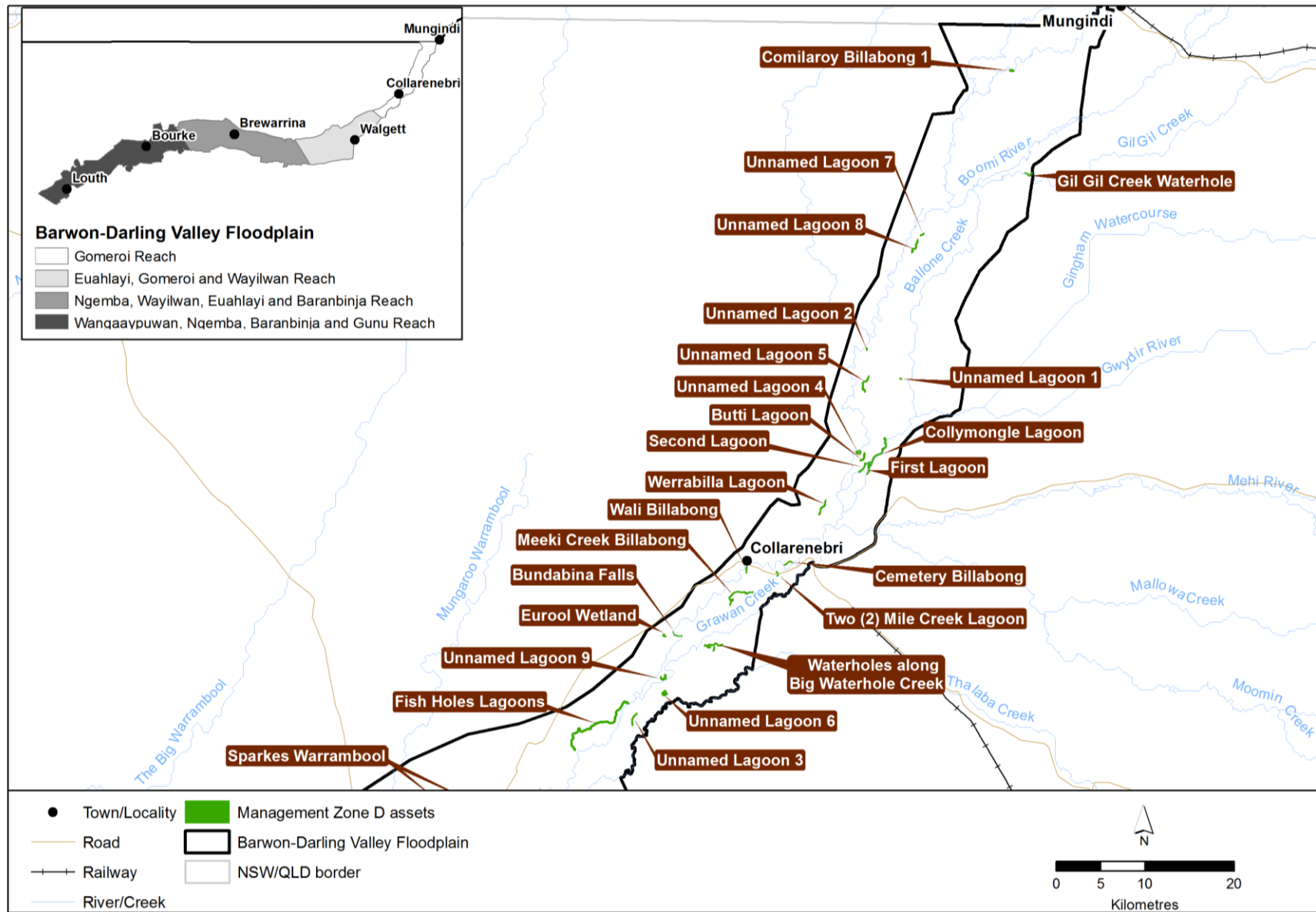


Figure A13.1. Location of ecological management zone D assets, Gomeri Reach

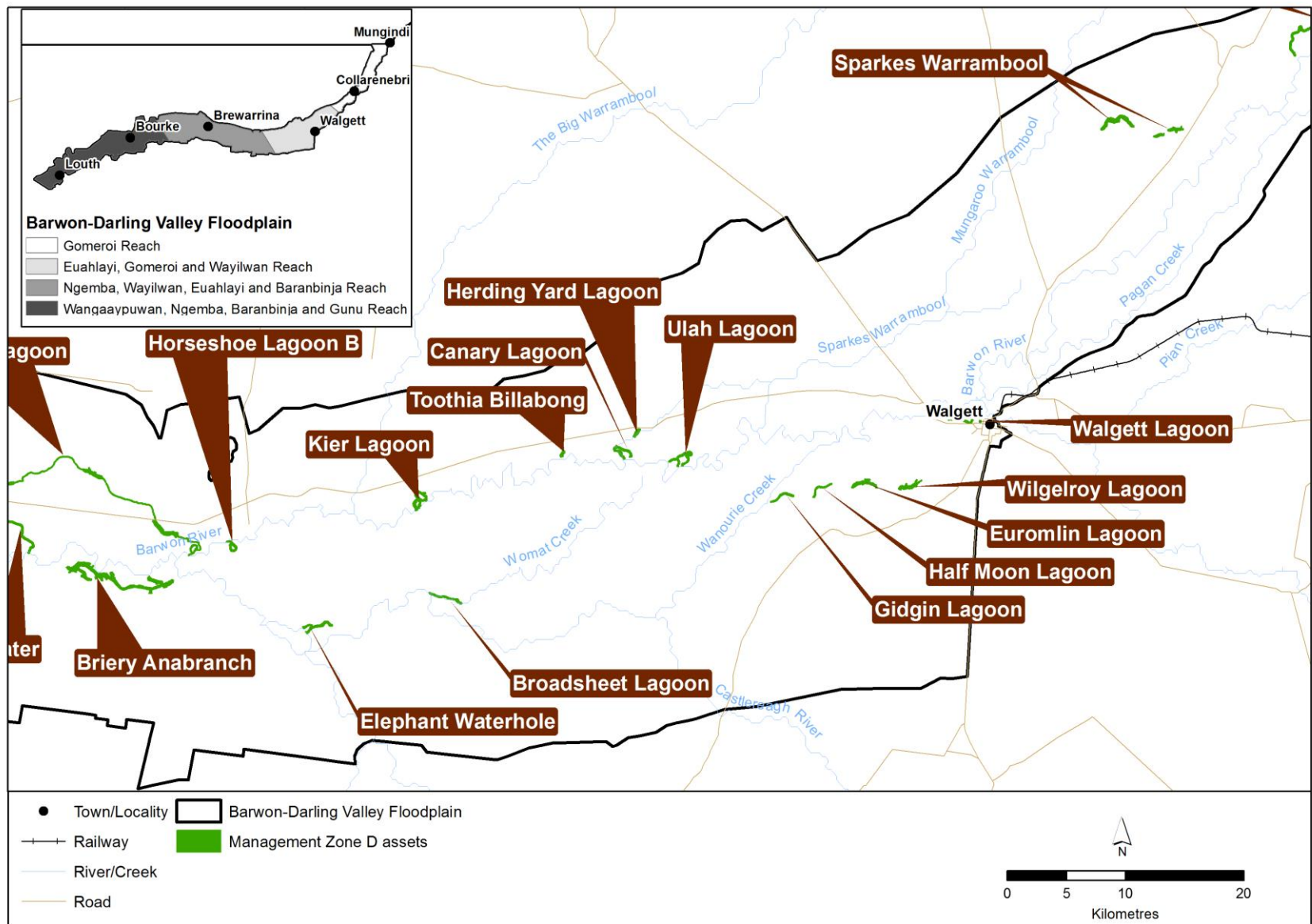


Figure A13.2. Location of ecological management zone D assets, Euahlayi, Gomeri and Wayilwan Reach

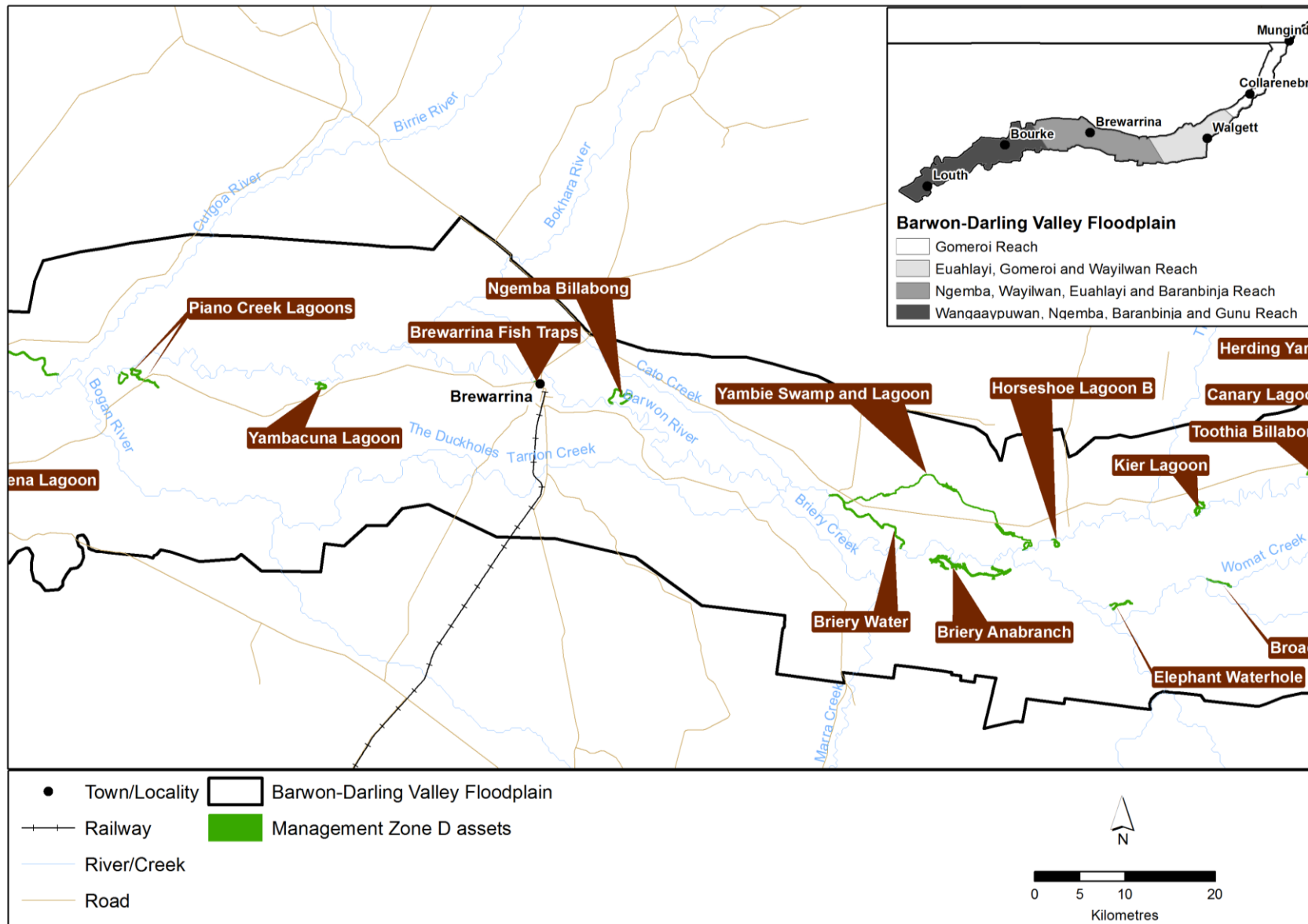


Figure A13.3. Location of ecological management zone D assets, Ngemba, Wayilwan, Euahlayi and Baranbinja Reach

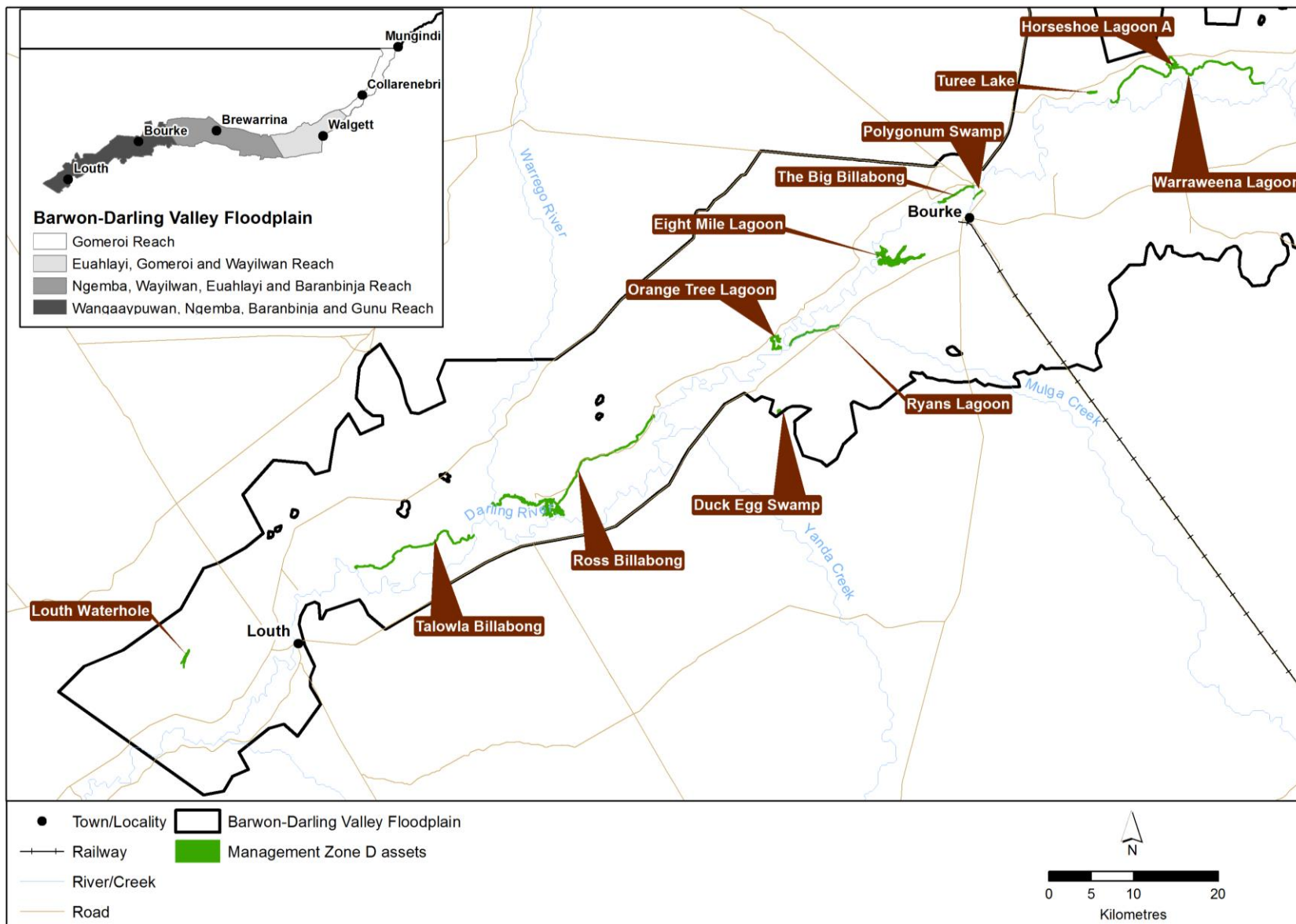


Figure A13.4. Location of ecological management zone D assets, Wangaaypuwan, Ngemba, Baranbinja and Gunu Reach

Appendix 14: Peak discharge calculation points

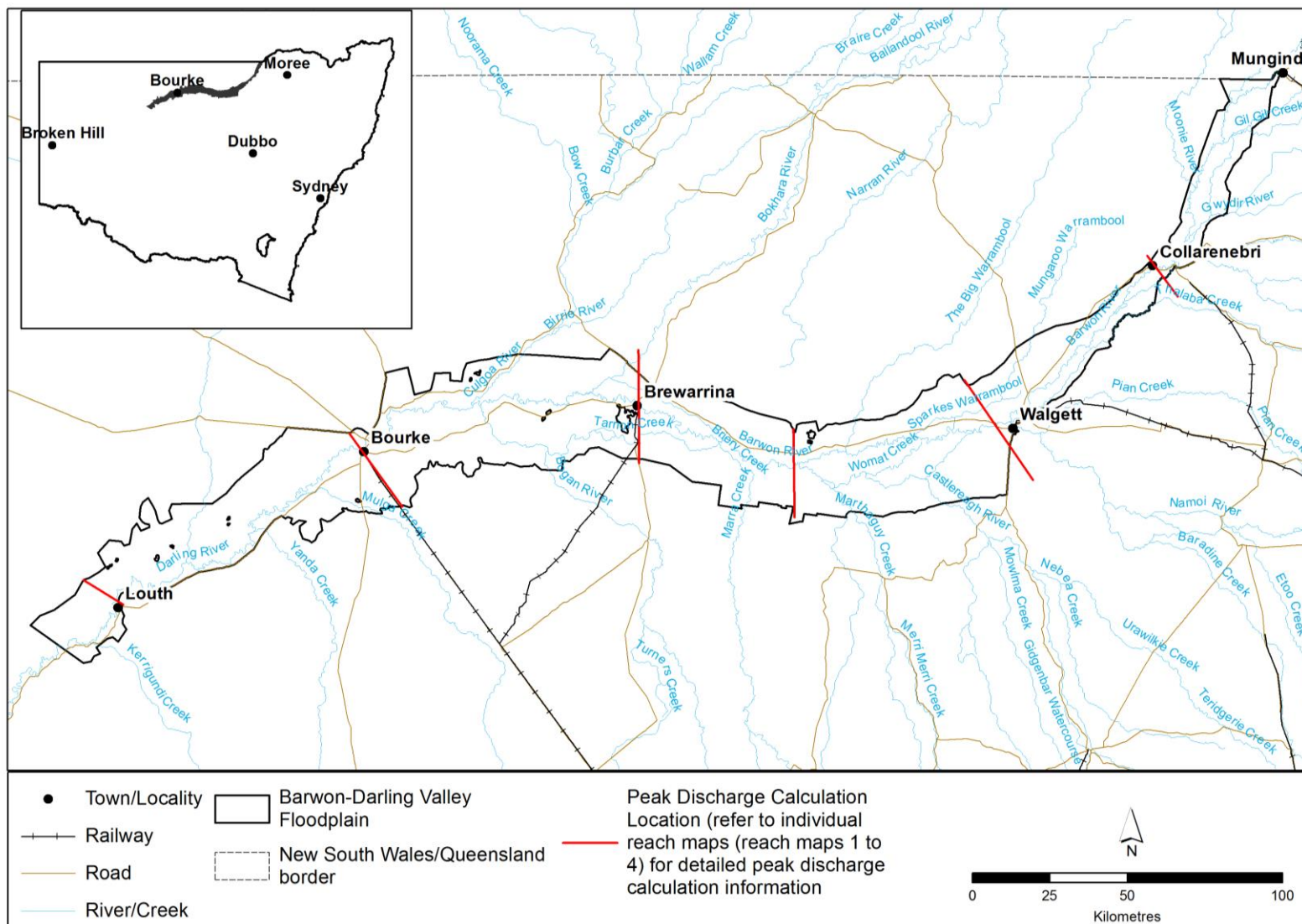


Figure A14.1: 1976 Peak discharge calculation locations across the Barwon-Darling Valley Floodplain (refer to individual maps for detailed peak discharge calculation information)

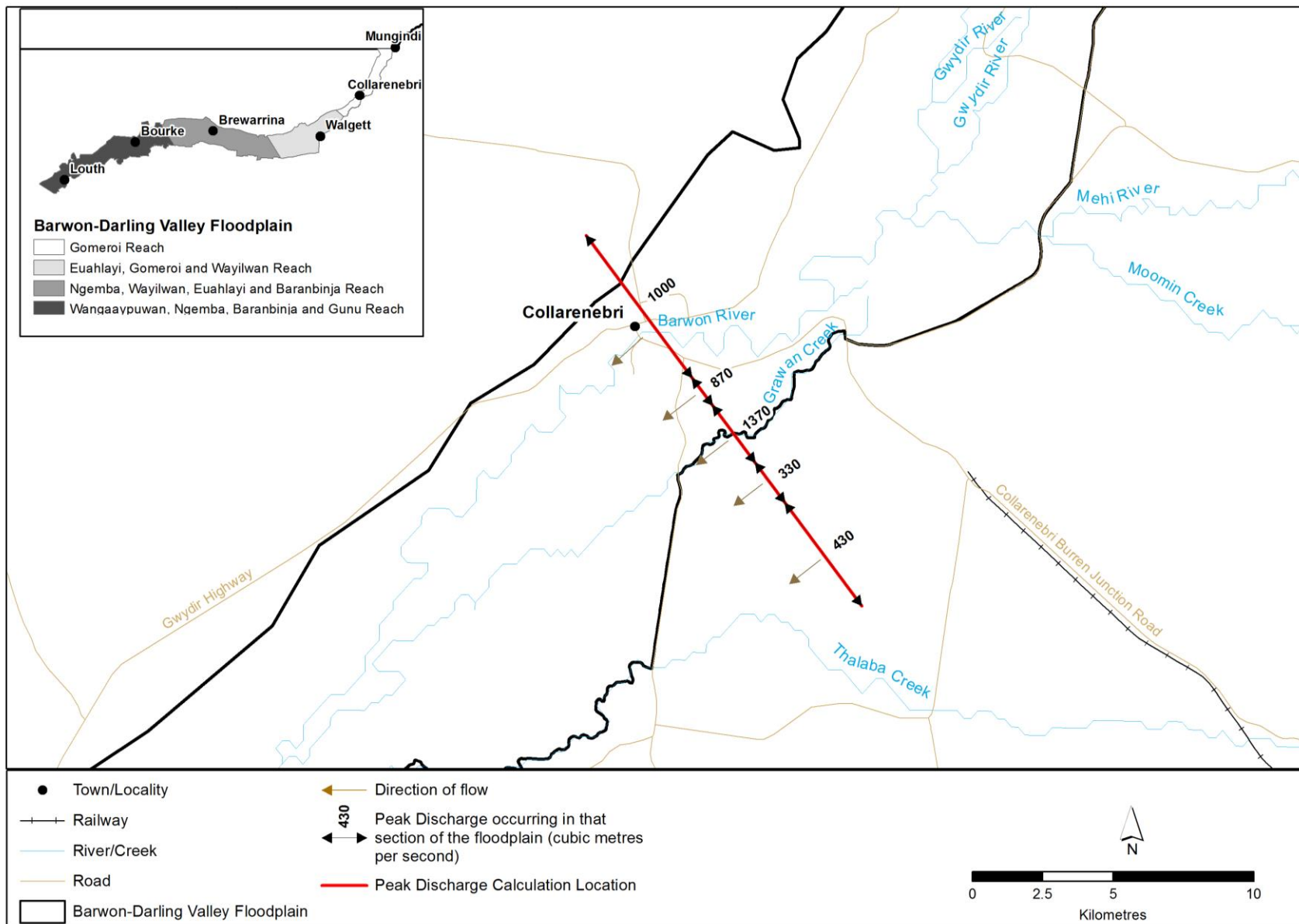


Figure A14.2: 1976 Peak discharge calculation location near Collarenebri in Gomeri Reach

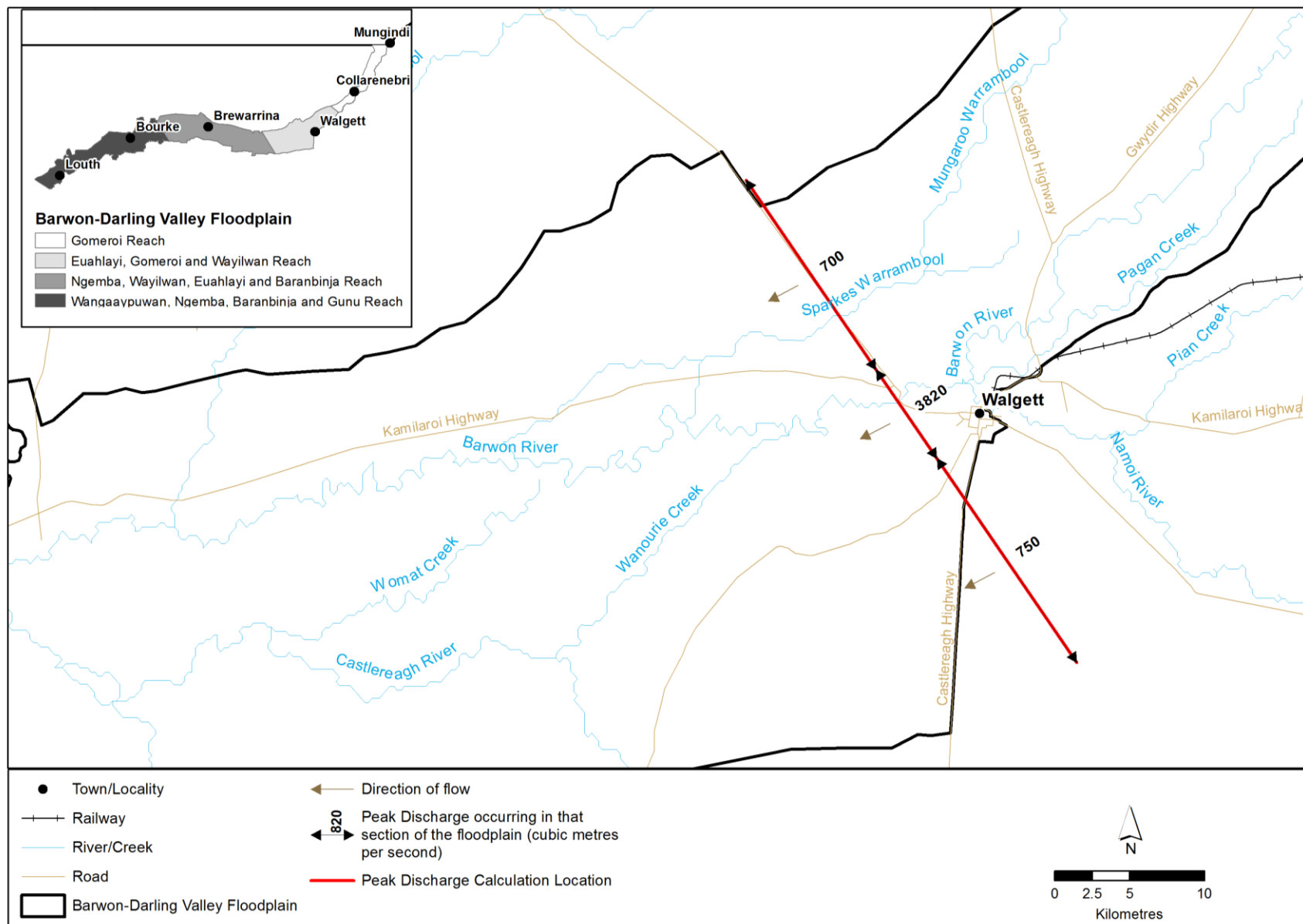


Figure A14.3: 1976 Peak discharge calculation location near Walgett in Euahlayi, Gomeri and Wayilwan Reach

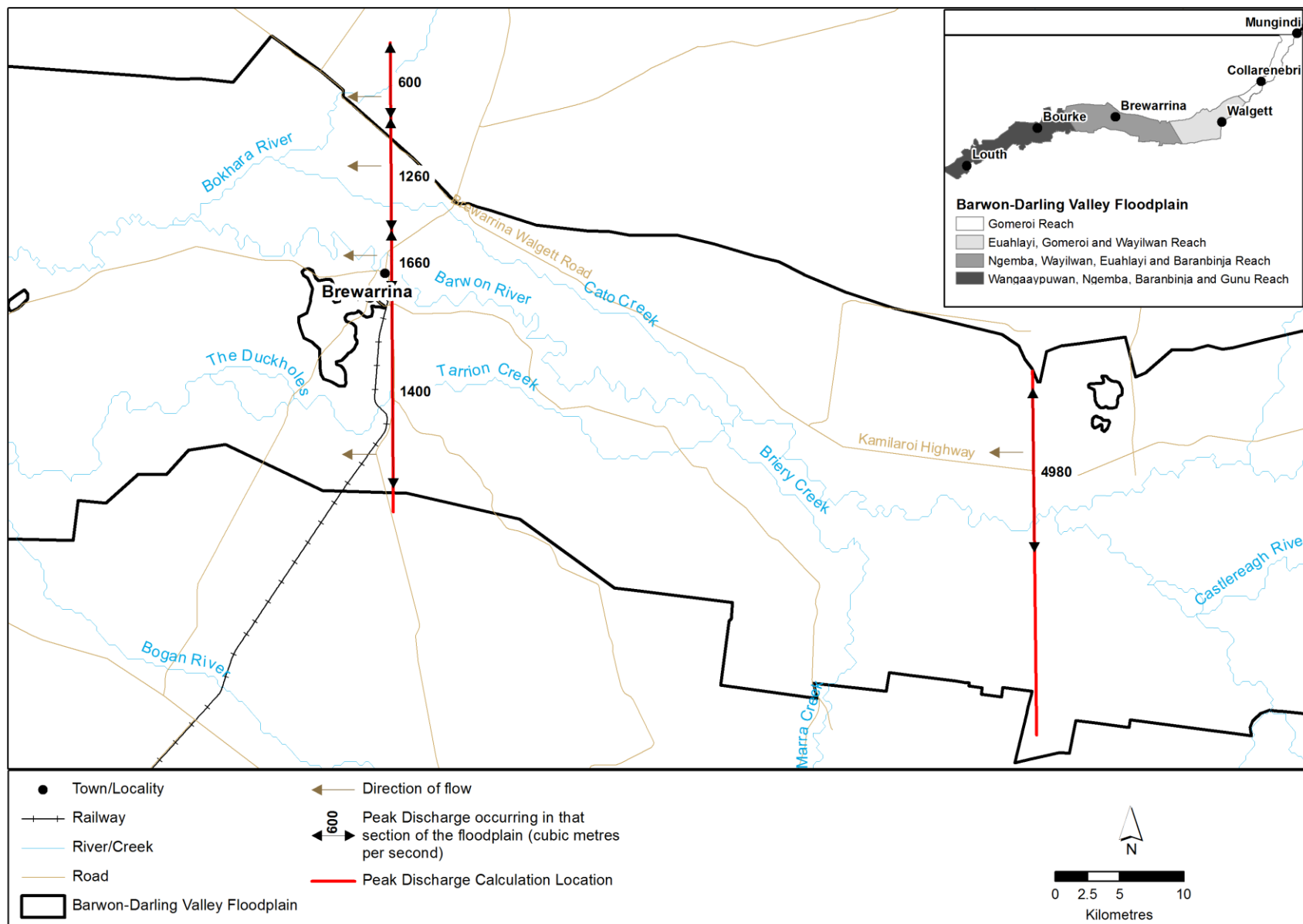


Figure A14.4: 1976 Peak discharge calculation locations upstream of Brewarrina in Ngemba, Wayilwan, Euahlayi and Baranbinja Reach

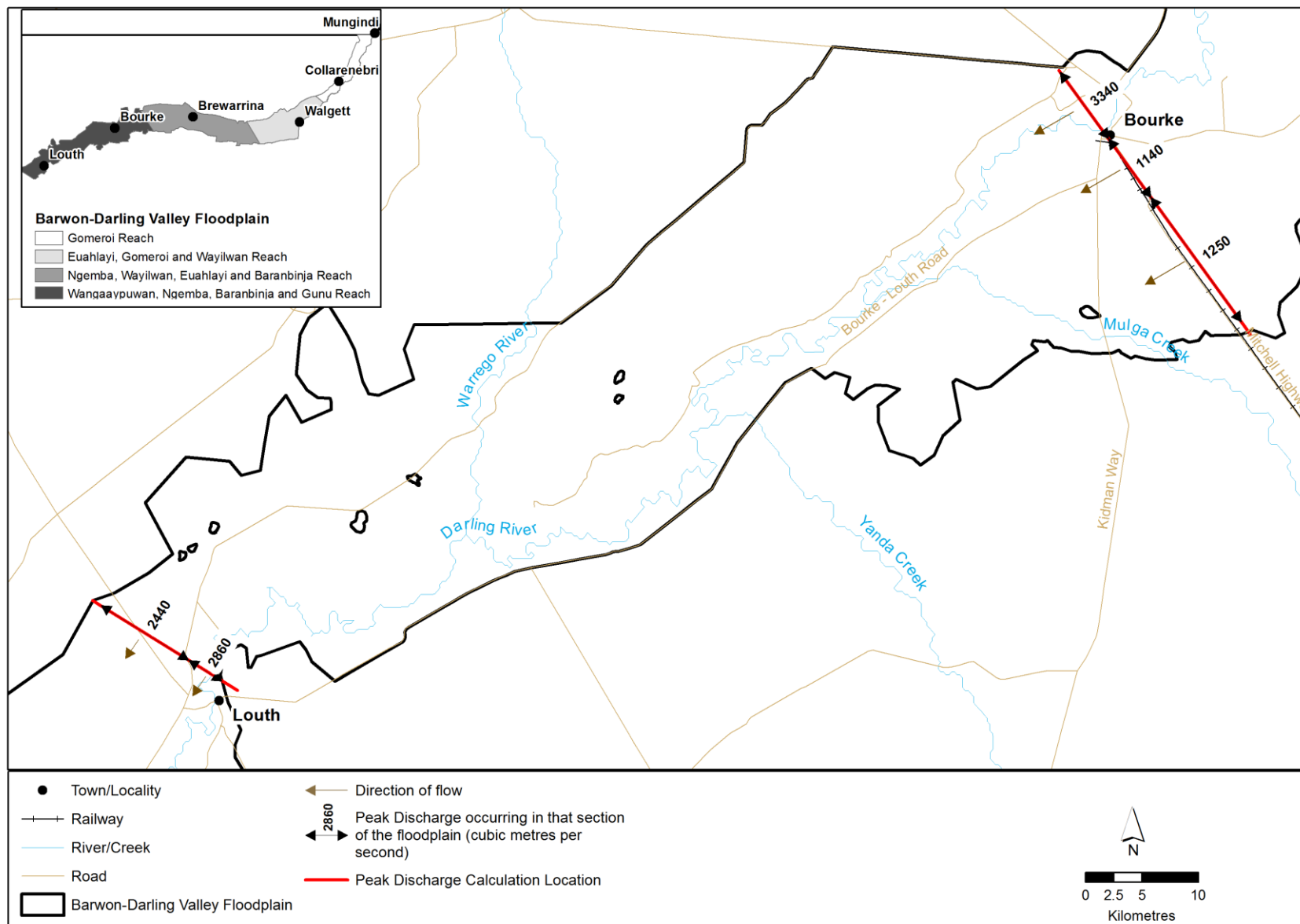


Figure A14.5: 1976 Peak discharge calculation locations near Bourke and Louth in Wangaaypuwan, Ngemba, Baranbinja and Gunu Reach

Appendix 15: Approach for consulting with Aboriginal stakeholders

As the first peoples of Australia, Aboriginal people have certain inherent rights, including the right to maintain culture, which requires the ability to maintain links with Country (including traditional lands and seas). Aboriginal stakeholders include individuals of Australian Aboriginal descent who have a cultural connection to the Barwon-Darling Valley Floodplain. Aboriginal stakeholders and interests may be represented by communities, formal or informal working groups or committees and Aboriginal Land Councils.

DPIW worked closely with OEH when consulting with Aboriginal stakeholders. OEH undertakes many environment protection, natural resource management and conservation activities that have direct relevance to and impacts on Aboriginal communities. OEH has developed principles and frameworks to guide the implementation of meaningful community engagement that ensures the needs of Aboriginal communities are met in relation to the conservation and continuation of their cultural heritage and values. These documents include:

- Aboriginal People, the Environment and Conservation (APEC) principles (Department of Environment and Conservation NSW 2006)
- An Aboriginal Community Engagement Framework for DECC (unpublished, 2007)
- Working to protect Aboriginal cultural heritage (OEH 2011b).

The APEC principles guided the inclusion of the rights and interests of Aboriginal people into OEH work by supporting OEH and Aboriginal people to jointly and openly identify the level of involvement that Aboriginal communities would like in OEH's environmental management and conservation activities. The five principles are:

1. Spirituality and connection
2. Cultural resource use
3. Wellbeing
4. Caring for country
5. Doing business with Aboriginal people.

Both the Aboriginal Community Engagement Framework for DECC and the Working to protect Aboriginal cultural heritage documents support the implementation of the APEC principles.

The Aboriginal cultural heritage and contemporary cultural values and connections of the Barwon-Darling Valley Floodplain are rich and vibrant. Many of the cultural values of the Aboriginal peoples of the Barwon-Darling are linked to flooding and floodwater and the FMP has an objective to contribute to the protection of cultural, heritage and spiritual features of the floodplain that are significant to Aboriginal people and other stakeholders.

References (Appendices)

- Anstis, M. (2013). *Tadpoles and frogs of Australia*. New Holland Publishers.
- Apropos Information Systems (2014). *Plugin Qmarxan version 1.3.1*, Quantum GIS Plugin Repository, Calgary, Alberta. Retrieved from <http://www.aproposinfosystems.com/products/qmarxan/>
- Australian Bureau of Statistics (ABS) (2011a). Australian Bureau of Statistics, Census of Population and Housing 2011, Statistical Area level 1 data. Retrieved from <http://www.abs.gov.au/ausstats/abs@.nsf/ViewContent?readform&view=productsbyCatalogue&Action=Expand&Num=2.1>
- Australian Bureau of Statistics (ABS) (2011b). Australian Bureau of Statistics, Census of Population and Housing 2011 Socio-economic Indexes for Areas. Retrieved from <http://www.abs.gov.au/ausstats/abs@.nsf/ViewContent?readform&view=productsbyCatalogue&Action=Expand&Num=2.1>
- Australian Bureau of Statistics (ABS) (2011c). Australian Bureau of Statistics, Agricultural Census 2011. Retrieved from <http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/7101.0main+features2Dec%202012>
- Australian Bureau of Statistics (ABS) (2013). Australian Bureau of Statistics, Regional Population Growth 2012-2013. Retrieved from <http://www.abs.gov.au/ausstats/abs@.nsf/mf/3218.0/>
- Ayers, D.Y., Mazzer, T.M., Ellis, M.V. (2004). *Reptiles and amphibians of the Darling basin*. (Pages 194-231, 456 – 458). In R. Breckwoldt, R. Boden, and J. Andrew (eds), *The Darling*. MDBC Publication No. 69/04.
- Baggiano, O. (2012). The Murray-Darling Turtles: Gene Flow and Population Persistence in Dryland Rivers. Ph.D. Thesis, Griffith School of Environment. Science, Environment, Engineering and Technology. Griffith University, Australia.
- Ball, I.R., Possingham, H.P., and Watts, M. (2009). Marxan and relatives: Software for spatial conservation prioritisation, in A. Moilanen, K.A. Wilson and H.P Possingham (eds), *Spatial conservation prioritisation: Quantitative methods and computational tools*, Oxford University Press, Oxford, UK.
- Baumgartner, L., Conallin, J., Wooden, I., Campbell, B., Gee, R., Robinson, W., and Mallen-Cooper, M. (2013). Using flow guilds of freshwater fish in an adaptive management framework to simplify environmental flow delivery for semi-arid riverine systems. *Fish and Fisheries* doi:10.1111/faf.12023.
- Benson, J.S., Allen, C.B., Togher, C., and Lemmon, J. (2006). New South Wales Vegetation Classification and Assessment: Part 1 Plant communities of the NSW Western Plains. *Cunninghamia* Vol.9, pp.383-450.
- Bowen, S., and Simpson, S. (2009). *2008 Vegetation map for the Gwydir wetlands and floodplain*. NSW Department of Environment Climate Change and Water. Sydney South NSW.
- Bower, D.S., and Hodges, K.M. (2014). *Chelodina expansa* Gray 1857 – Broad-Shelled Turtle, Giant Snake-Necked Turtle. Conservation Biology of Freshwater Turtles and Tortoises. Chelonian Research Monographs, No. 5.
- Bower, D.S., Hutchinson, M., and Georges, A. (2012). Movement and habitat use of Australia's largest snake-necked turtle: implications for water management. *Journal of Zoology*, Vol.287, pp.76-80.

- Boys, C., and Thoms, M. (2006). A large-scale, hierarchical approach for assessing habitat associations of fish assemblages in large dryland rivers. *Hydrobiologia* Vol.572, pp.11 – 31.
- Boys, C.A., Esslemont, G., and Thoms, M.C. (2005). *Fish habitat assessment and protection in the Barwon-Darling and Paroo Rivers*. Final report to the Department of Agriculture, Fisheries and Forestry – Australia. NSW Department of Primary Industries. September 2005.
- Brennan, S., O'Brien, M., Thoms, M., and Maher, S. (2002). *The physical character and flow criteria for wetlands along the Barwon - Darling River*. CRC for Freshwater Ecology Technical Report to the Department of Land and Water Conservation. 60pp.
- Carvalho, S.B., Brito, J.C., Pressey, R.L., Crespo, E., and Possingham, H.P. (2010). Simulating the effects of using different types of species distribution data in reserve selection. *Biological Conservation*, Vol.143, pp.426 – 438.
- Cheshire, K.J., and Ye, Q. (2008). *Larval fish assemblage structure below Locks 5 and 6, in the River Murray, South Australia from 2005 to 2007: with reference to the water manipulation trials*. SARDI Publication Number F2007/000705-1. SARDI Research Report Series No.175. South Australian Research and Development Institute (Aquatic Sciences), Adelaide.
- Chessman, B.C. (1988). Habitat preferences of freshwater turtles in the Murray valley, Vic and NSW, *Australian Wildlife Research*, Vol. 15, pp. 485-491, CSIRO.
- Claus, S., Imgrabben, S., Brennan, K., Carthey, A., Daly, B., Blakey, R., Turak, E., and Saintilan, N. (2011). *State of the catchments 2010: Assessing the extent and condition of wetlands in NSW*, project report. Office of Environment and Heritage, Sydney.
- Cogger, H., G. (2000). *Reptiles and amphibians of Australia*. Reed New Holland, Sydney.
- Cooney, T. (1994). *Barwon - Darling River Riparian Health Report: Wetland Inundation*. NSW Department of Water Resources, Sydney.
- Cotton, B.C. (1935). The Australian viviparous river snails. *Victorian Naturalist* Vol.52, pp.96-99.
- Cox, S., Thomas, R., and Lu, Y. (2012). *Flooding patterns of Toorale: the confluence of the Warrego and Darling Rivers*. Office of Environment and Heritage, Sydney South NSW.
- Croft, R. (2012). *Using population abundance, size and stage measurements of two common species of frog and tadpole (Limnodynastes fletcheri and Limnodynastes tasmaniensis) as indicators of response to flooding of Australian floodplain wetlands in two distinct regions*. Honours, Charles Sturt University, Charles Sturt University.
- CSIRO. (2004). *Taxon attributes profiles - Hydromys chrysogaster, Water-rat*. Page Factsheet Factsheet: Water for a healthy country - Taxon attribute profiles. CSIRO Canberra, CSIRO Water for a Healthy Country Canberra.
- Davies, P., Harris, J.H., Hillman, T.J., and Walker, K.F. (2008). *SRA Report 1: A Report on the Ecological Health of Rivers in the Murray-Darling Basin, 2004-2007*. Prepared by the independent sustainable rivers audit group for the Murray-Darling Basin Ministerial Council. Murray-Darling Basin Commission, Canberra.
- Davies, P.E., Stewardson, M.J., Hillman, T.J., Roberts, J.R., and Thoms, M.C. (2012). *Sustainable Rivers Audit 2: The ecological health of rivers in the Murray-Darling Basin at the end of the Millennium Drought (2008-2010)*. Volume 3, Murray-Darling Basin Authority, Canberra.
- Department of Environment and Climate Change NSW (2007). *An Aboriginal Community Engagement Framework*. Unpublished. Department of Environment and Climate Change, Sydney.

- Department of Environment and Conservation NSW (2006). *Aboriginal people, the environment and conservation: Principles to incorporate the rights and interests of Aboriginal people into the work of the Department of Environment and Conservation NSW*. Department of Environment and Conservation NSW, Goulburn Street, Sydney NSW 1232
- Department of Infrastructure, Planning and Natural Resources (DIPNR) (1998a). *Preclearing and Existing Vegetation Mapping of the Western Division section of Bourke Shire, Northern Floodplains Far Western NSW*, Edition 3.
- Department of Infrastructure, Planning and Natural Resources (DIPNR) (1998b). *Preclearing and Existing Vegetation Mapping of the Western Division section of Brewarrina Shire, Northern Floodplains Far Western NSW*, Edition 2.
- Department of Infrastructure, Planning and Natural Resources (DIPNR) (1998c). *Preclearing and Existing Vegetation Mapping of the Western Division section of Walgett Shire, Northern Floodplains Far Western NSW*, Edition 3.
- Department of Land and Water Conservation (DLWC) (2001). *Barwon-Darling River Floodplain Management Plan – Walgett to Bourke*, Final Report on Scoping Study.
- Department of the Environment (2014). *Bidyanus bidyanus* in Species Profile and Threats Database, Department of the Environment, Canberra. Retrieved from <http://www.environment.gov.au/sprat>.
- Dickman, C. (2004). Mammals of the Darling River Basin. (Pages 170-191). In R. Breckwoldt, R. Boden and J. Andrew (eds), *The Darling*. MDBC Publication No. 69/04.
- Eco Logical Australia (2008). *Vegetation Mapping for the Namoi and Border Rivers-Gwydir CMAs* Compilation of API Datasets and Preparation of a Hierarchical Vegetation Classification (Project Nos. 125-002 & 129-002). Final Report prepared for: Namoi and Border Rivers-Gwydir CMAs.
- Elith, J., and Leathwick, J. (2009). The contribution of species distribution modelling to conservation prioritization. In A. Moilanen, K.A. Wilson and H.P Possingham (eds), *Spatial conservation prioritisation: Quantitative methods and computational tools*, pp.70-93. Oxford University Press, Oxford, UK.
- Esselman, P.C and Allan, J.D. (2011). Application of species distribution models and conservation planning software to the design of a reserve network for the riverine fishes of northeastern Mesoamerica, *Freshwater Biology*, Vol. 56, pp. 71-88.
- Gehrke and Harris (2004). Fish in the Darling River System. (Pages .256-277). In R. Breckwoldt, R. Boden, and J. Andrew (eds), *The Darling*. MDBC Publication No. 69/04.
- Gilmore, S., Mackey, B., and Berry, S.B. (2007). The extent of dispersive movements in Australian vertebrate animals, possible causes, and some implications for conservation. *Pacific Conservation Biology*, Vol.13, pp.93-103.
- Glaubrecht, M., Brinkmann, N., and Pöppe, J. (2009). Diversity and disparity 'down under': Systematics, biogeography and reproductive modes of the 'marsupial' freshwater Thiaridae (*Caenogastropoda, Cerithioidea*), *Australia.Zoosystematics and Evolution*, Vol.85, pp.199–275.
- Goodman and Nel (2011)
- Gowans, S., Milne, R., Westbrooke, M., and Palmer, G. (2012). Survey of vegetation and vegetation condition of Toorale, Version 1-1. Unpublished report to NSW Office of Environment and Heritage. Centre for Environmental Management, University of Ballarat, Mt Helen, Victoria.
- Growns, I., and West, G. (2008). Classification of aquatic bioregions through the use of distributional modelling of freshwater fish. *Ecological Modelling*. Vol.217, pp.79 - 86.

- Healey, M., Thompson, D., and Robertson, A. (1997). Amphibian communities associated with billabong habitats on the Murrumbidgee floodplain. *Australia Australian Journal of Ecology*, Vol.22, pp.270-278.
- Hermoso, V., Kennard, M.J., and Linke, S. (2013b). Data acquisition for conservation assessments: is the effort worth It? *PLOS ONE* 8: e59662.
- Hermoso, V., Ward, D.P., and Kennard, M.J. (2013a). Prioritizing refugia for freshwater biodiversity conservation in highly seasonal ecosystems. *Diversity and Distributions*, Vol.19, pp.1031 – 1042.
- Hudson, S.R., and Bacon, P. (2009). Culturally significant lagoons and salt affected sites project. Report prepared for Border Rivers – Gwydir Catchment Management Authority.
- Humphries, P., King, A.J., and Koehn, J.D. (1999). Fish, flows and flood plains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia, *Environmental Biology of Fishes*, Vol.56, pp.129-151.
- Humphries, P., Serafini, L.G. and King, A.J. (2002). River regulation and fish larvae: variation through space and time. *Freshwater Biology*, Vol.47, pp.1307-1331.
- Hunter, S. (2010). *Vegetation and Floristics of the Barwon Nature Reserve*. A report prepared for the Department of Environment, Climate Change and Water (DECCW).
- Institution of Engineers, Australia (IEA) (1987). *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Vol. 1, D.H. Pilgrim, Revised Edition 1987 (Reprinted edition 1998), Barton, ACT.
- Johnston, T.H., and Beckwith, A.C. (1945). Larval trematodes from Australian freshwater molluscs. *Transactions of the Royal Society of South Australia*, Vol.69, pp.229-242.
- Jones, H.A. (2011). Crustaceans and molluscs. In K. Rogers and T. Ralph (eds), *Water requirements of biota in the Murray-Darling Basin*, CSIRO Publishing Canberra.
- Kalatzis, and Baker, L. (2010). Murray Cod fact sheet. Industry and Investment NSW and Southern Cross University.
- Kennett, R., Roe, J., Hodges, K., and Georges, A. (2009). *Chelodina longicollis*, Eastern Long-Necked Turtle, Common Long-Necked Turtle, Common Snake-Necked Turtle. Chelonian Research Monographs No. 5. Chelonian Research Foundation.
- King, A.J. (2004). Ontogenetic patterns of habitat use by fishes within the main channel of an Australian floodplain river. *Journal of Fish Biology*, Vol.65, pp.1582-1603.
- Kingsford, R.T., Brandis, K.J., Jenkins, K.M., Nairn, L.C and Rayner, T.S (2010). Measuring ecosystem responses to flow across temporal and spatial scales. In N. Saintilan and I. Overton (eds), *Ecosystem Response Modelling in the Murray-Darling Basin*, CSIRO Publishing Canberra.
- Koehn, J.D., and Crook, D.A. (2013). Movements and Migration, In P. Humphries and K. Walker (eds), *Ecology of Australian Freshwater Fishes*, pp 105-129, CSIRO Publishing, Victoria, Australia.
- Koehn, J. D., and Harrington, D. J. (2005). Collection and distribution of early life stages of the Murray cod (*Maccullochella peelii peelii*) in a regulated river. *Australian Journal of Zoology*, Vol.53, pp.137–144.
- Kuzera, G., (2006). Introductory instructions for the use of FLIKE, Department of Civil, Surveying and Environmental Engineering, University of Newcastle
- Land and Property Information (LPI) (2013). Hydro area feature class of the NSW Digital Topographic Database. Retrieved from <https://sdi.nsw.gov.au/sdi.nsw.gov.au/catalog/search/resource/details.page?uuid=%7BF5A786A6-6611-46F9-B09D-0FB69AC47B5A%7D>

- Law, B.S., and Bradley, R.A. (1990). Habitat use and basking site selection in the Water Skink, *Eulamprus quoyii*. *Journal of Herpetology*, Vol.24, pp.235-240.
- Linke, S., Turak, E., and Nel, J. (2010). Freshwater conservation planning: the case for systematic approaches. *Freshwater Biology*, Vol.56, pp.6 – 20.
- Lintermans, M. (2007). *Fishes of the Murray-Darling Basin: An introductory guide*.
- Lintermans, M., and Osborne, W. (2002). *A Field Guide to the Freshwater Animals of the Southern Tablelands and High Country of the ACT and NSW*. Environment ACT.
- Loos, S. (2011). Marxan analyses and prioritization of conservation areas for the Central Interior Ecoregional Assessment, *BC Journal of Ecosystems and Management*, Vol.12, pp.88–97
- Maclean, K., Bark, R.H., Moggridge, B., Jackson, S., Pollino, C. (2012). *Ngemba Water Values and Interests. Ngemba Old Mission Billabong and Brewarrina Aboriginal Fish Traps (Baime's Nguunhu)*. CSIRO, Australia.
- Margules, C., and Pressey, R. (2000). Systematic Conservation Planning, *Nature*, Vol.405, pp.243-254
- Margules, C.R., Pressey, R.L, Williams, P.H. (2002). Representing biodiversity: data and procedures for identifying priority areas for conservation, *Journal of Biosciences*, Vol. 27, 4, pp.309–326.
- Murray Darling Basin Authority (MDBA) (2010). Appendix A – Key environmental assets. Guide to the proposed Basin Plan. Retrieved from <http://www.mdba.gov.au/kid/guide/>
- Mackey, B., Possingham, H.P., and Ferrier, S/ (2013)/ Connectivity conservation principles for Australia's National Wildlife Corridors. In J. Fitzsimons, I. Pulsford and G. Wescott (eds), *Linking Australia's Landscapes. Lessons and Opportunities from Large-scale Conservation Networks*. CSIRO Publishing.
- Murray Darling Basin Authority (MDBA) (2012). *Assessment of environmental water requirements for the proposed Basin Plan: Barwon-Darling River upstream of Menindee Lakes*. Murray Darling Basin Authority. MDBA Publication No: 41/12. ISBN: 978-1-922068-49-1.
- Murray Darling Basin Authority (MDBA) (2014). *Reviewing the scientific basis of environmental water requirements in the Condamine-Balonne and Barwon-Darling*. Technical Report.
- Northern Floodplains. Regional Planning Vegetation Committee (NFRPC) (2004). Book 3. *Vegetation Communities of the Northern Floodplains Western NSW. North Eastern Section of Bourke Shire*. Northern Floodplains Regional Planning Committee.
- Nhancale, B., and Smith, R. (2011).The influence of planning unit characteristics on the efficiency and spatial pattern of systematic conservation planning assessments, *Biodiversity and Conservation*, Vol.20, pp.1821-1835
- NSW Department of Primary Industries (NSW DPI) (2005). *Threatened species in NSW. Silver perch, Bidyanus bidyanus*. Primefact 8. Retrieved from <http://www.dpi.nsw.gov.au/fisheries/species-protection/conservation/what-current/vulnerable-species/silver-perch/silver-perch>
- NSW Department of Primary Industries (NSW DPI) (2006). *The Assessment and Modification of Barriers to Fish Passage in the Namoi Catchment*. Report to the Namoi Catchment Management Authority. Department of Primary Industries (Aquatic Habitat Rehabilitation Unit), Tamworth.
- NSW Department of Primary Industries (NSW DPI) (2007a). *Threatened species in NSW. River snail, Notopala sublineata*. Primefact 182.

- NSW Department of Primary Industries (NSW DPI) (2007b). *Endangered Ecological Community - Lowland Darling River Aquatic Ecological Community*. Primefact 173.
- NSW Department of Primary Industries (NSW DPI) (2011). *Final Recommendations of the Fisheries Scientific Committee – Aquatic Ecological Community in the natural drainage system of the lowland catchment of the Darling River*, Department of Primary Industries website. Retrieved from http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/208297/FR22-Darling-River-EEC.pdf
- NSW Department of Primary Industries (NSW DPI) (2012). *Living on the Lower Namoi. Stories about the River, Fish and the People in and around Walgett*, NSW Department of Primary Industries, Tamworth
- NSW Department of Primary Industries (NSW DPI) (2013). *NSW Floodplain Harvesting Policy*, NSW Department of Primary Industries, Office of Water, Sydney.
- NSW Department of Primary Industries (NSW DPI) (2014a). Fisheries Scientific Committee. Final determinations. Retrieved from <http://www.dpi.nsw.gov.au/fisheries/species-protection/fsc/final>
- NSW Department of Primary Industries (NSW DPI) (2014b). *Installation and operation of instream structures*. Retrieved from <http://www.dpi.nsw.gov.au/fisheries/species-protection/conservation/what-current/key/instream-structures>
- NSW Government (2005). *Floodplain Development Manual: the management of flood liable land April 2005*. Published by Department of Infrastructure, Planning and Natural Resources, 23-33 Bridge Street, Sydney 2000
- Ocock, J.F. (2013). *Linking frogs with flow: Amphibian community response to flow and rainfall on a dryland floodplain wetland*. A thesis in fulfilment of the requirements for the degree of Doctor of Philosophy. Australian Wetlands, Rivers and Landscapes Centre. School of Biological, Earth and Environmental Sciences. University of New South Wales, Australia.
- Ocock, J.F., Kingsford, R.T., Penmen, T.D and Rowley, J.J.L. (2014). Frogs during the flood: Differential behaviours of two amphibian species in a dryland floodplain wetland. *Austral Ecology* (2014).
- Office of Environment and Heritage (OEH) (2011a). *NSW Landuse*. A data set of land use between June 2000 and June 2007 for New South Wales. ANZLIC Metadata Profile: An Australian/New Zealand Profile of AS/NZS ISO 19115:2005, Geographic information - Metadata. OEH Spatial Data Catalogue Online. Retrieved from <http://mapdata.environment.nsw.gov.au/geonetwork/srv/en/main.home> Downloaded on 3 December 2014.
- Office of Environment and Heritage (OEH) (2011b). *Working to protect Aboriginal cultural heritage*. OEH, Department of Premier and Cabinet, Goulburn Street, Sydney South 1232
- Office of Environment and Heritage (OEH) (2012) *Gwydir Valley – Annual environmental watering plan 2012 -13*. Office of Environment and Heritage, Department of Premier and Cabinet, Sydney.
- Office of Environment and Heritage (OEH) (2014a) *Statement of Management Intent: Toorale National Park and State Conservation Area*. ISBN 978 1 74359 546 6. OEH 2014/0234. June 2014.
- Office of Environment and Heritage (OEH) (2014b). *Statement of Management Intent: Barwon Nature Reserve and State Conservation Area*. ISBN 978 1 74359 426 1. OEH 2014/0114. June 2014
- Office of Environment and Heritage (OEH) (2015). *BRG-Namoi Regional Native Vegetation Mapping. Technical Notes*. Office of Environment and Heritage, Sydney, Australia.

- Peasley, B., and Walsh, A. (1999). *Mapping Vegetation Landscapes of the NSW North Western Slopes and Plains - A Project Overview*. NHT Project NW0339.97. Report to the Natural Heritage Trust and North West Catchment Management Committee, DLWC.
- Phillips, S., Dudik, M., and Schapire, R. (2010). Maxent Software, ver. 3.3.3e. Retrieved from <http://www.gbif.org/resources/2596>.
- Ponder, W.F. (1996). *Notopala sublineata*. The IUCN Red List of Threatened Species. Version 2014.1. <www.iucnredlist.org>. Downloaded on 14 July 2014.
- Possingham, H.P., Grantham, H., and Rondinini, C. (2007). How can you conserve species that haven't been found? *Journal of Biogeography*, Vol.34, pp.758-759.
- Pressey, R.L., Cowling, R.M., and Rouget, M. (2003). Formulating conservation targets for biodiversity pattern and process in the Cape Floristic Region, South Africa. *Biological Conservation*, Vol.112, pp.99 – 127.
- QGIS Development Team (2013) *QGIS Geographic Information System Developers Manual*. Open Source Geospatial Foundation Project. Electronic document: http://www.qgis.org/wiki/Developers_Manual
- Ralph, T., Spencer, J., and Rayner, T. (2011). Fish. In Rogers, K and Ralph, T.J, *Floodplain wetland biota in the Murray-Darling Basin. Water and Habitat Requirements*. CSIRO Publishing.
- Rivers-Moore, N.A., Goodman, P.S., and Nel, J.L. (2011). Scale-based freshwater conservation planning: towards protecting freshwater biodiversity in KwaZulu-Natal, South Africa. *Freshwater Biology*, Vol. 56, pp.125-141.
- Roberts, J. and Marston, F. (2011). *Water regime for wetland and floodplain plants: a source book for the Murray–Darling Basin*. National Water Commission, Canberra.
- Rogers, K. and Ralph, T.J. (2011). *Floodplain wetland biota in the Murray-Darling Basin: Water and habitat requirements*. CSIRO Publishing, Collingwood VIC.
- Scott, A. (1997). *Relationships between waterbird ecology and river flows in the Murray Darling Basin*. Technical Report No. 5/97. CSIRO Land and Water.
- Scott, A., and Grant, T. (1997). *Impacts of water management in the Murray-Darling Basin on the platypus (Ornithorhynchus anatinus) and the water rat (Hydromys crhysogaster)*. CSIRO Land and Water School of biological Science, University of NSW, CSIRO Land and Water.
- Sheldon, F. and Walker, K.F. (1998). Spatial distribution of littoral invertebrates in the lower Murray–Darling River system, *Australia. Marine and Freshwater Research*, Vol.49, pp.171–182.
- Shultz, N., Gowans, S., and Westbrooke, M. (2014). *Survey and mapping of Darling floodplain vegetation between Tilpa and Brewarrina*. September 2014. Report prepared for the NSW Government – Office of Environment and Heritage by Centre for Environmental Management, Federation University Australia, Ballarat.
- Spark, P (2013). *Frogs, Reptiles and Mammals of the North Western Floodplain of NSW. A guide to species identification and habitat management*. Namoi Catchment Management Authority.
- Spatial Ecology (2014). Geospatial Modelling Environment. Retrieved from <http://www.spatial ecology.com/gme/index.htm>.
- Stevens, M.M. (2007). Rice. In P.T. Bailey (Ed.), *Pests of Field Crops and Pastures: Identification and Control*, pp 279-296. CSIRO Publishing. Melbourne.

- URS (2008). *Flood Study - Darling River (Bogan River confluence to Louth) Compendium of Data*. Artarmon NSW 2064. Report for the NSW Department of Environment, Climate Change and Water.
- URS (2009). *Flood Study Report – Rural Flood Study Darling River Floodplain (Bogan River Confluence to Louth)*. Report for the NSW Department of Environment, Climate Change and Water.
- Wager, R. (1996a). *Bidyanus bidyanus*. In: *IUCN 2014*. IUCN Red List of Threatened Species. Version 2014.1. Retrieved from www.iucnredlist.org
- Wager, R. (1996b). *Maccullochella peelii*. In: *IUCN 2014*. IUCN Red List of Threatened Species. Version 2014.1. Retrieved from www.iucnredlist.org
- Wassens, S. (2010). Flooding regimes for frogs in lowland rivers of the Murray Darling Basin. In NSaI Overton (eds), *Ecosystem Response Modelling in the Murray-Darling Basin* CSIRO Publishing, Canberra,
- Wassens, S. (2011). *Frogs* in K. Rogers and T. Ralph, (eds). Water requirements of biota in the Murray-Darling Basin CSIRO Publishing Canberra.
- Water Resources Commission (1986a). Guidelines for Flood Plain Development Darling River Little Bogan confluence to Yanda Creek confluence. NSW.
- Water Resources Commission (1986b). *Guidelines for Flood Plain Development Darling River Yanda Creek confluence to Louth*. NSW.
- Wen, L., Saintilan, N., Yang, X., Hunter, S., and Mawer, D. (2015). MODIS NDVI based metrics improve habitat suitability modelling in fragmented patchy floodplains. *Remote Sensing Applications: Society and Environment*.
- Wilson, K.A., Cabeza, M., and Klein, C.J. (2009). Fundamental concepts of spatial prioritization. In A Moilanen, KA, Wilson and HP, Possingham (eds), *Spatial conservation prioritisation: Quantitative methods and computational tool*, Pages 185-196. Oxford University Press, Oxford, UK.
- Woollard, P., Vestjens, W. J. M., and Maclean, L. (1978). The ecology of the Eastern Water Rat *Hydromys chrysogaster* at Griffith, NSW: food and feeding habits. *Australian Wildlife Research*, Vol.5, pp.59-73.
- Young, W.J., Scott, A.C., Cuddy, S.M., and Rennie, B.A. (2003). *Murray Flow Assessment Tool –a technical description*. Client Report, 2003. CSIRO Land and Water, Canberra.