Barwon-Darling Valley – IQQM Cap Implementation Report

Version 1
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Executive Summary

What has initiated the work?

The Murray Darling Basin Ministerial Council Cap requires that NSW develop a suitable planning tool to enable review of water use and sharing arrangements in the Barwon-Darling River Valley. The tool accepted as suitable for this purpose is a calibrated water balance model that includes all relevant important features on and in the system. The adopted model is called the Integrated Quantity/Quality Model (IQQM).

Scope of this report summarises the Gwydir IQQM status

This report summarises and documents the IQQM calibration, validation and model use for representation of Cap conditions in the unregulated sections of the Barwon-Darling River.

Purpose is to prove model suitability as a Cap estimation tool and present Cap modelling results

The primary purpose of this IQQM summary report is to demonstrate to the reader that the developed model includes <u>all</u> of the important features in the system, and <u>closely</u> replicates records of flow and water extraction behaviour. The secondary purpose is to demonstrate that the model can be successfully used to define the 1993/94 diversion Cap.

Model configuration includes all important features

Chapter 2 describes inclusion of the main physical and management features in the model. The availability and extent of time series data is also described in this chapter.

Calibration to 1988/89 – 2003/04 configures the model parameters

Chapter 3 also describes the model calibration procedure and results. Comparison is made between time series observed data and time series model simulated data using model parameters to determine appropriate values for use in scenario runs. Quality ratings were applied to the components of the model calibration as follows:

- Flow Time Series Replication: Daily at Wilcannia, “High” CMAAD rating;
- Diversion Time Series Replication: Annual whole system “Very High” CMAAD rating;
- Planted Area Time Series Replication: Annual whole system “High” CMAAD rating;

The overall was also assessed based on the quality of the individual calibrations and the length of the calibration period. The model achieved a “V. High” rating.

Statement of model adequacy

The overall quality of the Barwon-Darling River Valley IQQM calibration suggests that it is suitably robust for Cap Auditing, 100+ year scenario running and for comparison of impacts from alternative management scenarios.

Validation for the 1993/94 scenario

Section 4.9 describes the 1993/94 development conditions and management rules. These are configured into what NOW is defining as the 1993/94 Cap scenario. Presented are the model validation results over the 1993/94 to 1995/96 period using the static 1993/94 Cap scenario parameters. Comparison is made between time series observed data and time series model simulated data. Analysis and discussion of the model's performance over this period is presented.

Simulation of the 1993/94 Cap benchmark scenario

Section 4.10 also describes the use of the Barwon-Darling IQQM to simulate the 1993/94 Cap scenario. Results are presented for:

- the 114 year period from 1895 to 2009 inclusive, to estimate the long term Cap scenario average annual diversions;
- the 1997/98 to 2009/10 period, to produce estimates of the Cap for auditing under the provisions of Schedule E of the Murray-Darling Basin Agreement.

Improvement suggestions

Chapter 5 lists a series of short and long term improvement plans, categorised as upgrades to flow, demand, storage behaviour and other general upgrades. These suggestions are not intended to reduce the credibility of the current model, but should be viewed as part of NOW's quality assurance process, which promotes continuous improvement to its key planning tools and products.

Glossary of Terms

account balance	This is the current amount of water an irrigator is entitled to access for irrigation. For annual accounting in unregulated rivers, like Barwon-Darling, it is a function of the amount of water they have already diverted for that year.
annual accounting	An annual accounting system is where water users get their licence volume of water each year. This system permits no carryover (i.e. where any unused licence volume at the end of the year is lost fro the irrigators account).
Cap	The Murray Darling Basin Ministerial Council Cap on extractions for consumptive users at the level that would have occurred under 1993/94 development conditions and management rules over a long term period of varying climatic conditions [MDBMC, 1996].
Cap Audit scenario	An IQQM that has been configured for the simulation of 1993/94 development conditions and management rules, commencing in 1997/98, to provide a cumulative target for the diversions that would have occurred under Cap conditions. This model uses observed tributary inflows which are updated each year for the annual accounting run.
Cap Share	See “water share”.
Cap scenario	An IQQM that has been configured for the simulation of 1993/94 development conditions and management rules, commencing in 1895, to provide an estimate of the long term average diversions that would have occurred over the last 100+ years under these rules. This model uses simulated tributary inflows which are at CAP levels of development.
coefficient of determination	See “r^2”.
coefficient of mean absolute annual differences (CMAAD)	A comparative statistic developed by NOW to assess the match between simulated and observed annual values for model calibration. Further details are provided in (Appendix E).
coefficient of mean absolute monthly	A comparative statistic developed by NOW to assess the match between simulated and observed monthly values for model calibration. Further

differences (CMAMD)	details are provided in (Appendix E).
continuous accounting	In a continuous accounting system on the un-regulated Barwon-Darling, water users have individual accounts that build up at the beginning of each water year when the Cap share is accredited to their account or when water is transferred in from another irrigators account. Similarly their accounts are reduced by water diversions or by transfers out. There are usually limits on the maximum amount of water that can be used in a water year(s). This system could also be considered an annual account with unlimited and unrestricted carryovers.
NOW	NSW Office of Water former names included NSW Department of Water and Energy (DWE), NSW Department of Natural Resources**,** Department of Infrastructure, Planning and Natural Resources (DIPNR), the Department of Land and Water Conservation (DLWC) and the Department of Water Resources (DWR).
d/s	Downstream.
entitlement	See “water share”.
floodplain harvesting (FPH)	Water obtained by irrigators through pumping or direct inflows of water off the flood plain. This includes water: • Pumped from the floodplain into spare OFS capacity (i.e. during floods from higher up in the catchment), using secondary lift pumps; and • Gravity fed from the floodplain into spare OFS capacity (i.e. during large floods from higher up in the catchment). This water is not metered and hence there is no good quality historical FPH data available.
hot-start	To configure IQQM with the correct boundary or initial conditions (ie, river flows, storage volumes, soil moisture levels and releases for water orders), it is started several weeks before the commencement of the analysis period. The purpose of this is to minimise the effect of initial assumptions on results produced by short term scenario runs, such as the Cap Audit scenario.
irrigator behaviour function	This relates to the irrigator’s area planting decision and the main factors affecting this decision. For example, given a drought period with dry antecedent climatic conditions, low on-farm storage volume and low **Error! Reference source not found.**, an irrigator who plants the same area as in wet years (i.e. years when storages are full) is taking a higher than previous risk. That is, there is an increased likelihood that the irrigator will run out of water supplies unless additional streamflows or

	rainfall occurs.
IQQM	An integrated quantity/quality river basin simulation model developed by DNR since the early 1990's. It is a tool that can be used to investigate water resources management issues in large river basins, with complex combinations of water regulation for irrigation and environmental requirements. It operates on a daily time-step. Further information is contained in the IQQM Reference Manual [, 1998].
irrigators' planting risk	see "irrigator behaviour".
license volume	See "water share".
link	The stretch of river in the model between two nodes. This may or may not represent a real length, noting that a link can be used to separate two processes at the same location.
MDBA	Murray Darling Basin Authority (formerly Murray Darling Basin Commission), a joint interstate/federal commission with responsibility for managing the Murray River system and coordinating water management issues in the Murray Darling Basin.
MDBMC	Murray Darling Basin Ministerial Council, a body composed of the relevant state and federal ministers which oversees the management of the Murray Darling Basin Commission.
ML/d	Units of flow rate, in terms of megalitres (i.e. millions of litres) per day.
node	A model node is used to represent a point on a river system where certain processes occur. The node type identifies the rules and parameters that are used by the model to simulate the relevant processes at a given location.
Officer-in-Charge (OIC) sheets	These sheets record daily storage levels/volumes, rainfall and releases at a major on-river storage. They are called OIC sheets because they are usually filled in every morning by the officer-in-charge at the storage.
on-farm storage (OFS)	On-farm storage, usually referring to a large private storage constructed on an irrigator's property to store water.
OFS airspace	This is the portion of an on-farm storage that is left unfilled by pumping from river and floodplain, ready to capture any future storm runoff from the cropped areas. The exact amount of the airspace is calculated on a farm-by-farm basis, but it is generally a function of surface area of OFS.
pump capacity	The maximum pump extraction rate for an irrigation node (ML/d).

r^2	This is the symbol used in a statistical sense to express the degree of correlation between two sets of data (eg historical data versus model simulations). Its value is always expressed as a decimal less than 1.0, such that the closer its value is to 1.0, then the better the correlation.
rainfall harvesting (RFH)	Water obtained from local rainfall events that are sufficiently intense to generate runoff on the land-holder's property or nearby land. Existing water recycling systems are usually enhanced to catch runoff from the planted and/or developed area of a property. This includes water: • Pumped from the on-farm cropped area or nearby areas into spare OFS capacity (i.e. during localised storm events), using secondary lift pumps; and • Gravity fed from the on-farm cropped area or nearby areas into spare OFS capacity (i.e. during large localised storm events). This water is not metered and hence there is no good quality historical RFH data available.
rainfall-runoff model	see "Sacramento model".
reach	A defined length of river. Usually represented by a number of model links connected together.
regulated river	The section of river that is downstream of a major storage from which supply of water to irrigators or users can be regulated or controlled.
residual catchment	This is an ungauged catchment existing between known upstream and downstream river gauges. It can include ungauged creeks or rivers as well as areas of land adjacent to the main-stream between the gauges. The outflow from this catchment is estimated using a combination of: • the difference between the flow of upstream and downstream gauges, taking into consideration river losses and irrigation extractions; and • a correlation with nearby gauged tributaries, taking into consideration differences in catchment characteristics and rainfall distribution.
RMC	The River Management Committee of the unregulated sections of the Barwon-Darling. Set up in 1999 to introduce the environmental commence to pump thresholds for the river.
Sacramento model	The Sacramento rainfall-runoff model is used to estimate long term streamflows at gauging stations where there are short period of records or gaps in the flow data. The model tries to represent the physical processes that impact on runoff; it uses local rainfall and evaporation data as well as catchment details. The model is calibrated to reproduce the short term observed flow at the gauging station. A long-term streamflow sequence can then be generated by inputting the long-term rainfall and evaporation.
tributary	An river that flows into a larger stream or water body.

unregulated river	A river with no major storages by which flows are regulated. All rivers represented in the Barwon-Darling IQQM are unregulated except for a small section of Mehi River which supplies “regulated” water to one large Barwon-Darling irrigator.
u/s	Upstream.
water share	Also referred to as “entitlement”, “quota” or “license volume”. This is the total amount of licensed water an irrigator has and remains static over time. For the 2006/07 water year the volumes were severely reduced (i.e. about 2/3^{rds}) when the continuous accounting was introduced on the Barwon-Darling.
water year	A continuous period (usually 12 months) starting from a specified month for water accounting purposes. Since 2000, the water year starts on the 1st of July for the whole Barwon-Darling Valley. Prior to that date the water year for the reaches upstream of Walgett started on 1st of October.

1 Introduction

1.1 BACKGROUND TO BARWON DARLING IQQM

Prior to 1986, most of the investigations with reference to water policy and water sharing initiatives in NSW river valleys including the Barwon-Darling Valley were examined through monthly time-step computer models. The limitations of the monthly models in water resource investigation were recognized, and in 1986 a daily time step modelling software called WARAS model [Lyall & Macoun, 1986] was developed by a consultant for the then Department (Department of Water Resources – DWR), and applied to one of the River Valleys in NSW. Building on the concepts in the WARAS model, DLWC proceeded to develop a more generalised and complete modelling tool, in the form of an Integrated Quantity and Quality Model (IQQM). Since 1993, the IQQM software has been used in a number of river valleys in NSW, and the Barwon-Darling Valley was one of the first river valleys chosen for the implementation of IQQM.

The initial Barwon-Darling IQQM was developed for the valley in 1993 and was flow calibrated and validated [DLWC, 1995] with the data from 1987-1992 This period of data was the most lengthy for which streamflows and some irrigation diversion data was available at that time. Although the initial IQQM was able to simulate the flows satisfactorily, it only provided poor irrigation diversion estimates. These poor estimates were attributed to incomplete irrigator records, and to the model's inability to satisfactorily simulate the irrigator behaviour of the large individual irrigators with on-farm storages.

With the advent of the Murray-Darling Basin Ministerial Council (MDBMC) cap and NSW river flow objectives, in the mid-90s, IQQM became an important tool to study the effect of a number of water policy alternatives. In 1997, the Barwon-Darling River Management Committee (RMC) decided to use the Barwon-Darling IQQM to investigate the effect of environmental flow rules on river flow. Arising from these needs, a series of upgrades were made to the initial IQQM, in order to enhance its capability. These upgrades, apart from the general upgrades of better representing the processes involved, were also targeted towards modelling valley specific requirements such as better representation of on-farm water management by the unregulated irrigators of the valley.

In December 1999, the RMC established a reference group (IQQM Reference Group) to oversee and assist with the development of an upgraded model for the Barwon-Darling River. Previously the RMC had established a History of Development Project to reliably define the history of development of on-farm infrastructure for 13 years from the winter of 1987 to the summer of 2000. See Section 2.5 for details. The Barwon-Darling IQQM was subsequently upgraded to the then latest version (No. 6.54.1899) with the aim to address the following issues:

- representation of individual major irrigators;
- better estimates of tributary inflows;

- improved calibration of river losses;
- improved representation of flow paths;
- better conformation with the generic IQQM; and
- improved replication of end of system (Wilcannia) flows.

The following tasks were undertaken to upgrade the model:

- the collection of improved irrigation data;
- representation of individual irrigators;
- revision of tributary flows, residual catchment inflows and streamflow losses;
- generation of daily synthetic evaporation for 100 years;
- re-calibration of irrigators to reflect improved crop area, crop mix and diversion data;
- include an individual planting behaviour for each irrigator;
- improve the representation of irrigated area between summer and winter crops; and
- include separate soil moisture modelling for each different crop types and fallow fields for each individual irrigator.

The following further upgrades to the Barwon-Darling model have occurred since the upgrade to version 6.54.1899:

- the coverage of the model was extended downstream from Wilcannia to Menindee
- the IQQM version was upgraded to 6.54.1901 to incorporate the 2006 revision of the water management access rules for irrigator on Barwon-Darling;
- modification of Menindee Lake inflows [MDBA, 2008];
- the IQQM version was upgraded from DOS to GUI version 7.67.19
- all inflows to system were upgraded and extended to 1895 – 2009 using the latest appropriate models; and
- re-calibration of irrigation demand using extended data available from 1995 to 2005.

A full description of IQQM, including details about model structure, algorithms, processes that can be modelled and assumptions are described in the IQQM Reference Manual [DLWC, 1998^{b}]. A simplified outline of IQQM and its principal features that are utilised in the Barwon-Darling IQQM are described in Appendix I .

1.2 AIM OF IMPLEMENTING IQQM IN THE BARWON DARLING RIVER

The IQQM was implemented for the Barwon-Darling Valley from Mungindi to Menindee. The aim of this implementation was to establish and define a tool that is capable of simulating daily hydrologic processes over approximately a 100 year period. It was intended that the model would be capable of the following:

- reproducing river system behaviour;
- reproducing daily streamflows at key locations for assessment of environmental flow rules. Details of the three primary and six secondary locations are given in Section 3.2.1;
- reproducing irrigator behaviour;
- analysing the impacts of alternative irrigation development scenarios. Impacts are normally assessed by the comparison of streamflows, irrigation diversions and cropping areas, etc produced by alternative scenarios;
- developing and analysing the impacts of proposed environmental flow and river operation rules to meet specific river flow objectives;
- estimating the long-term average annual diversions for the Barwon-Darling Valley under a 1993/94 Development Conditions scenario, i.e. *the Cap scenario*; and
- estimating the annual irrigation diversions using 1993/94 development conditions for comparison with observed irrigation diversions. This model uses observed inflows, climatic and various management data and it runs from 1997 to date. These scenarios are required for the MDBMC Cap auditing process.

1.3 AIMS AND OBJECTIVES OF THIS REPORT

This Barwon-Darling Cap Implementation Summary Report is of a highly technical nature and is intended to be used as a technical reference document. The aim of this report is to summarise the model set up, detail the calibration and the 1993/94 configuration. The report will be presented to the Murray-Darling Basin Authority (MDBA) in order to obtain approval of the model for Cap auditing purposes.

1.4 SCOPE OF THIS REPORT

The scope of work covered in this report includes:

- description of the Barwon-Darling River Valley (Chapter 2);
- configuration and calibration of the Barwon-Darling IQQM (Chapter 3);
- configure, validate and simulate the long term 1993/94 Cap scenario (Chapter 4);
- configure and simulate the short term 1993/94 Cap Audit scenario (Chapter 4);
- outline of model improvement plans (Chapter 5);
- details of the climatic and streamflow stations used in the model (Appendix A);
- sample of the data collected for each ‘Major’ Irrigator (Appendix B);

- details of the 1993/94 Cap development conditions and management rules (Appendices C, F, H and I);
- node link diagram and a summary of the model configuration (Appendix D);
- a description of the quality assessment guidelines (Appendix E);
- reach calibration results at the completion of planted area (Appendix G); and
- some background to modelling the planting decision (Appendix J);

1.5 QUALITY ASSURANCE

A consistent set of quality assessment guidelines (Appendix E) has been used in this report to evaluate and report on the main features of the model's calibration and validation. The general meanings attributed to the quality ratings are expressed in relation to the confidence that the model can replicate historical flows, diversions, storage behaviour and planted areas as follows:

- very high confidence;
- high confidence;
- moderate confidence;
- low confidence; and
- very low confidence

The quality of the observed data is also considered. The climatic representativeness of the data is assessed based on the period of calibration.

1.6 PREVIOUS REPORTS

A number of reports exist, dealing with the development of IQQM and its implementation in the Barwon-Darling River. These reports include:

- work on the initial Barwon-Darling IQQM development which is the subject of a separate report [DLWC, 1995];
- work on the generation of effluent inflows from Border Rivers (Little Weir and Boomi Rivers, and Gil Gil Creek) which is also the subject of a separate report [DLWC & QDNR, 1999];
- *IQQM Reference Manual* [DLWC, 1998^b]: which describes the technical details of IQQM;
- Water Management Plan [DWR, 1992] for the north-west flows which describe a basis for sharing unregulated flows between irrigators, environment and other extractors;

- re-calibration and development of the 2000 Barwon-Darling IQQM which is the subject of a separate report [DNR, 2006]; and
- work on the extension from Wilcannia to Menindee of Barwon-Darling IQQM which is the subject of a separate report [DLWC, 2008].

2 The Barwon Darling River Valley

2.1 CATCHMENT FEATURES

The Barwon-Darling Valley represented by the IQQM is shown in Figure 2.1. Along its course, the Darling River takes several names i.e. Dumaresq, Macintyre, Barwon and finally the Darling. The upstream end of the Barwon River is commonly recognised as being the confluence of the Weir River and Macintyre River, just upstream of Mungindi. For the Darling River the confluence of the Barwon and Culgoa Rivers is recognized as its starting point

The Barwon-Darling River traverses the western plains of NSW, and extends from near Mungindi in the north to Wentworth in the south. In the Barwon-Darling IQQM only the unregulated section of the River from Mungindi to Menindee is represented.

The Barwon-Darling River has nine principal tributaries namely Barwon (from Border River Catchment), Gwydir, Namoi, Castlereagh, Macquarie and Bogan Rivers in NSW, while the Bokhara and Culgoa Rivers (from Condamine-Balonne River Catchment), and Moonie Rivers provide inflows principally from Queensland. There are also three intermittent tributaries namely the Narran, Warrego and Paroo Rivers that make contributions to various degrees. Over the last fifty years major storage construction and irrigation development on most of the principal tributaries has resulted in some degree of flow regulation and reduction in flow. The only tributaries to not experience significant development are the Castlereagh, Bogan, Warrego and Paroo Rivers.

The river has five major systems of anabranches:

- effluents which leave the Border River system and returning to the Barwon-Darling system downstream of Mungindi: namely the Boomi River, Little Weir River and Gil Gil Creek;
- Ballone, Barnaway and other effluent creeks which leave the river upstream of Mogil Mogil and rejoin downstream;
- Grawan Creek which leaves the river upstream of Collarenebri and rejoins downstream;
- Cato, Tarrion and other effluent creeks which leave the river upstream of Brewarrina and rejoin downstream;
- Talyawalka Creek (i.e. middle section of Talyawalka Creek on the left bank of the Darling River), which leaves the river upstream of Wilcannia, and carries up to a third of total flood flows, most of these flood flows rejoins the Darling River downstream; and
- Talyawalka Creek and Menindee Floodplain the continuation of Talyawalka Creek (i.e. lower section) beyond point where most flow returns to Darling River. Flows pass down this system before bifurcating into Teryaweynya Creek or continuing down Talyawalka Ck and rejoin Darling River below Weir 32. The Teryaweynya Creek and associated Lakes are a terminal system.

The lower segments of the river are also characterised by the presence of a number of lakes, the largest of these being Lake Wongalara and Lake Poopelloe. Together with their interconnected shallow depressions these floodplain storages are capable of holding large quantities of water during major floods. The stored water is either returned to the river or lost through evaporation and seepage.

Large scale agricultural development is limited in this arid region with irrigation development of about 45,000 hectares, situated along the river system mostly located between Mungindi and Louth. Because flows in the Darling River are not regulated, large scale irrigation developments (i.e. irrigated areas in excess of about 100 hectares) are normally supported by water supplies held in privately-owned on-farm storages. By 2004/05 OFS capacity was about 290,000 ML.

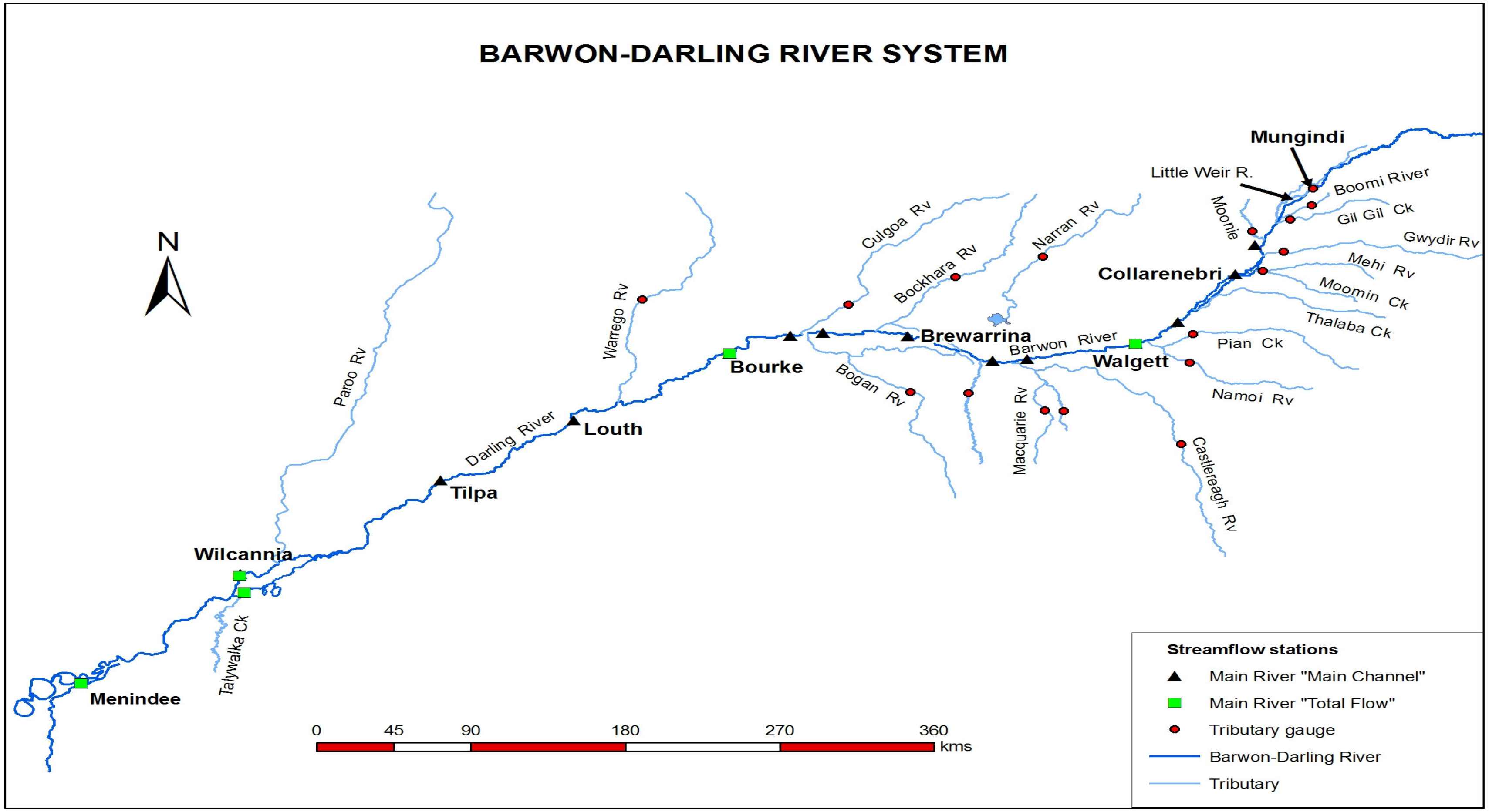


Figure 2.1 Barwon-Darling River System

2.2 WATER MANAGEMENT SYSTEM

2.2.1 Overview

Although the Barwon-Darling River between Mungindi and Wilcannia is unregulated (in the sense that users do not order water from a headwater storage), access to river flow is controlled for the vast majority of users through the granting of licences (or entitlements) that specify the amount and conditions under which users can access the river flow. Irrigation, which is the principal user, has access conditions which specify river flow thresholds at specific stream gauges under which an individual is permitted to pump.

In addition to the above licensing controls on users, their access to flows events is also controlled through the development of management plans which can suspend or limit diversions for specific lengths of time.

The data requirements for modelling the components of the water management system are discussed below.

2.2.2 Stream Gauges

An extensive network of stream gauging stations measures the flows throughout the catchment, both on the main river, effluents and tributary streams. Of these, a number of gauges will need to be selected to define the tributary inflows to the Barwon-Darling. Gauges on the main river are also required for calibration purposes (i.e. used to derive losses and flow routing parameters for each river reach).

The following criteria were used to select an appropriate sub-set for calibration of main-stream flows:

- enough sites to limit the length of river reaches;
- sites upstream and downstream of key features such as tributary inflows and effluent outflows;
- sites with good quality records to cover the intended calibration period, with a minimum number of missing periods; and
- sites that are used to define access for irrigation.

2.2.3 Storages

Although, 15 weirs have been constructed on the Barwon-Darling with total capacity in excess of 100,000 ML, they have not been represented in IQQM. This is because their purpose is only to supply town water supplies and riparian users located in their weir pools. They have no impact on streamflows and irrigators other than their routing and evaporation impacts which have been explicitly modelled.

2.2.4 Town Water, Stock and Domestic, Riparian and Industrial Water Requirements

Although there are 8 towns and villages extracting water from the Barwon-Darling, none of their diversions are directly or explicitly modelled. With a combined population of less than 10,000 and an estimated annual usage of between 1,000 and 2,000 ML, their usage has been included with stream losses. This is because their consumption is relatively small when compared to the irrigation diversions and streamflow loss volumes (i.e. one of the larger irrigators has a daily pump capacity that exceeds a 1,000 ML/day and the observed loss of streamflow between Bourke and Wilcannia during the 1971 flood exceeded 2,000,000 ML). Also the lack of available diversion data limits the ability to model town water extractions.

Unlicensed riparian or basic right usage (water front land holders who divert small volumes for non commercial purposes), licensed stock, domestic and industrial requirements are all **not** modelled for similar reasons as town water supplies and their usage has been included with stream losses.

2.2.5 Irrigation

Irrigation in the Barwon-Darling Valley is dominated by the growing of cotton using flood / furrow irrigation methods. These large individual properties rely on large scale on-farm storages to satisfy their crop's water needs.

Data required for the modelling of irrigation diversion and demand includes:

- historical water use data;
- time series of rainfall and evaporation;
- licence conditions;
- pump capacities; and
- on-farm storage details including:
    - type of storage (lagoon or turkeys nest);
    - storage volume/surface area relationship;
    - storage filling and emptying rules (to minimise evaporation losses);
    - volume in storage.

Sources of this data and methods of checking are described in Section 2.5.

2.2.6 Water Licensing System

On the Barwon-Darling the water licensing system has undergone a series of changes over the years as NOW and its predecessors has sought better methods of sharing water resources among competing users and the environment.

In July 1991, the then Department proposed a new water licensing policy for the Barwon-Darling [DWR, 1991], this policy sought to define:

- four classes of irrigation entitlement on the unregulated Barwon-Darling River;

- access for classes based on river sections (reach) and associated commence to pump threshold; and
- a replacement of the then limitation on irrigation licences which was based on maximum cropped area to maximum annual volume of water or an annual entitlement or quota (i.e. volumetric conversion).

Irrigation Entitlement Classifications

A Class - licenses up to 20.5 hectares with pump capacity not exceeding 5 ML/day and any existing A class entitlements to retain status.

B Class - licenses up to 162 hectares with pump capacity not exceeding 80 ML/day and any existing B class or with B class pumping conditions to retain status.

C Class - generally authorised greater than 162 hectares and/or pump capacity exceeding 80 ML/day and/or entitlement with special conditions.

D Class - generally licences approved since the first “embargoing” of licences in the early 1980’s. These licences may only be used when NOW announces that flows are sufficient to meet all other users. To date NOW has never declared access available for this class of irrigation.

Access Conditions

These ‘new’ pumping conditions were imposed to protect essential river flows for stock, domestic and town water supplies and to ensure these essential flows were passed along the whole river system. The basis of the ‘new’ pumping conditions was to divide the Barwon-Darling into sections or reaches and to establish “commence to pump” thresholds (i.e. flow thresholds) at both upstream and downstream ends of their respective river reach. Eight reaches were defined and pumping thresholds for each class of irrigation licence were also established.

Apart from these river flow conditions, some of the irrigators have established rosters which share flows during those times when there is insufficient volume available for all irrigators to simultaneously access flows. In the Brewarrina to Louth reach, the Bourke Water Users Association has established a roster which shares flow proportional to an individual’s percentage of total irrigation entitlement volume in the reach.

In 2000, the reach delineations were revised and increased from 8 to 13 reaches. Also higher pumping thresholds based on environmental flow concept were introduced. A summary of these reaches and access conditions by class are shown in Appendix C: Table C.0.2.

Entitlement Volumes

Following studies undertaken by the then Department to account for differing evapotranspiration and evaporation rates (i.e. from on-farm storages) and for differing soil types, in 1991 irrigation entitlements were converted from an area basis to volume. Conversion factors based on location were proposed. These factors, based on the above river reaches, varied from 15 ML/ha for the Mungindi Weir to Pressbury Weir reach to 20 ML/ha for the Wilcannia Weir to Lake Wetherell reach.

In 2006, entitlement volumes were altered from an annual basis, which had no carryover provisions to an annual increment with unlimited carryover, with an annual limit on usage equal to the previous annual entitlement volume. The annual increment is a substantial reduction (about two thirds) when compared to the old annual entitlement.

Summary of 1993/94 Conditions

Reach summaries of these entitlements and access conditions by class, which were applicable in 1993/94 are shown in Appendix C: Table C.0.1.

2.2.7 River Flow Requirements

Even in an unregulated river system a number of river flow requirements must be met. These requirements may be necessary for the purposes of maintaining the quality of the riverine environment, (i.e. algal suppression and fish migration). These requirements may take the form of long-term flow targets at locations along the river, such as the environmental flow requirements which set the licensing flow thresholds above. Alternatively these targets could be variable and dependent on prior flow conditions or river health, etc.

The Unregulated Flow Plan for the North-west [DWR, 1992] which was adopted in 1992 set out such operational flow targets and triggers for their implementation, the areas of application and the basis for sharing of unregulated between irrigators of the north-west. Details of the procedures for implementing the plan and the model developed for forecasting flows is available from a report [Water Studies, 1993].

The Unregulated Flow Plan, which has been implemented on a few occasions, is not modelled in either the Cap or Current scenarios of Barwon-Darling IQQM or any of the tributary IQQMs. However the Plan’s impact (i.e. an embargoing of pumping on those days when it was declared) is modelled in the Cap audit scenario model (i.e. using hindsight information available). Overall the impact on irrigation diversions of not representing the Plan in an IQQM is small from a long term perspective but can be critical in annual auditing of Cap performance.

Ensuring water for critical human needs during the recent drought (i.e. since 2001) lead to two lengthy pumping embargo periods. These embargoes effectively prevented irrigators from diverting any water for crops in order that sufficient volumes reached Menindee Lakes. Although these embargoes had quite profound effects in stopping irrigators in diverting any flows in two years (i.e. 2002/3 and 2006/7) they were largely measures in response to emergency conditions and have not been modelled in either the Cap or Current scenarios of Barwon-Darling IQQM . However these embargoes are modelled in the Cap audit scenario model.

2.3 CLIMATE DATA

This chapter discusses the data used for setting up of IQQM for the Barwon-Darling River Valley. The data required can be grouped under the following major headings:

- Rainfall;
- Evaporation;
- Streamflow; and
- Irrigation information.

2.3.1 Rainfall

Rainfall data is required by the model for its soil moisture updating module and for computing the contributions to on-farm storage volumes and river reaches due to rain over the water surface. Daily rainfall data was obtained from the Bureau of Meteorology.

Daily data from seven rainfall stations was used to represent rainfall at different places within the system. The rainfall stations used are shown, together with the average annual rates, in Figure 2.2. The criteria for the selection of the rainfall stations were:

- continuity of data;
- availability of long term records; and
- availability of a suitable nearby station that could be used to substitute missing data and disaggregate accumulated records.

Further statistical information for the 7 rainfall stations is included in Appendix A. The statistical information supplied includes:

- tables of mean and median, monthly and yearly rainfalls; and
- time series and ranked plots of annual rainfalls.

The information shows that rainfall in this arid region exhibits very little seasonal variability. The maximum seasonal variability in average monthly rainfalls, of only 40 mm, occurs between summer and winter at Mungindi. At Menindee there is virtually no seasonal trend. There is a progressive decrease in annual rainfalls from Mungindi (504 mm/yr) to Menindee (240 mm/yr). The distribution of annual rainfalls across the Barwon-Darling is very similar with the lowest rainfall years being only about 10 – 20 % of the wettest years at all stations.

Table 2.1. Rainfall stations used for model calibration

Location	Station No	Data Availability	Used for all processes in the River Reach
Mungindi Post Office	52020	1887 Date	Mungindi to Boomi River confluence on Barwon River
Mogil Mogil (Benimore)	52019		Boomi River confluence to Mogil Mogil on Barwon River
Collarenebri Post Office	48031	1884 - Date	Mogil Mogil to Walgett on Barwon River
Walgett Post Office	52026	1878 - Date	Walgett to Macquarie River confluence on Barwon River
Brewarrina Post Office	48015	1872 - Date	Macquarie River confluence on Barwon River to Brewarrina
Bourke Post Office	48013	1871 - Date	Brewarrina to Louth on Darling River
Wilcannia Post Office	46043	1879 - Date	Louth to Wilcannia on Darling River
Menindee Post Office	47019	1876 - Date	Wilcannia to Menindee on Darling River

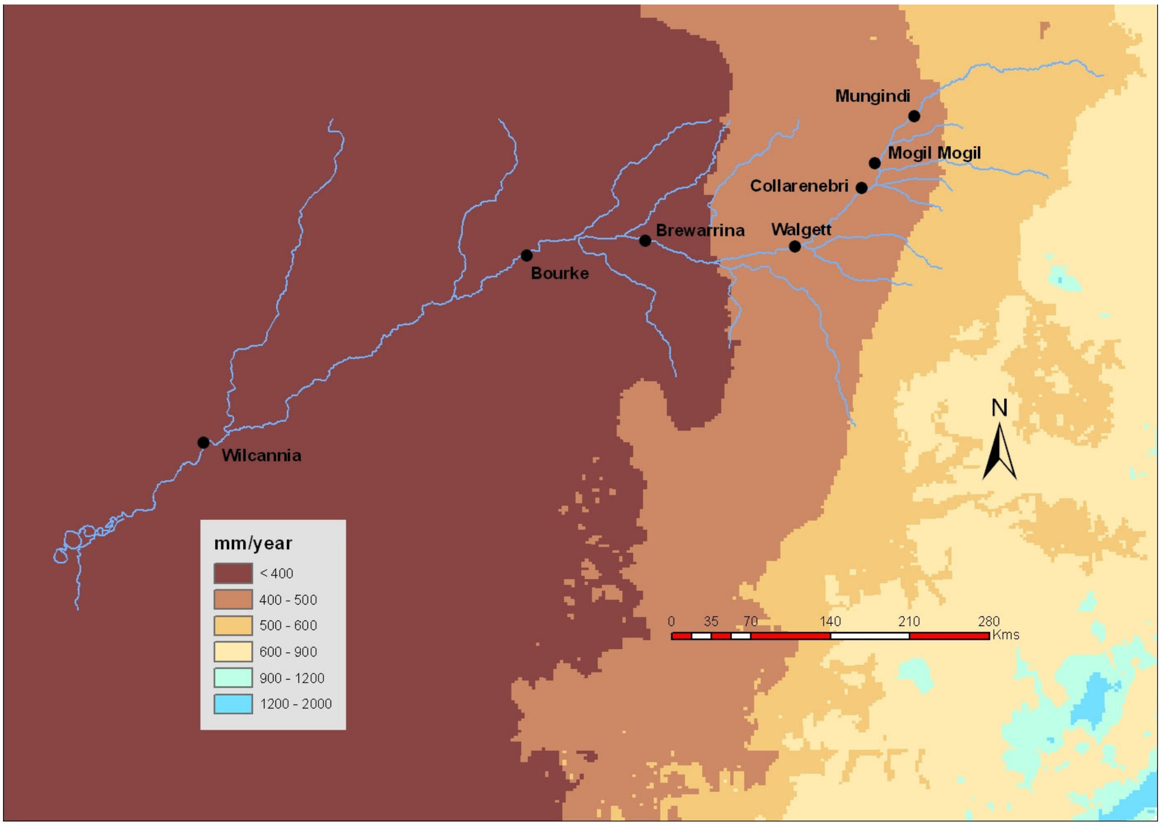


Figure 2.2 Average Annual Rainfalls on the Barwon-Darling

2.3.2 Evaporation

Evaporation data is used in IQQM to estimate the evapotranspiration from crops and for computing evaporation losses from on-farm storages and from river reaches.

Of the available evaporation stations (Class A Pan) in the valley, the following criteria were used to select an appropriate sub-set for use in the Barwon-Darling IQQM:

- adequate representation of spatial variability of the evaporation;
- availability of long term records, it should be noted that unlike rainfall data, evaporation data has only been regularly recorded for the last 30 years or so;
- continuity and quality of data; and
- availability of a nearby rainfall site that could be used to generate long term evaporation data.

Based on these criteria, 3 evaporation stations (Walgett, Bourke and Menindee) were selected to represent the spatial evaporation distribution in the Collarenebri to Wilcannia reaches of the Barwon-Darling. Evaporation sites located outside of the catchment had to be used to represent the evaporation in the Mungindi to Collarenebri reach. Evaporation data from Boggabilla (53004), Moree (53048) and St. George (43053) was utilised to produce a weighted mean value for Mungindi. The weighting was based on distances to cropping areas with the final weighting adopted as

Mungindi = 0.5* Boggabilla + 0.5*(Moree + St. George)

Information on all four sites used in IQQM is shown in Table 2.2 while Figure 2.3 shows the annual Class A Pan evaporation rates across the Barwon-Darling.

Further statistical information for the 4 evaporation stations is included in Appendix A. The statistical information supplied includes:

- table of mean monthly rates; and
- time series plots of annual evaporation.

Table 2.2. Evaporation stations used for model calibration

Location	Station No	Average Annual Observed (mm/yr)	Used for all processes in the River Reach
Mungindi(*)	053020	1900	Mungindi to Collarenebri on Barwon River
Walgett	052026	1765	Collarenebri to Brewarrina on Barwon River
Bourke	048239	1825	Brewarrina to Louth on Darling River
Menindee	047058	2140	Louth to Menindee on Darling River

* weighted mean of Boggabilla(53048), Moree (53048) and St George (43053).

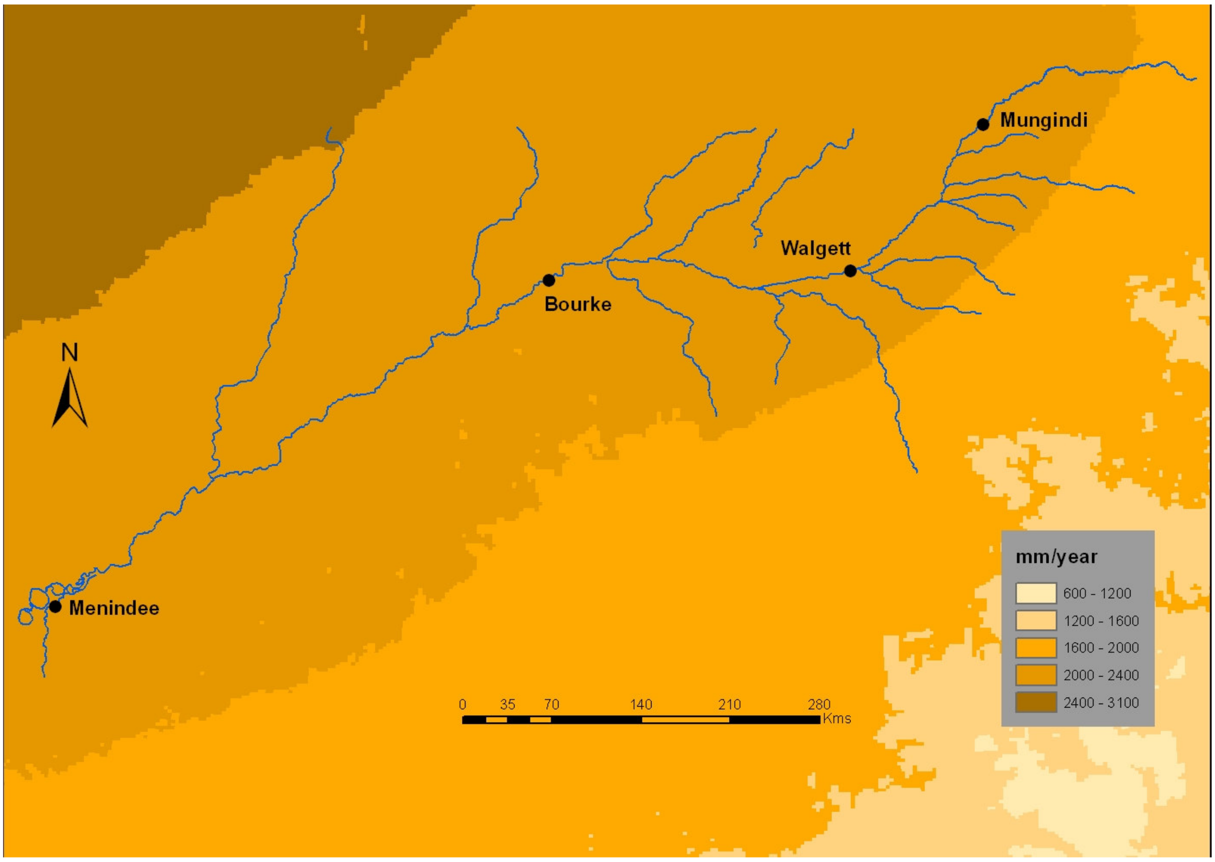


Figure 2.3 Average Annual Evaporation Rates on the Barwon-Darling

2.3.2.1 Evaporation in IQQM

Daily Class A pan evaporation rates are converted to the evaporation losses from river reaches and large on-farm storages (i.e. open water surfaces) through multiplication of pan evaporation data (i.e. observed data) by a factor or coefficient (K_p). This coefficient is dependent on wind and humidity conditions, in the absence of any field data; a K_p of 0.88 was applied.

For the calculation of evapotranspiration from reference crop a different pan coefficient (K_p) is required. A coefficient value of 0.7 was adopted and like the open water coefficient, it also reflects the location and conditions surrounding the pan. When multiplied by the pan evaporation data it provides estimates of the potential evapotranspiration of the reference crop [Doorenbos, 1984].

A sequence of daily pan evaporation data covering not just the calibration period (1970 – 2005) but the full period of simulation (1895 – 2009) was needed in IQQM. As there is insufficient data available it was necessary to synthesise evaporation data to obtain the length of record needed. Also because of the frequent large errors in observed data, especially during winter, only generated data was used in IQQM. This overcomes the problem of calibrating with one quality of data (i.e. in this case actual observed evaporation readings) and then undertaking long term simulations with another quality of data (i.e. using generated evaporation data for the majority of the study).

The procedure adopted for synthesising long term pan evaporation considers mean monthly pan evaporation and the variation of pan evaporation as a function of the number of rain days in each month. The procedure adopted was based on mean monthly pan evaporation instead of daily evaporation because of the relatively large errors or variations frequently seen in daily evaporation readings. The monthly values are more likely to be reasonable, since these errors in the recorded daily values are generally random and can be expected to compensate over a month. For each month of the year the procedure for synthesising daily evaporation followed by the model was as follows:

1. compute the mean monthly evaporation and standard deviation;
2. derive regression relationship between monthly evaporation and number of rain days in the month;
3. compute correlation coefficient for regression relationship;
4. estimate monthly evaporation values for period of simulation based on historical rain day data and using the regression relationship together with a random component which is a function of the standard deviation and the correlation coefficient; and
5. disaggregate the monthly values into the daily data taking into account whether the day is rain or non-rain day.

The difference in daily evaporation rates, between the observed and the synthesised using the adopted procedure are shown in Figure 2.4.

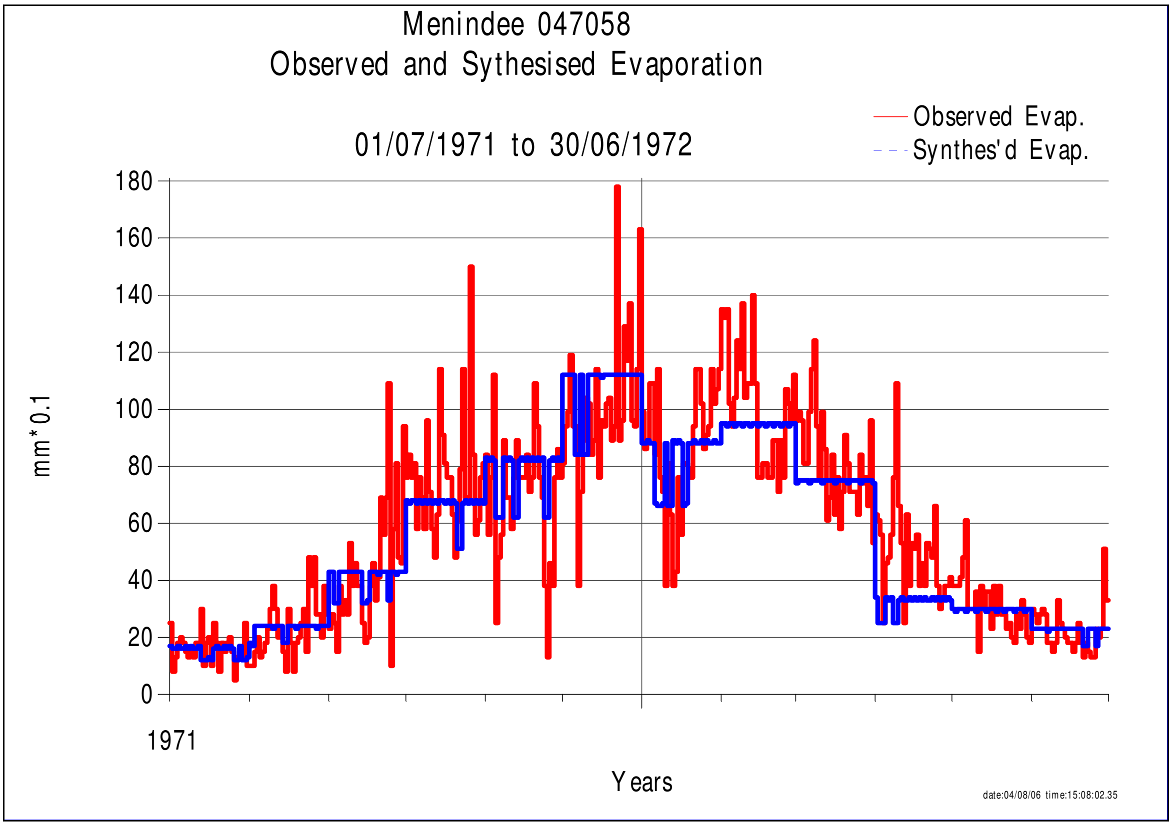


Figure 2.4 Comparison of Observed and Synthesised Daily Evaporation

2.4 STREAMFLOW

In the calibration of IQQM, observed streamflow data was required:

1) at points along the Barwon-Darling River (i.e. main river) to confirm that flow calibration (i.e. routing, lag and transmission loss, etc; See Section 3.2) has been able to reproduce observed flows; and

2) to define 'tributary' inflow into the Barwon-Darling.

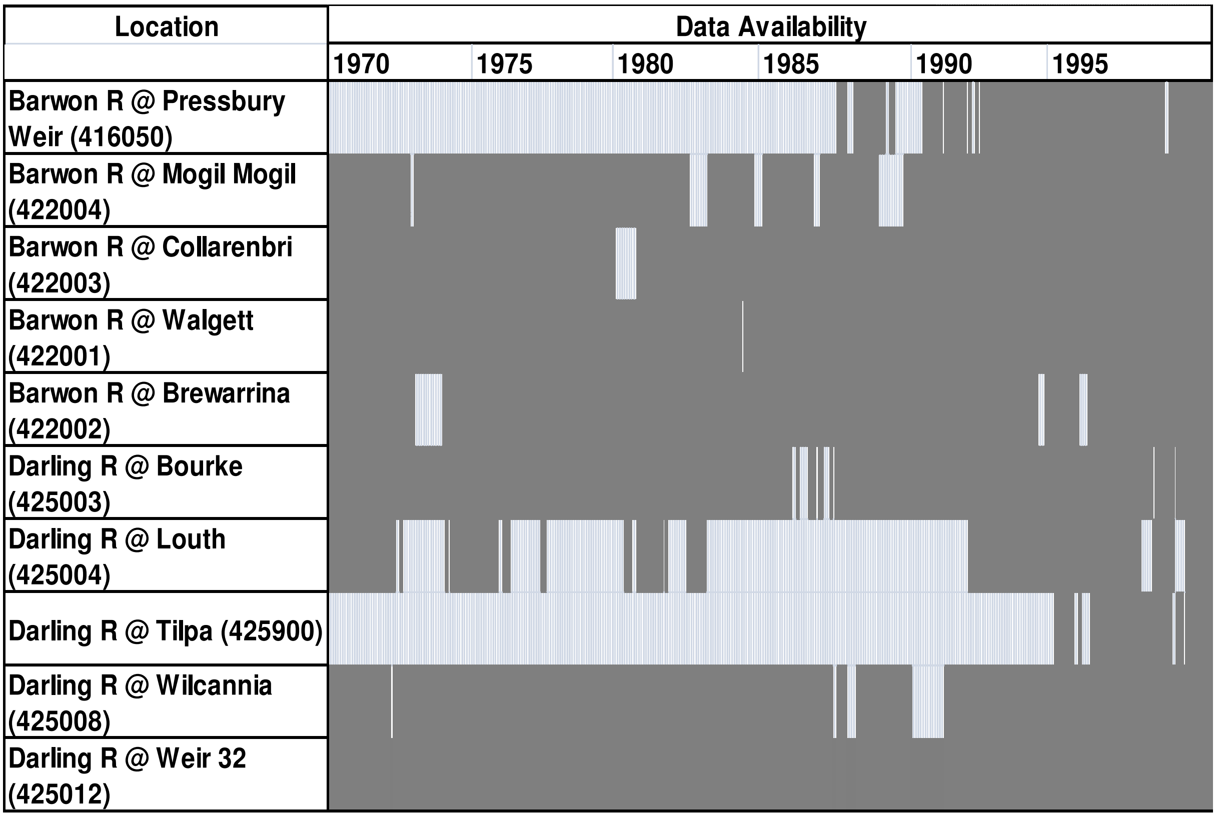
NOW maintains a stream gauging station network throughout the Barwon-Darling and its tributaries. All of the streamflow data used in the calibration was extracted from the NOW's HYDSYS database. A full listing of all the potentially useful streamflow gauges used in the development of the Barwon-Darling IQQM is shown in Table.A.0.3. Also shown in the table is the purpose that each gauge was used for.

2.4.1 Availability

There are 15 ‘main river’ streamflow gauges which are potentially useful for flow calibration. However, only 10 of the gauges are listed in Table.2.3 because the remaining 5 gauges virtually have no data available to undertake any worthwhile flow comparisons as they were established in mid 1999. Even for the 10 ‘useful’ gauges there is insufficient data to undertake both flow calibration and validation at Pressbury and Tilpa. The locations of all the gauges are shown in Figure 2.1.

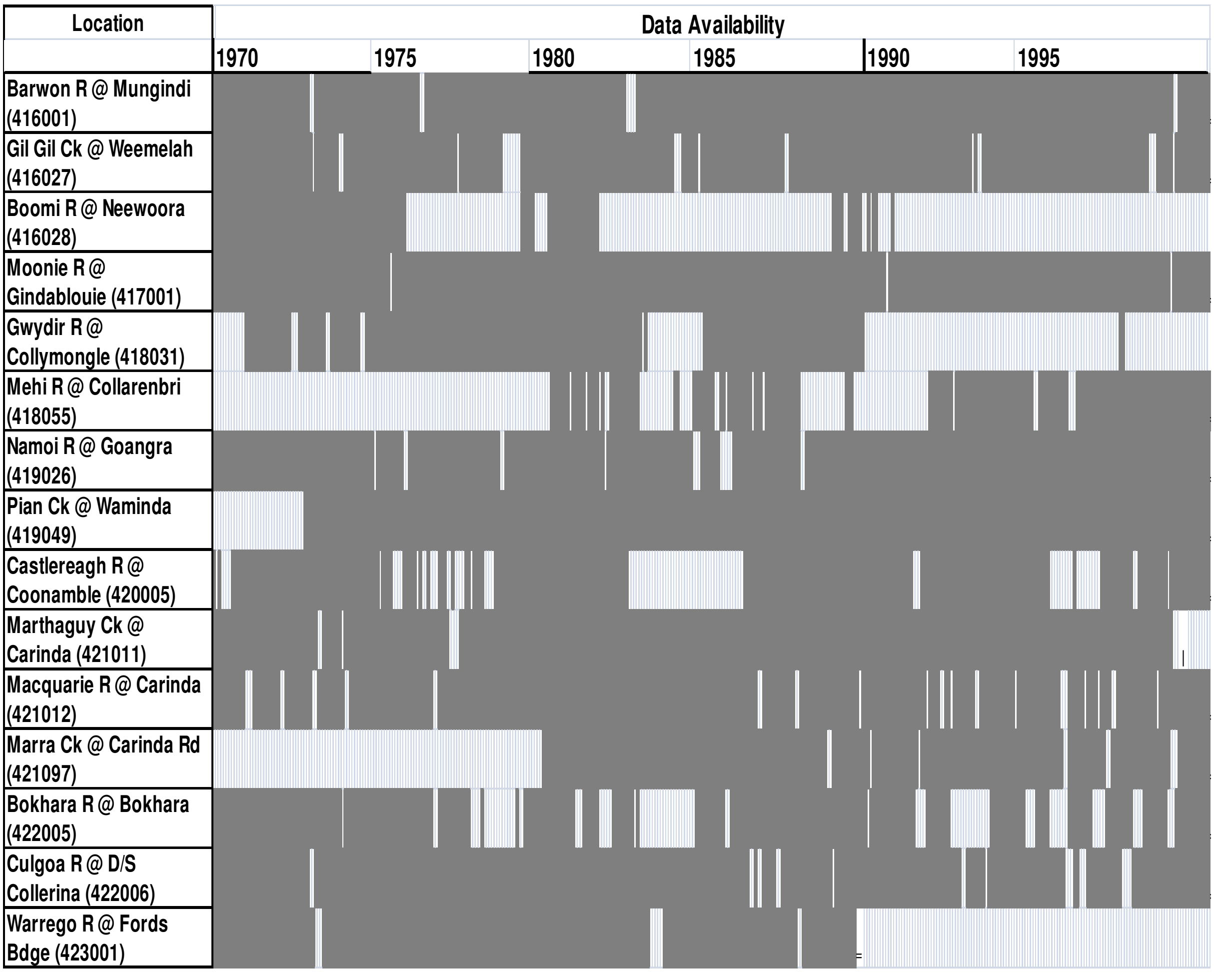
As shown in Table.2.3 there is some missing data, no attempt was made to fill those gaps for streamflow statistics purposes, as it is considered inappropriate to compare simulated flows with estimated data.

Table.2.3. Data available for ‘Main River’ Streamflow stations



There are 17 gauges located on tributaries that inflow into the Barwon-Darling system. These ‘tributary’ gauges where selected on the basis of there location, being the nearest available ‘tributary’ gauge to the confluence of the Barwon-Darling. The data available from the ‘tributary’ gauges is shown in Table 2.4. For streamflow calibration purposes any missing data from these gauges was filled using correlation techniques from nearby gauges.

Table 2.4. Data available for 'Tributary' Streamflow stations (1970-2000)



2.4.2 Reliability

The collection of time series data by NOW is quality accredited to ISO 9000. This, the appropriate Australian Standard, covers the collection of discharge measurements (i.e. instrumentation, water level measurements and gauging, etc) and the processing to produce estimates of daily flow.

Most gauging stations have a gauging undertaken every 2 to 4 months on average and have 'controls' which are termed 'stable'. As most station also have their rating tables (i.e. water level height to discharge relationship) revised reasonably frequently then the accuracy of streamflow measurement is as good as possible, certainly within +/- 5% for the majority of flow range. However, at very low flows (i.e. approximately < 10 ML/d) and also at very high flows (i.e. overbank flows) there can always be problems with the consistency of the height to discharge relationship. At very low flows the collection of debris or algal growth at the control can affect the relationship. Similarly, at very high flows the different behaviour of floods caused by changes in vegetation growth and land uses can also lead to relatively large differences in flow measurements. Although, streamflow on Barwon-Darling are reliably measured, a systematic problem was discovered with the water balance calculations at many of the gauges. These problems only occurred during significant flood events which although they occur very infrequently, are in terms of total volumes, very significant.

Table.2.5 shows the water balances undertaken at each gauge. Two periods of flow were considered, the 1971 flood event and a 'low' flow period during 1980. For each period the following comparisons, with observed data, were undertaken at each gauge:

- the sum of all upstream tributary inflows, and
- the sum of all inflows into the reach above the gauge, this includes the flow at the next upstream 'main river' gauge as well as any tributary inflows within the reach.

As there is no EOS guage at Menindee, statistics were not included in Table.2.5.

Table.2.5. Water Balance at Streamflow stations

Details of Gauging Stations and contributions	Volume: 1971 Major Event (19/07/70 – 16/07/71)		Volume: 1980 Low Flows (15/01/80 -17/12/80)	
	GL	% of Obs. Reach Gauge	GL	% of Obs. Reach Gauge
Total Tributary Inflow above Mogil Mogil	3151	144%	129	109%
Flow @ Mogil Mogil (422004)	2192	100%	122	100%
Total Tributary Inflow above Collarenebri	3673	92%	166	-
Inflows into Mogil Mogil – Collarenebri Reach (1)	2714	68%	159	-
Flow @ Collarenebri (422003)	3918	100%	(2)	
Total Tributary Inflow above Walgett	6136	82%	213	119%
Inflows into Collarenebri – Walgett Reach (1)	6468	86%	204 (3)	114%
Flow @ Walgett (422001)	7496	100%	179	100%
Total Tributary Inflow above Brewarrina	7093	95%	279	115%
Inflows into Walgett – Brewarrina Reach (1)	8453	113%	245	101%
Flow @ Brewarrina (422023)	7486	100%	242	100%
Total Tributary Inflow above Bourke	8845	102%	310	134%
Inflows into Brewarrina – Bourke Reach (1) (Walgett – Bourke)	9238 (10,205)	107% (118%)	273 (276)	118% (119%)
Flow @ Bourke (425003)	8662	100%	231	100%
Total Tributary Inflow above Louth	8959	127%	315	158%
Inflows into Bourke – Louth Reach (1)	8776	125%	238	119%
Flow @ Louth (425004)	7027	100%	199	100%
Total Tributary Inflow above Wilcannia	8959	144%	315	179%
Inflows into Louth – Wilcannia Reach (1) (Bourke – Wilcannia)	7027 (8776)	113% (141%)	199 (238)	113% (135%)
Flow @ Wilcannia (425003)	6216	100%	176	100%
Total Tributary Inflow above Wilcannia	8959	144%	315	179%
Inflows into Wilcannia-Menindee Reach (1)	7027	113%	199	113%
Flow @ Wilcannia (425003)	6216	100%	176	100%

(1) Inflows into a reach comprise flow at the U/S main river gauge plus any tributary contributions within the reach.
(2) missing data
(3) Inflows into 2 reaches combined.

The comparisons during the 'low' flow period (1980) showed that the volume of flows at almost all gauges appear reasonable, as at all times upstream tributary inflows exceeded downstream 'main river' gauges. The variations in the differences between inflows and 'main river' flows can be attributed to losses and/or usage within a reach. Although for the Brewarrina to Walgett reach it would appear that either, there are some missing inflows. Note, it is likely in this dry period with very few streams actually flowing that streamflow measurement errors may have been the cause.

The comparisons during 1971 flood event showed a different trend, indicating that there were insufficient inflows to explain downstream 'main river' gauge flow. They also showed that there may be some problems with some 'main river' gauges.

The following can be concluded:

- although flows into Mogil Mogil reach appear reasonable subsequent analysis in the next two reaches (Mogil Mogil – Collarenebri & Collarenebri-Walgett) indicates there is a problem with both 'tributary' and 'main river' flow measurement upstream of Walgett. However, with 8 'tributary' and 2 'main river' gauges upstream of Walgett, it is not possible to readily determine which gauges and by how much do they under estimate high flows;
- similar problems with 'tributary' gauges downstream of Walgett were also encountered;
- evaluation of the reach losses relative to floodplain areas suggests that both Brewarrina and Louth under estimate flood flow; and
- the comparisons during 1971 flood event showed that only the gauges at Walgett, Bourke and Wilcannia appear to estimate the total flow during significant flood events. Given the topography at these sites, it appears that for most gauges either the lack of access during flood time and/or the inability to define what is the flow 'passing' the gauge leads to the under estimate.

Careful evaluation over a number of events was required to determine the likely amounts that each tributary gauge was under estimating high flows by (i.e. the degree of "factoring up" of tributary flows needed). Details of the amount of 'factoring up' required at each tributary gauge is shown in Table 3.4 and Table 3.6.

2.4.3 Behaviour

Flow statistics for each 'main river' gauging station are available in Table A.0.4. This table shows the following statistics for the calibration and validation periods:

- percentage of period for which recorded data was available;
- average daily flow; and
- maximum, minimum and median daily flows.

Flow behaviour in the first reach (Mungindi to Pressbury) shows very little seasonality as these flows are significantly affected by the regulation of flow at Mungindi and there is very little tributary inflow into this reach other than some flood effluents of the Barwon River (i.e. Little Weir and Boomi Rivers). The difference in median daily flows between the driest (September) and wettest months (March) is only 280 ML/d (i.e. from 50 to 330 ML/d).

Flow behaviour in the second reach (Pressbury to Mogil Mogil) shows an increase in seasonality as more tributary flows (Moonie River and Gil Gil Creek) enter into this reach. The difference in median daily flows between the driest (June) and wettest months (February) is about 550 ML/d (i.e. from 130 to 675 ML/d). With inflows rich in seasonality continuing to enter the Barwon-Darling River system then seasonality becomes more pronounced as you move downstream.

2.5 IRRIGATION INFORMATION

The availability of the information about an irrigation enterprise or farm is dependent on the scale of that enterprise. If an irrigator is an active irrigator (i.e. has an installed pump) and is growing in excess of 20 hectares then they are termed ‘major’ irrigators. There are about 37 of these ‘major’ irrigators who are individually represented in the IQQM (Note the number of these irrigators change dependent on the year of representation). For major irrigators extensive diversion data is available from the 1995/96 season. For the remaining small ‘B’ Class and ‘A’ Class irrigators (i.e. known as ‘reach’ irrigators because they have been aggregated by reaches), who are numerous in number but very small in area irrigated, there is no metered diversion data available.

Since 1997, NOW has been developing and collecting data for the Barwon-Darling IQQM’s. Details of the major events associated with the data collection that are used in the present IQQM are:

- in August 1997, Hydrology Group commenced their ‘voluntary’ written surveys of all ‘major’ irrigators. This survey requested information on their farm infrastructure, as well as land use and water management details. A number of irrigators were also interviewed about their farms. In July 1998, these irrigators were asked for written confirmation of some survey details, principally pump and OFS capacities, crop areas and crop types. Note all data was based on irrigator estimates without any opportunity for independent objective validation, although some internal checks were conducted;
- in September 1999, the RMC commenced their Development History Project (DHP). The aim of this project was not only to definitively establish the level of irrigation development that existed on the Barwon-Darling in 1993/94 but also to define changes in development and management overtime (1987/88 – 1999/2000).

  The levels of detail and the methods used for collecting the data differed depending on the size of the irrigation enterprise, for:

- small or reach irrigators, they where contacted by telephone to determine the amount and types of crops grown and the irrigation infrastructure used for growing these crops in 1993/94 and 1999/00. This data was generally not adequate to subsequently determine any subtle changes in on-farm management behaviour over time; and
- major irrigators, the process was a lot more detailed and extensive. High resolution colour satellite imagery was purchased for each year during summer cropping season from 1987/88 to 2000/01. As the Barwon-Darling was almost mono cropped with cotton, the months of January and February were preferred because of the greater contrast in reflectance at this time. This satellite imagery was used for the following main purposes:
    1. As a visual aid during an on-farm interview;
    2. As a basis for accurate digitising of irrigation infrastructure;
    3. To provide an independent verification of the development and usage of each field and each water storage; and
    4. As a basis to determine if there had been developments in on-farm irrigation layouts which may affect irrigation or re-cycling efficiencies.

  Following the on-farm interview, documents detailing the development history of each individual property were developed and returned to owner/manager of the property. Following the resolution of any outstanding disagreements about on-farm infrastructure a 'final' document was signed off.

  A sample copy of the data gathered for each 'major' irrigator is attached at Appendix B. This process provided an accurate determination of areas based on remote sensed information.

- Annual surveys of 'major' irrigators completed at the end of each water year. The State Water metering inspector (M. Allen) undertook surveys from 1994/95 to 2004/05. Data available from these surveys include areas and types of crops grown, areas developed for irrigation and OFS capacity and volume in storage, this information was obtained in an interview process. Like the hydrology surveys all the data was based on irrigator estimates without any opportunity for independent objective validation.

2.5.1 Licence Conditions

Irrigator's access to the river flow is a vital feature that is represented in IQQM. Their access is controlled through the granting of one or more licences that specify the amount of water and access conditions (i.e. the river flow thresholds) under which they can divert river flows. Note, up to 2006/07 Barwon-Darling irrigators were not permitted to carryover any unused portion of their entitlements from one year to the next. However from 2006/07, when their entitlement volumes were reduced to a Cap share, irrigators were permitted to carryover any unused portion of their Cap share (i.e. new entitlements) from one year to the next. Although 'carryover' volumes were unlimited, irrigators were limited to an annual extraction volume equivalent to their old (i.e. pre 2006/07) annual volume entitlement.

Differing classes of irrigation licenses in a reach (i.e. A, B, C and D) have differing river flow thresholds under which those licences are permitted to pump. Licences also specify maximum permissible pump capacities both overall and for any special conditions, if applicable.

Generally, irrigators operate on the basis of trying to divert the maximum volume of water whenever possible subject to their annual volume entitlement or account limits (i.e. carryover volume) or within the limits of a set of flow conditions that are specified for their respective licence classes. However as the available river flow volumes often do not exceed potential demand (i.e. there is competition for available river flows), some irrigators have developed a roster to share available flows. The roster places a limit on the available river flow that an individual irrigator may extract on a particular day (eg Association of Bourke Water Users).

The accounting date for irrigators downstream of Walgett has always been the 30th of June, while for those upstream it was initially the 30th of August. The accounting date of all irrigators was unified in the 2000/01 water year to the 30th of June. Irrigators upstream of Walgett had a 9 month from 01/10/2000 to 30/06/2001 water year.

In addition to the Barwon-Darling River entitlements described above, a few irrigators also extract water directly from its tributaries. These irrigation farms are operated as a single entity with some portion of their total irrigation demand being satisfied by these tributaries. In IQQM the access to these tributaries is modelled to reflect reality which include where an irrigator:

- utilises a license on a regulated tributary then in IQQM either the observed or simulated diversions from the regulated tributary are available to be diverted into OFS; or
- has access to an unregulated tributary because the farm layout allows flow directly into the OFS or allows a 2nd lift pump to extract water directly into the OFS. In IQQM these tributary streamflows, which are either observed or synthesised, are the basis for determining the tributary diversions which are only limited by a pump capacity equivalent to 2nd lift pump or airspace available in their OFS.

Information from NOW's comprehensive historic records of the licences (as indicated by entitlements and conditions) that were granted to the Barwon-Darling irrigators has been used to define the annual amounts and conditions (i.e. the river flow thresholds) that govern irrigator's access to river flows. Reach summaries of these amounts and conditions are shown in Appendix C.

Being an unregulated system, temporary transfers of licences are not a big feature of the Barwon-Darling. Although a small volume was transferred prior to 1993/94 there has been none since due to an embargo being placed on transfers.

2.5.2 Pump Information

Pump capacities for ‘major’ irrigators are measured by State Water when they undertake their ultrasonic probes to determine approximate pump capacity. However there’s a problem with the annual assessment capacity for many pumps (i.e. rpm to discharge relationship) during the period 1995/96 to 1999/2000. This change was not due to physical equipment changes but due to one or more of the following:

- errors in the pump probe process, the process is somewhat subjective and operator dependent variations of over 20% have been encountered when trying to derive average velocity of water flowing in pipes;
- different river levels at the time of probing, changes in river levels by up to 10 meters can occur which can cause the axial flow pumps (i.e. most common installed) to discharge up to almost 200% of low flow rate; or
- the pump had never been probed and an estimated capacity had been assumed.

To overcome these unrealistic fluctuations in pump capacities during the 1995 – 2000 period, the 1999/2000 capacities have been **adopted** as **maximum pump capacity** for the Cap model, unless there was physical changes to the installed pumping plants. These changes to pumping plants over time (i.e. 1988 – 2000) have been identified by the DHP and have been incorporated into the IQQM.

For reach irrigators, the 1994 pump capacity as indentified by the DHP was adopted. Summaries of all installed irrigation pump capacities are shown in Table 2.6.

Table 2.6. Installed River Pump Capacities

	Installed Pump Capacity (ML/d)			
Reach Section	Major Irrigators		Reach Irrigators	
	1993/94	1999/00	1993/94	1999/00
Mungindi – Walgett	1,250	1,375	154	154
Walgett - Brewarrina	805	1860	49	47
Brewarrina - Bourke	2,120	2,880	138	136
Bourke - Wilcannia	795	1,280	145	181
Wilcannia - Menindee	0	0	0	0
Total River	4,970	7,395	486	518

2.6 IRRIGATION EXTRACTION DATA

Water use for 'major' irrigators on the Barwon-Darling is monitored using 'time and event' meters. These meters record, at 2 hourly intervals, the rate in revolutions per minute (i.e. rpm) that each pump operates. The rpm of the pump is then multiplied by its capacity to give a pumped volume per 2 hour interval. This method of metering is sensitive to the measurement (or in some cases the estimate) of pump capacity and the effects of changes to river water levels (which are not considered).

There is no monitoring of water use by 'reach' irrigators.

As noted in the previous section for a large number of pumps, the annual assessment of the pump capacity (i.e. rpm to discharge relationship) has changed over the period 1995/96 to 1999/2000. Consequently for calibration purposes the metered diversions were adjusted to reflect the most recent probe information on pump capacity. This process effectively standardised all metered data to the pump capacity derived from the 1999/2000 probing. For the vast majority of pumps their annual assessment capacity has not changed since 1999/2000.

In total this process led to the adjusted usage figure that is used for calibration being about 2% less then the raw historical data. Annual summaries of the metered irrigation 'observed' and 'adjusted' diversions are shown in Table.2.7.

Table.2.7. Total Metered Irrigation Diversion by Water Year (ML)

Water Year	Total 'Observed' Diversions	'Adjusted' Diversions *
1995/96	215,625	206,435
1996/97	211,915	200,210
1997/98	176,820	161,045
1998/99	228,870	231,010
1999/00	168,250	No Adjustment
2000/01	246,770	"
2001/02	64,590	"
2002/03	15,875	"
2003/04	274,900	"
2004/05	155,385	"

* Standardised to 1999/00 pump capacity probing.

2.7 CROP DATA

Two extensive but independently developed data sets are available for 'major' irrigators on the Barwon-Darling. Each set (Table 2.8) include annual summaries of areas developed and areas cropped for irrigation.

The DHP data, which was based on remote sensed information and was effectively "ground truthed" during the on-farm interview process, provides the definitive areas. While the more time expansive State Water Survey data, provides information after

2000/01. A comparison of the two sets shows that irrigator estimates (i.e. State Water Survey data) can vary considerably, with a tendency to over-estimate development and cropping.

Table 2.8. Total Developed and Irrigated Areas for 'Major' Irrigators

Year	Developed Area (Ha)			Irrigated Area (Ha)		
	State Water Surveys	DHP	% Difference	State Water Surveys	DHP	% Difference
1995/96	29,635	28,477	4%	20,058	21,486	-7%
1996/97	30,365	30,083	1%	23,233	24,358	-5%
1997/98	30,425	31,182	-2%	23,293	23,330	0%
1998/99	38,135	32,668	17%	26,179	24,702	6%
1999/00	38,755	34,142	14%	24,673	23,366	6%
2000/01	41,790	36,394	15%	28,983	26,531	9%
2001/02	44,255	N.A.	N.A.	27,860	N.A.	N.A.
2002/03	44,635	N.A.	N.A.	2,310	N.A.	N.A.
2003/04	43,895 *	N.A.	N.A.	100/1,025 #	N.A.	N.A.
2004/05	44,175 *	N.A.	N.A.	21,270	N.A.	N.A.

Notes: * Excludes Boomi users
Summer Area/Total area including winter 2003

Irrespective of the data set used or the total area planted, cotton is the totally dominate crop in terms of summer irrigation area and water use for 'major' irrigators. Irrigated winter crop areas, except for 2003/04 drought year, are insignificant, with most 'major' irrigators growing only cotton.

For 'reach' irrigators the only extensive information available are irrigator estimates for the years 1993/94 and 1999/2000. This information, which was collected as part of the DHP, did not use any remote sensed information. Reach irrigators grow about 1,700 hectares of crops annually but do not grow any cotton, rather, they grow a mix of crops with winter cereals more dominant than summer cereals, fodder and orchard crops.

2.8 ON-FARM STORAGE INFORMATION

2.8.1 Capacity

On-farm storages are a significant feature of the Barwon-Darling with almost 300 GL of currently installed capacity by ‘major’ irrigators. Table 2.9 shows the annual summaries of OFS capacity from the two available data sets. Problems similar to those encountered with crop areas exist with the OFS data. However, in this instance the DHP is no more reliable then State Water Survey data as both OFS capacities are sourced directly from irrigators.

Table 2.9. Total OFS Capacity for ‘Major’ Irrigators on Barwon-Darling

Year	State Water Surveys (ML)	Development History Project (ML)	% Difference
1995/96	240,200	233,680	3%
1996/97	247,170	238,570	4%
1997/98	247,520	240,170	3%
1998/99	238,970	237,255	1%
1999/00	274,370	271,070	1%
2000/01	293,870	287,470	2%
2001/02	298,270	N.A.	N.A.
2002/03	297,470	N.A.	N.A.
2003/04	298,270	N.A.	N.A.
2004/05	297,970*	N.A.	N.A.

*Reduction due to resurveying performed during drought when storages were empty.

For the calibration period (1995/96 – 2004/05) State Water Survey data was used and if there was growth in on-farm capacity then these increases are incorporated through the use of a time series file of annual developments for each irrigator affected.

Most ‘reach’ irrigators have no OFS’s with the total installed capacity being less than 800 ML.

The OFS information that is represented in IQQM includes the **volume / surface area relationships**. These where developed from DHP data and from OFS characteristics as noted in the Hydrology Survey, together with any irrigator advice.

2.8.2 Behaviour

The behaviour of OFS is an important ingredient in model calibration, as the capacity of these storages is frequently equal to the annual diversion volumes. However with many storages lacking even basic water level gauges the estimates of the volume in OFS, frequently made months or even years after the event, are somewhat subjective at times. There are two available “data sets”:

- the first, is from the annual survey which supplies “the volume in storage at the start of the water year” (expressed as percentage). This information is collected during the State Water Survey at the end of each water year; and
- the second, is a broad assessment of volume in storage using annual remote sensed scenes available from 1995 to 2000. Realistically this information can only describe the OFS as being “empty or with little water” and “Full with clear or dirty water” which indicates the timing of pumping but not necessarily whether the storage is actually full. This ‘data’ is only slightly better than a qualitative assessment but as it is a scene on a specific date, it gives some assistance to understanding OFS behaviour.

2.8.3 Operating Procedures

Many of the ‘major’ irrigators on the Barwon-Darling who have multiple storages have instituted operating procedures to minimise their evaporation losses. These practises of establishing a priority for emptying their storages was supplied in the Hydrology Survey and have been incorporated into IQQM through the development of appropriate OFS volume / surface area relationships.

2.8.4 Airspace

Most OFS’s are also operated to maintain airspace for the collection of rainfall-runoff harvesting. Based on the Hydrology Survey and advice from irrigator representatives on the IQQM Reference Group, an airspace equivalent to 0.3 metres on top of the OFS was provided for this purpose. This volume was provided for all OFS unless there was designated surge storage on the property.

2.8.5 On-farm Water Management

This ‘major’ irrigator behaviour includes; accessing river flows and floodplain flows, and rainfall-runoff harvesting.

2.8.5.1 Accessing River Flows

Based on the Hydrology Survey and advice from irrigator representatives on the IQQM Reference Group, ‘major’ irrigators will always, regardless of the time of season, pump river flows once their access conditions have been exceeded and they will continue to do so until their OFS are full or their license entitlement is exhausted. Note this practice makes no allowance for irrigators who may occasionally make the decision to stop diverting metered river water and wait for floodplain water. About 15 of the 37 ‘major’ irrigators are able to take un-metered floodplain water. During calibration it was noted that there were a few irrigators whose observed diversions practises and OFS behaviour did not support the adoption of this ‘fill at all costs rule’.

2.8.5.2 Accessing Floodplain Flows

Floodplain harvesting (FPH) is collecting water from the floodplain once the Barwon-Darling has broken its banks, as defined in the “*Glossary of Terms*”.

Floodplain access **thresholds** and the **extraction rates** where obtained from information supplied in the Hydrology Survey and are incorporated into the model. In the survey each irrigator advised on the river threshold levels (i.e. nearby gauge heights) when they could get access to floodplain flows and whether they had to use 2nd lift pumps or gravity to get it into their OFS. Irrigators also advised on the years when floodplain flows were obtained and approximate amounts diverted, enabling some ratifying of irrigator access estimates to be made during calibration.

2.8.5.3 Rainfall Harvesting

Rainfall harvesting (RFH) is collecting water generated by rainfall directly on farm or from nearby land, as defined in the “*Glossary of Terms*”.

There is no comprehensive information on RFH, with most of the information gained from the Hydrology Survey, discussion with irrigators and an assessment completed by members of the IQQM Reference Group. These surveys, discussions and assessments indicated that the amount of RFH is a function of:

- the characteristics of the storm event. Higher intensity rainfalls generate more RFH volume since the rainfall rate exceeds infiltration rate;
- the antecedent conditions (i.e. if a soil is already saturated then more RFH will occur);and
- the time of year, as the ‘cost’ or impact of flooding / saturation of soil by rainfall is dependent on the stage of the crop cycle.

They also indicated that the rainfall harvesting “on-farm areas” would best be defined as the area developed for irrigation on each farm. For those farms that had additional “nearby” areas there was scant data available to indicate the value, a trial and error approach was adopted, during diversion calibration, to define the dryland area that could supply RFH volumes.

3 Model Calibration

3.1 MODEL CONFIGURATION

The Barwon-Darling River was configured in IQQM using input data as described in Chapter 2. The number and types of nodes and links were selected in accordance with the aims of the modelling detailed in section 1.3. The Barwon-Darling IQQM contains almost 380 nodes. Presentation of the node/link diagram and a listing of all nodes used is contained in Appendix D.

3.2 FLOW CALIBRATION

The objective of this step is to calibrate the river system flows module over a calibration period. The period 1970/71 to 1983/84 was selected because of the prevalence of streamflow data and there were only a few small scale irrigators operating. All known system inflows (gauged tributaries) of the system are forced to the observed data and the remaining unknowns (river routing (DLWC, 1998[k]) and transmission losses (DLWC, 1998[e]) are calibrated by trial and error to achieve the best overall match of stream flows at main-stream gauges (DLWC, 1998[d]).

3.2.1 Division of River System into Reaches

Streamflow data was required at all key main stream gauging stations and for all major tributaries represented in the model over the calibration period. An extensive network of streamflow gauging stations represents the main river flows in the Barwon-Darling River catchment. The following criteria was used to select an appropriate sub-set for use in calibration of the main stream flows:

- isolation of key features such as tributary inflows and effluent outflows and return of flows
- the full extent of floodplain is included in flow measurements (i.e. whether all flows passing a point are included and the measured flows are “total” or only mainstream flows on some occasions)
- availability of good quality records to cover the intended calibration period, with a minimum number of missing records

As discussed earlier in Section 2.4.2 (Streamflow Reliability) a problem exists with total flow measurement at all but four of the main stream gauging stations. These four gauging stations (Walgett, Bourke, Wilcannia and Menindee) were selected for use in the model, thus creating four primary flow calibration reaches (Table 3.1). At each station flow calibration over the entire flow range has been undertaken and the results are reported in subsequent sections.

Table 3.1 Primary Flow Calibration Reaches and Periods

Primary Reach Number	Reach Description		
1	Mungindi (416001)	to	Walgett (422001)
2	Walgett (422001)	to	Bourke (425003)
3	Bourke (425003)	to	Wilcannia (425002)
4	Wilcannia (425002)	to	Menindee [Weir 32] (425012)

In addition to the four primary calibration reaches, a number of sub-reaches were also identified within each primary reach (Table 3.2). These sub-reaches were often de-lineated by a stream threshold location (as specified in licence conditions) and a gauging station for which some flow records were available. At these 'sub' reaches flow calibrations were limited to "low" or in-bank flows. In the development of these sub-reach losses, the overall water balance at the primary gauging stations was ensured. The results of the flow calibration for the sub-reaches are not reported in subsequent sections.

Table 3.2 Secondary Flow Calibration Reaches

Secondary Reach Number	Reach Description		
1a	Mungindi (416001)	to	Pressbury (416050)
1b	Pressbury (416050) (422004)	to	Mogil Mogil
1c	Mogil Mogil (422004)	to	Collarenebri (422003)
1d	Collarenebri (422003)	to	Walgett (422001)
2a	Walgett (422001)	to	Brewarrina (422002)
2b	Brewarrina (422002)	to	Bourke (425003)
3a	Bourke (425003)	to	Louth (425004)
3b	Louth (425004)	to	Tilpa (425900)
3c	Tilpa (425900)	to	Wilcannia (425002)

Rainfall and evaporation onto the river surface is modelled within IQQM. The link module of IQQM assumes a constant surface area for the river. This assumption is not valid during large flood events, when the river is a 'sheet' of water many kilometres wide. Hence, during these times the IQQM modelled evaporation losses or rainfall gains are an under-estimate of the true losses or gains. However, these under estimated components are incorporated within the overall calibrated losses as an increased proportion of streamflows.

3.2.2 Calibration Results and Discussion

Results from the final calibrated assembled model that was developed for river flow replication *(I:\IQQM\Darl\QuanQual\Calib\Flow\Stats 2005 \flowaaaa.sys)* are presented in the sections below. Results for the four primary gauging locations have been supplied. Objective measures of the quality of model fit achieved at each primary location are also presented. These measures of quality are based on the quality assessment guidelines described in Appendix E (DLWC, 1999).

3.2.2.1 Calibration of Mungindi to Walgett Reach

Initial attempts to calibrate the transmission losses were a failure. This was because during significant flow events, the simulated flows were substantially less than the flows recorded at Walgett. From an evaluation of observed flows (Section 2.4.2 for details) it was apparent that a portion of the tributary flows were 'missing' during flood events. To quantify the missing inflows, the calibration period was delineated into a series of event and intra-event periods. These periods were based on a visual inspection of the stream flow hydrograph and for each event and intra-event, the missing inflows were quantified (see Table 3.3). This table confirms that tributary flows are only 'missing' during flood events and that they are more predominant during larger flood events.

During an intra-event period, the recorded 'main river' flows were marginally less than the total tributary inflows, indicating slight loss or usage during this period.

Table 3.3. Missing Inflows into Mungindi to Walgett Reach

Flow Events	Major 1971 (1)	Intra (2) event	Major 1974 (3)	Intra (2) event	Major 1976 (4)	Minor 1977 (5)
Peak Flow @ Walgett (6) (ML/d)	230,000	25,000	470,000	30,000	540,000	60,000
	Vol. (GL)	Vol. (GL)	Vol. (GL)	Vol. (GL)	Vol. (GL)	Vol. (GL)
Total Tributary Inflows U/S of Walgett	6,235	2,095	3,375	378	6,135	4,445
Walgett Observed (422001)	7,496	2,035	5,622	353	9,272	4,631
Difference: U/S Trib's. – Walgett (7)	-1,260 (2)	+60	-2,250	+25	-3,140	-185
Difference as % of Trib. Inflows	-20%	+3%	-67%	+7%	-51%	-4%

Notes:
(1) Major event 1970-71: 29/09/70 – 10/07/1971
(2) Intervening period of generally low flows
(3) Major event 1974: 11/07/73 – 18/04/1974
(4) Major event 1976: 01/01/76 – 30/06/1976
(5) Minor event 1977: 01/07/76 – 31/12/1977
(6) Peak flow at Walgett is a more reliable measure of the extent of tributary over bank flow than volume at Walgett
(7) Negative = "missing" inflow volume

A search for the possible causes for ‘missing’ inflows showed that:

- the residual catchment of this reach (i.e. the catchment area downstream of the tributary gauges but upstream of Walgett) is relatively small, being effectively along-side the river. This area cannot generate large inflow volumes, equivalent to 20 – 60% of the total flows at Walgett, when its catchment area is only a few hundred square kilometres compared to Walgett’s catchment area of over 130,000 Km^2;
- although it was initially believed that the measured inflows encompassed the whole tributary flow regime, it became apparent that during flood times at least, this was not the case; and
- based on other D/S ‘’main river’ gauges Walgett gauge does not overestimate streamflows.

Further inspection of the recorded inflows showed that the periods of missing inflows coincided with times when over bank flows were predominant for the tributaries. Clearly this phenomenon of “missing” inflows is linked to the inability of the rating curves, probably at a number of gauging stations to include total floodplain flows (i.e. some portion of tributary floodplain flows is not included). When both the topography of the western plains and the difficulty associated with defining the extent of a floodplain are considered, it becomes apparent that the hydrographic task of defining the total flows for some tributary gauging stations is extremely difficult.

In IQQM, it is possible with the combination of factoring of inflows and an accompanying loss function to factor the floodplain portion of inflows from a tributary. Figure 3.1 shows the result of applying this process to flows at the Barwon River @ Mungindi gauging station (GSN: 416001). The ‘new’ curve shows how only the floodplain portion of tributary flows could be increased (i.e. above 60,000 ML/d). This ‘new curve’ effectively behaves like a revised rating curve to include “total” floodplain flow.

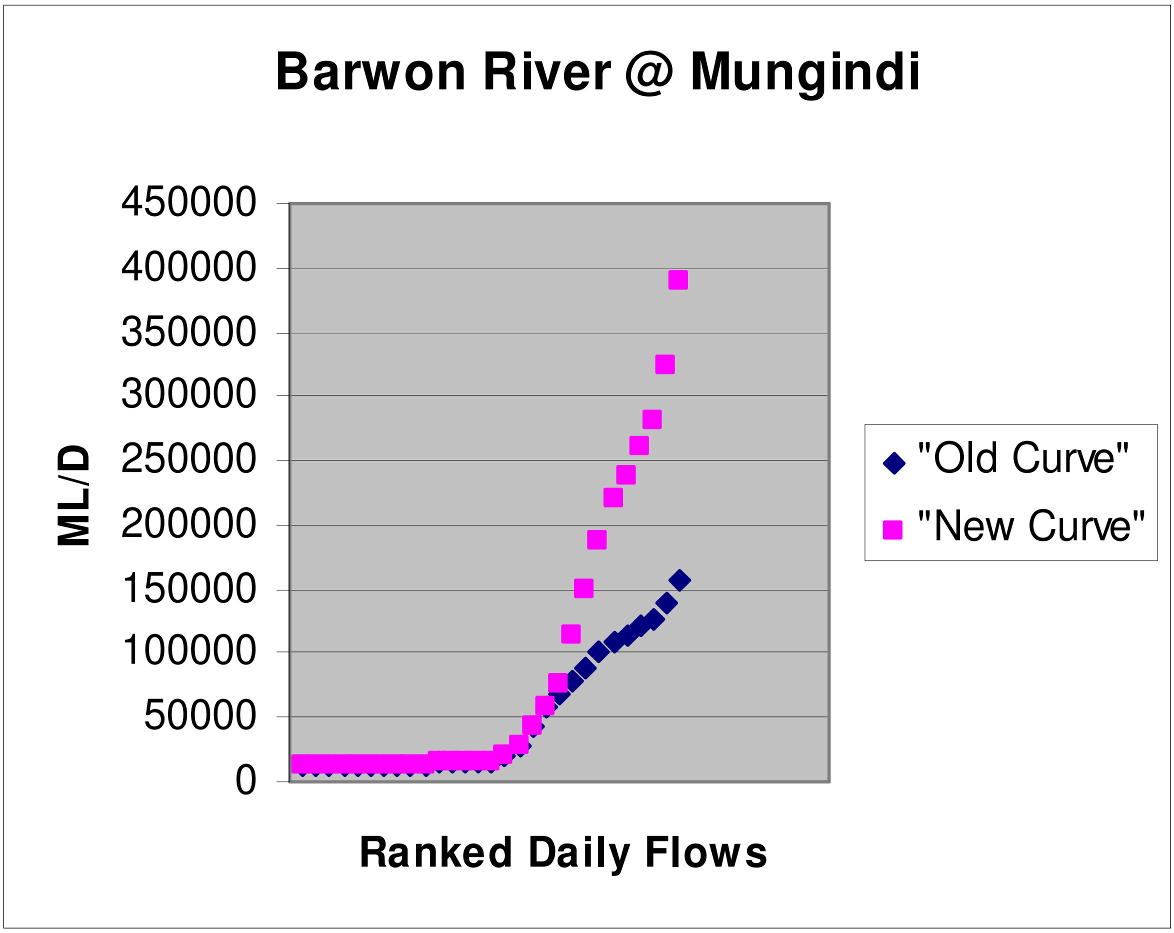


Figure 3.1 Barwon River at Mungindi : Comparison of "New" and "Old" Derived Flows

Through a trial and error process, tributary inflows were factored in order to produce the best fit of simulated streamflows at Walgett. Table 3.4 shows the extent of adjustment that was made to the tributary inflows between Mungindi and Walgett. It should be noted that this factoring up process is not an exact science as there are 9 tributary (i.e. unknowns) and only one 'main river' gauging station available to check the results. Also floods tend to occur in a number of tributaries at the same time further complicating our ability to define the amount of factoring required for each tributary.

Table 3.4 Factoring of Floodplain Flows Mungindi - Walgett

Tributary Gauge	Threshold Flow when Factoring Commences (ML/d)	Factoring up value
Barwon River @ Mungindi	65,000	2.5
Little Weir River @ End of system	Nil	None
Boomi River @ Neewoora	Nil	None
Gil Gil Creek @ Galloway	Nil	None
Moonie River @ Gundabluie	15,000 20,000	4.0 7.0
Gwydir River @ Collymongle	Nil	None
Mehi River @ Collarenbri	4,000 5,500	5.0 8.0
Namoi River @ Goangra & Pian Creek @ Waminda	80,000 (combined flow)	2.0

The results of the flow calibration for the reach from Mungindi to Walgett are shown in the subsequent figures and table. Figure 3.2 shows the daily flow frequency comparison over the calibration period 1970 – 1984. This figure is presented in log scale for ease of visual identification of flows in the pumping range (i.e. 600 – 25,000 ML/d). However, this scale also tends to exaggerate the ‘moderate’ calibration achieved in the very low flows. Figure 3.3 shows the time series of annual flow volume comparison and Table 3.5 shows the quality of model fit achieved.

The results shown in Table 3.5 are very good given the amount of uncertainty evident in the inflows and the adjustments that were necessary to achieve ‘water balance’. The results applicable to the pumping thresholds (i.e. mid flow range) are very good within 1% on a daily flow basis. However in low flow range, some of the ‘uncertainty’ associated with the calibration assumptions, particularly those assumptions associated with the water extractions by riparian users and small irrigators (i.e. they are ignored), show up with a ‘moderate’ classification for this range.

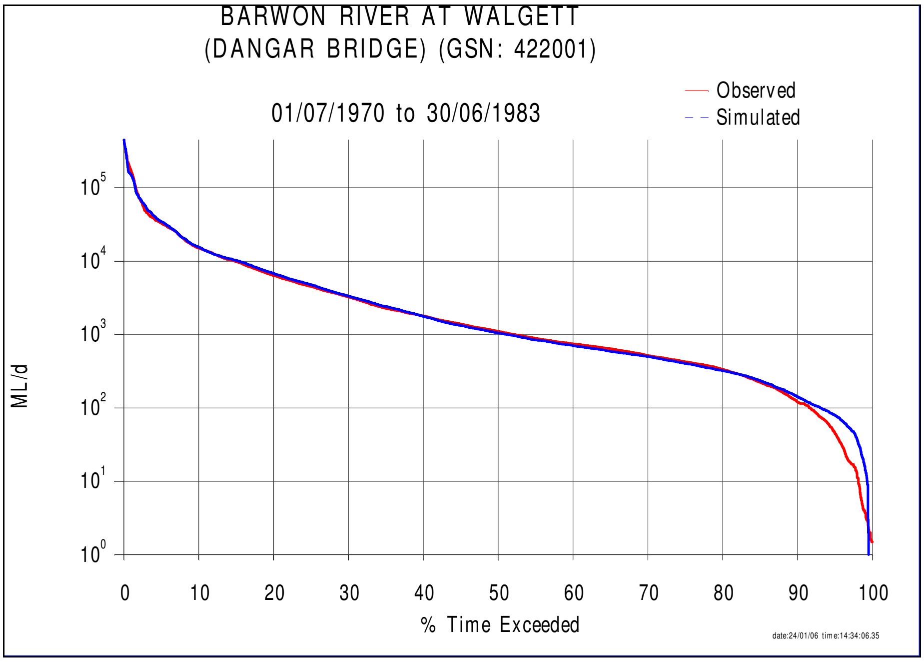


Figure 3.2 Barwon River at Walgett – Daily Flow Frequency

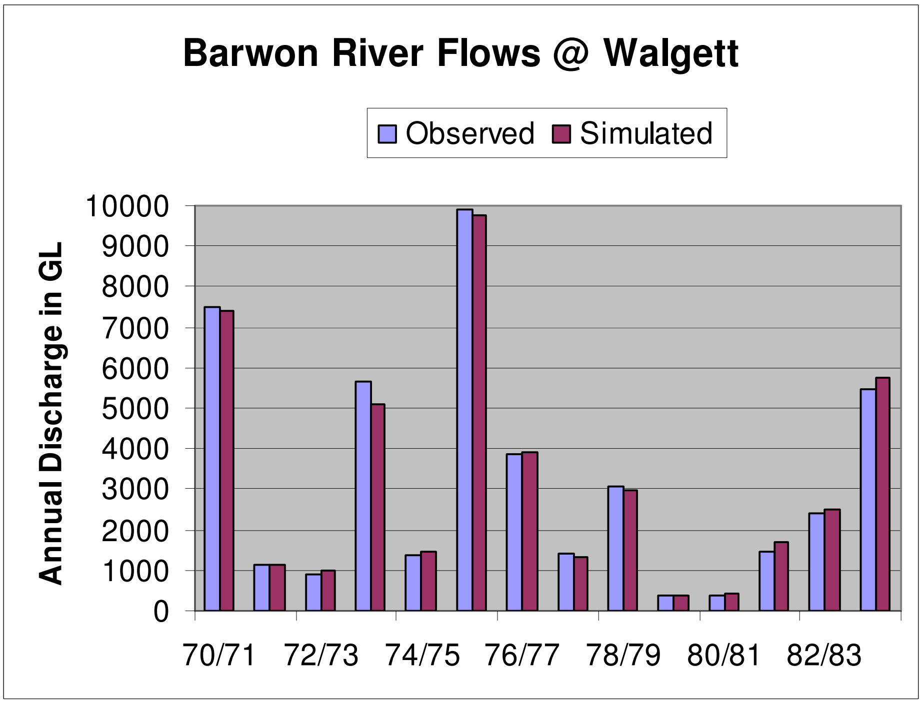


Figure 3.3 Barwon River at Walgett – Annual Discharge Comparison

Table 3.5 Walgett – Flow Calibration Quality Indicators(#) for period 1970 - 1984

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT*		*QUALITY RATING GUIDELINES* ***(See Appendix** Error! Reference source not found. **for details)***	*AVERAGE FLOWS FOR RANGE*
		Definition	***Apparent Error (AE)***		***OBSERVED / SIMULATED (ML/D)***
FLOW FREQUENCY REPLICATION (ranked daily flows)	VOLUME RATIO (vr) Where “vr” = 100 * (Simulated / Observed) Expressed as a %	Whole flow range	AE = (“vr” – 100) -0.4%	Very High	8,800 8,765
		Low flow range from 80%ile (330 ML/d) to 100%ile (0 ML/d)	AE = (“vr” – 100) +11.5%	Moderate	140 155
		Mid flow range from 10%ile (15,100 ML/d) to 80%ile (330 Ml/d)	AE = (“vr” – 100) +0.7%	Very High	3,195 3,220
		High flow range from 0%ile to 10%ile (15,100 ML/d)	AE = (“vr” – 100) -0.9%	Very High	54,500 54,000
FLOW TIME SERIES REPLICATION	Daily flow time series – line of best fit: r^2	“r^2” coefficient of determination, (or the degree of scatter around the line of best fit)	AE = 100 * (1- r^2) 2.2%	Very High	-
	Annual flow time series: Assembled reach calibration stages: CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD +4.4%	Very High	3,212 (1) 3,201 .

Notes:-

Average annual comparison in GL/yr

(#) See Appendix E for methodology of calculating the quality assessments

3.2.2.2 Calibration of Walgett to Bourke Reach

Similar “missing” inflows were also encountered in this reach and the same approach, as previously utilised was adopted to re-calculate tributary inflow volumes. Table 3.6 shows the extent of adjustment that was made to the tributary inflows between Walgett and Bourke. As previously there are large number of tributaries (i.e. 7 unknowns) and only one ‘main river’ gauging station available to check the results.

Presented below are the results obtained from the final calibrated assembled model for the Bourke gauging location. Figure 3.4 shows the daily flow frequency comparison and Figure 3.5 shows the time series of annual flow volume comparison, while Table 3.7 shows the quality of model fit achieved.

Table 3.6 Factoring of Floodplain Flows Walgett - Bourke

Tributary Gauge	Threshold Flow when Factoring Commences (ML/d)	Factoring up value
Castlereagh River @ Coonamble (G.Stn 420005)	5,000	1.25
Marthaguy Creek @ Carinda (G.Stn 421011)	4,000	1.5
Macquarie River @ Carinda (G.Stn 421012)	3,000	1.5
Marra Creek @ Billybingbone Bdge (G.Stn 421107)	Nil	None
Narran Lakes Overflow	Nil	None
Bokhara River @ Bokhara(Goodwins) (G.Stn 422005)	3,000	1.5
Bogan River @ Gongolgon (G.Stn 421023)	6,000	1.5
Culgoa River @ D/S Collerina (G.Stn 422006)	17,000	1.5

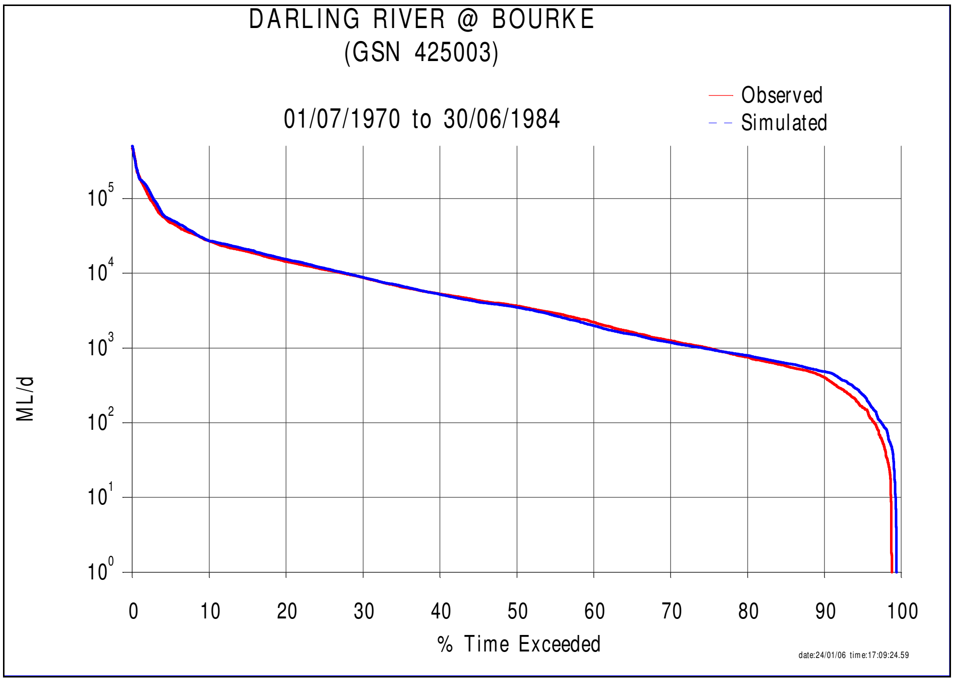


Figure 3.4 Darling River at Bourke – Daily Flow Frequency

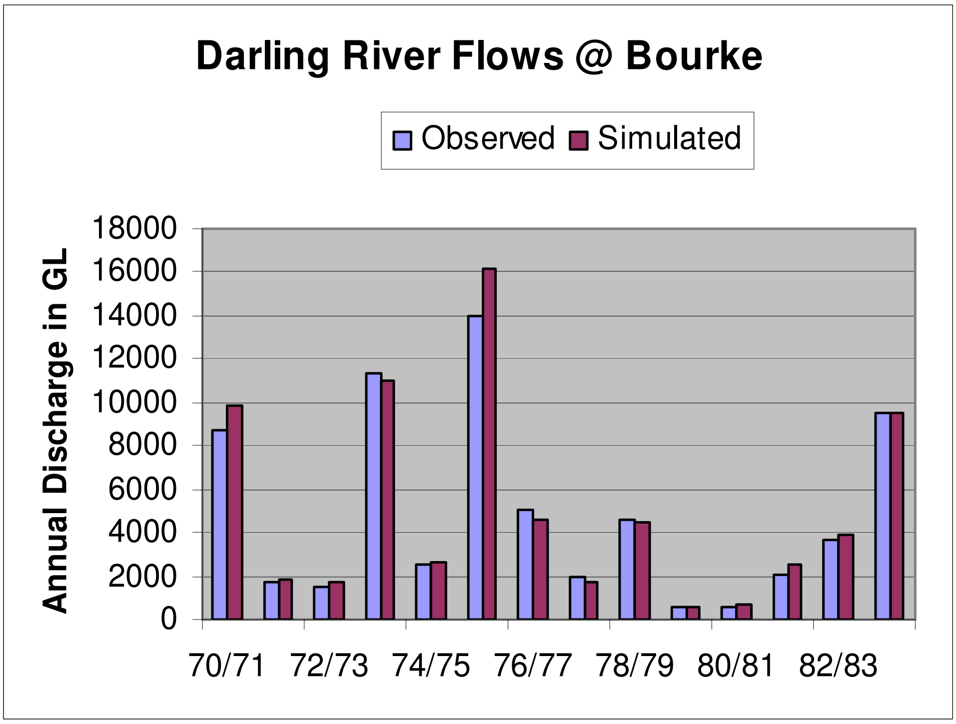


Figure 3.5 Darling River at Bourke – Annual Discharge Comparison

Table 3.7 Bourke – Flow Calibration Quality Indicators(#) for period 1970 - 1984

PRIMARY FOCUS	***QUALITY INDICATOR***	***SUB-ASPECT***		***QUALITY RATING GUIDELINES (See Appendix Appendix E for details)***	***AVERAGE FLOWS FOR RANGE***
		Definition	***Apparent Error (AE)***		***OBSERVED / SIMULATED (ML/D)***
FLOW FREQUENCY REPLICATION (ranked daily flows)	VOLUME RATIO (vr) Where “vr” = 100 * (Simulated / Observed) Expressed as a %	Whole flow range	AE = (“vr” – 100) +5.3%	High	13,220 13,920
		Low flow range from 88%ile (480 ML/d) to 100%ile (0 ML/d)	AE = (“vr” – 100) +40%	Very Low	165 235
		Mid flow range from 10%ile (27,000 ML/d) to 88%ile (480 Ml/d)	AE = (“vr” – 100) +2.7%	Very High	6,140 6,310
		High flow range from 0%ile to 10%ile (27,000 ML/d)	AE = (“vr” – 100) +6.7%	Very High	83,800 89,400
FLOW TIME SERIES REPLICATION	Daily flow time series – line of best fit: r^2	“r^2” coefficient of determination, (or the degree of scatter around the line of best fit)	AE = 100 * (1- r^2) 3.6%	Very High	-
	Annual flow time series: Assembled reach calibration stages: CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD +8.3%	Very High	4,829 (1) 5,086 .

Notes:-

Annual comparison in GL/yr

(#) See Appendix E for methodology of calculating the quality assessments

Like Walgett, the results shown in Table 3.7 (Bourke) are good given the amount of uncertainty evident in the inflows and the adjustments that were required in both this and reach U/S of Walgett.

As shown in Table C.0.1 and Table C.0.2 the flow pumping range at Bourke extends from as low as 350 ML/d (i.e. A Class under 1993/94 threshold conditions) to almost 60,000 ML/d (i.e. floodplain access). Table 3.7 indicates that for this flow range (i.e. 350 – 60,000 ML/d) the model was able to replicate daily flows very accurately and overall errors were between 3 to 7%. The cumulative impact of the uncertainty of water extractions shows up in the low flow range with quality classification slipping to ‘very low’ for flows less than the 88 percentile (480 ML/d).

3.2.2.3 Calibration of Bourke to Wilcannia Reach

In this reach there were no problems with "missing" inflows (see Table 3.8) as there is very little tributary inflows into this reach at all, only the Warrego River, which is gauged and regularly contributes relatively very small inflows. The Paroo River which has a very significant catchment and also receives a large contribution from the Paroo River via the Cuttaburra Channels, rarely contributes any inflows. In more then a century, the Paroo River has only flowed into the Darling River on less then the half a dozen times and the maximum rate of inflow was only a few thousand megalitres per day. As a consequence it is not represented in the model. With large losses dominating this reach, particularly during flood events, there was no need to factor tributary Warrego River inflows.

Table 3.8 Missing Inflows into Bourke to Wilcannia Reach

Flow Events	Major 1971 (1)	Intra (2) event	Major 1974 (3)	Intra (2) event	Major 1976 (4)	Minor 1977 (5)
Peak Flow @ Bourke (6) (ML/d)	220,000	21,000	470,000	26,000	530,000	65,000
	Vol. (GL)	Vol. (GL)	Vol. (GL)	Vol. (GL)	Vol. (GL)	Vol. (GL)
Total Tributary Inflows U/S of Wilcannia (Bourke flows plus Warrego)	8,765	3,260	11,575	3,300	15,245	5,990
Wilcannia Observed (425002)	6,215	2,980	9,170	3,265	11,290	5,090
Difference: U/S Trib's. – Wilcannia	2,550	280	2,405	35	3,955	900
Difference as % of Trib. Inflows	29%	9%	21%	1%	26%	15%

Notes:
(1) Major event 1970-71: 29/09/70 – 10/07/1971
(2) Intervening period of generally low flows
(3) Major event 1974: 11/07/73 – 18/04/1974
(2) Intervening period of generally low flows
(4) Major event 1976: 01/01/76 – 30/06/1976
(5) Minor event 1977: 01/07/76 – 31/12/1977
(6) Peak flow at Bourke is a more reliable measure of the extent of tributary over bank flow than volume

Presented below are the results obtained from the final calibrated assembled model for the Wilcannia (total flow) gauging location (GSN 425002). Figure 3.6 shows the daily flow frequency comparison and Figure 3.7 shows the time series of annual flow volume comparison. Due to the significance of Wilcannia as a measuring point, virtually an end of system, additional figures have been included. Figure 3.8 shows the daily time series of driest annual period while Figure 3.9 shows the wettest period. Table 3.9 shows the quality of model fit achieved.

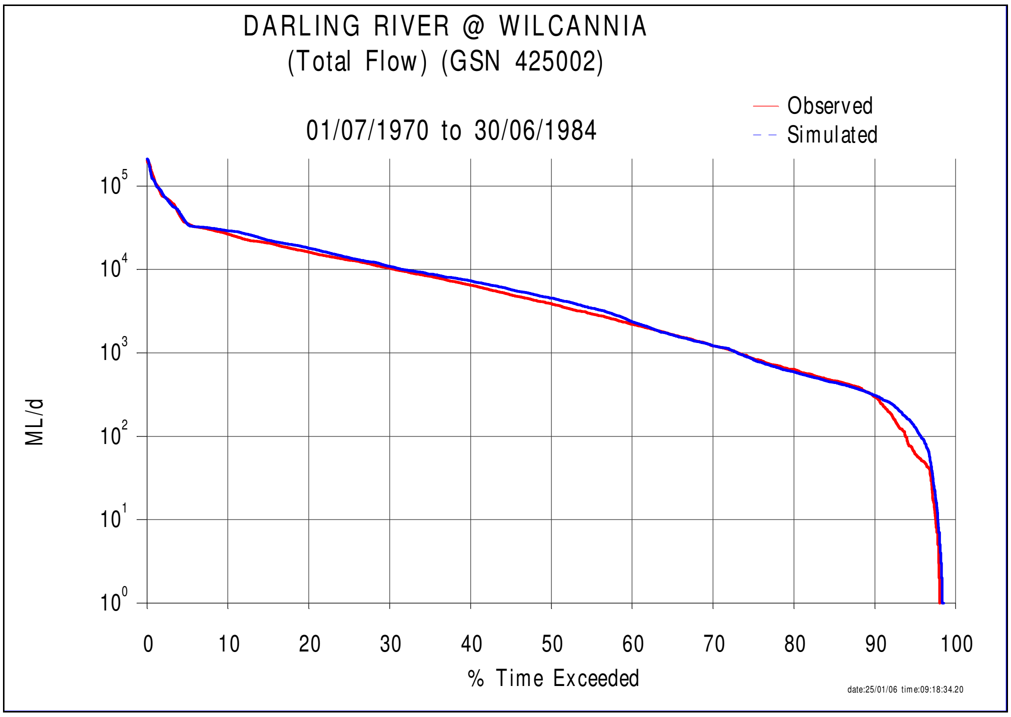


Figure 3.6 Darling River at Wilcannia – Daily Flow Frequency

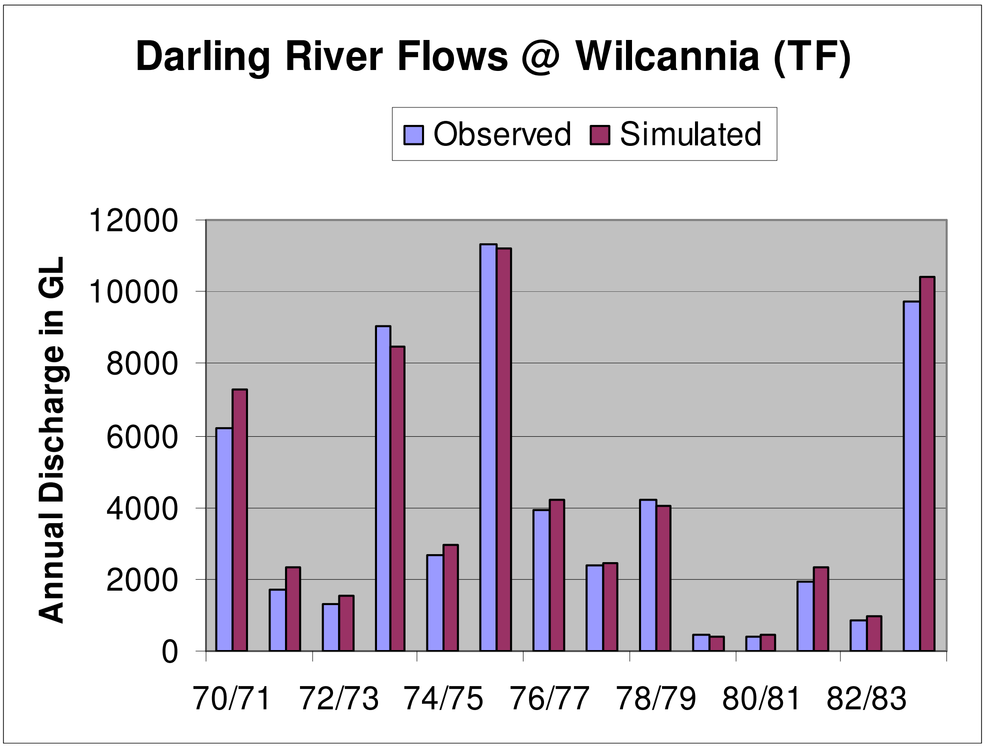


Figure 3.7 **Darling River at Wilcannia – Annual Discharge Comparison**

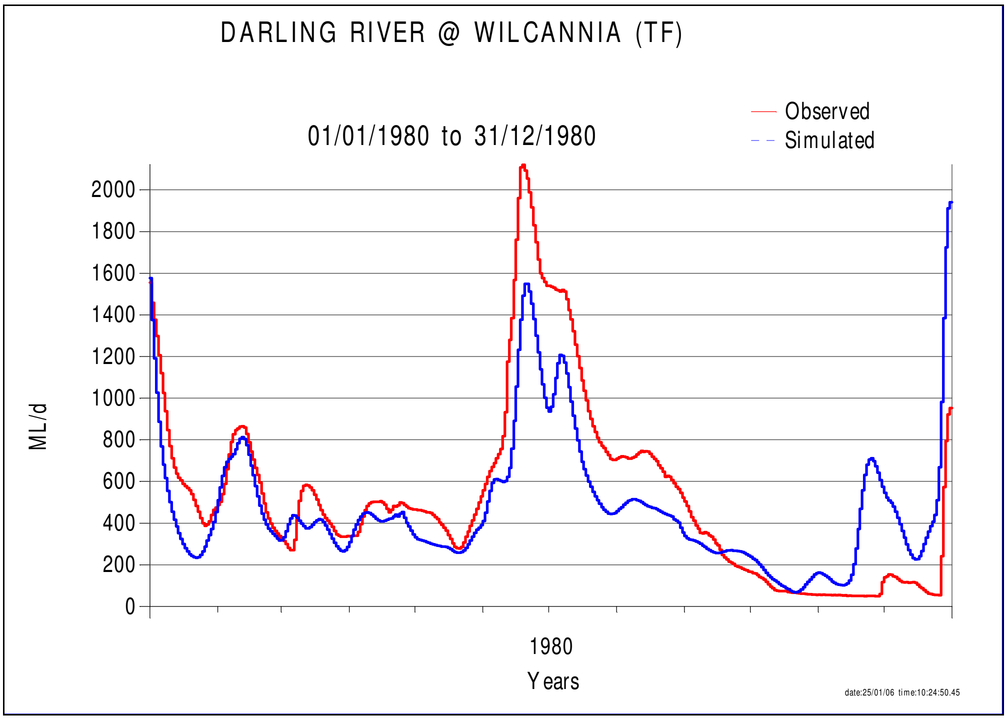


Figure 3.8 **Darling River at Wilcannia – Driest Annual Calibration Period**

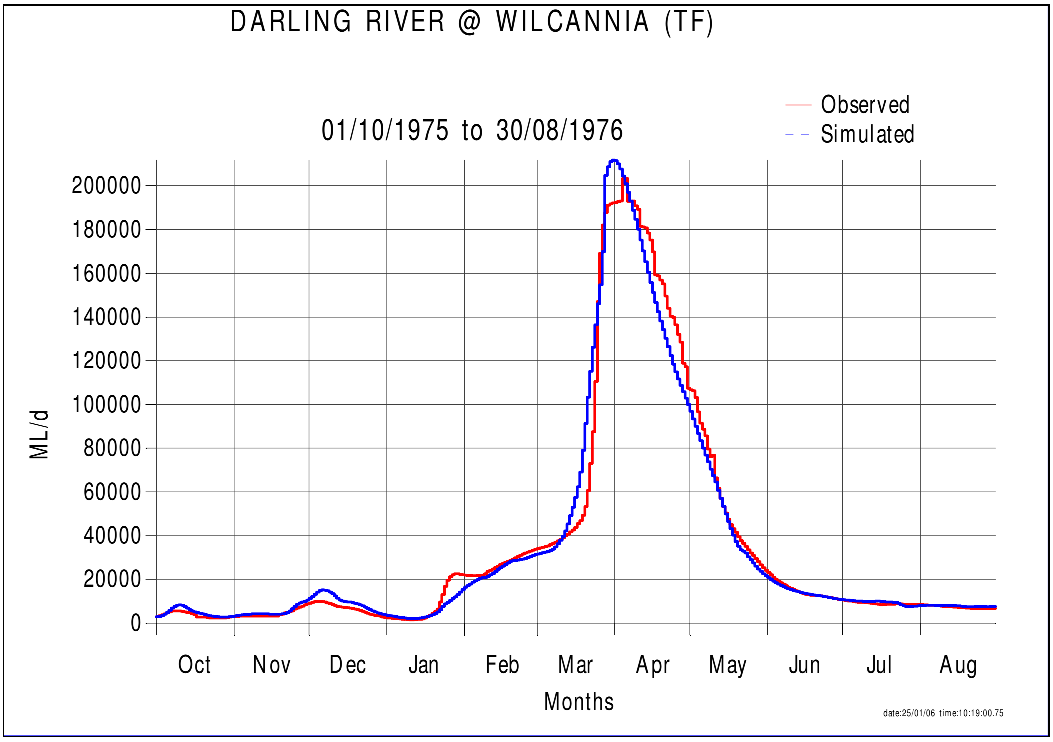


Figure 3.9 Darling River at Wilcannia – Wettest Annual Calibration Period

Table 3.9. Wilcannia – Flow Calibration Quality Indicators(#) for period 1970 - 1984

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT*		*QUALITY RATING GUIDELINES (See Appendix E for details)*	*AVERAGE FLOWS FOR RANGE*
		Definition	*Apparent Error (AE)*		*OBSERVED / SIMULATED (ML/D)*
FLOW FREQUENCY REPLICATION (ranked daily flows)	VOLUME RATIO (vr) Where "vr" = 100 * (Simulated / Observed) Expressed as a %	Whole flow range	AE = ("vr" – 100) +5.0%	High	10,980 11,5360
		Low flow range from 89%ile (340 ML/d) to 100%ile (0 ML/d)	AE = ("vr" – 100) +30.3%	Low	115 150
		Mid flow range from 6%ile (32,600 ML/d) to 89%ile (340 Ml/d)	AE = ("vr" – 100) +9.2%	High	7,820 8,555
		High flow range from 0%ile to 6%ile (32,600 ML/d)	AE = ("vr" – 100) -1.2%	Very High	74,500 73,900
FLOW TIME SERIES REPLICATION	Daily flow time series – line of best fit: r^2	"r^2" coefficient of determination, (or the degree of scatter around the line of best fit)	AE = 100 * (1- r^2) 5.0%	Very High	-
	Annual flow time series: Assembled reach calibration stages: CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD +8.2%	Very High	4,011 (1) 4,212

Notes:-

Annual comparison in GL/yr

(#) See Appendix E for methodology of calculating the quality assessments

The results shown in Table 3.9 are good, particularly as they are the accumulation of all errors upstream, but they continue to show the same "low flow" trends as was observed at Walgett and at Bourke. In the "low flow range" the apparent error between simulated and observed daily flows is +30%, with a quality rating described as only "low". Figure 3.8 visually demonstrates the daily variations that can occur between simulated and observed daily flows during a low-mid flow period. Although, these "low" flow errors seem significant, the impact on irrigation diversions is significantly less, not the least, because irrigation development in the reaches Louth to Wilcannia is so very small.

3.2.2.4Calibration of Wilcannia to Menindee Reach

The extension of the model from Wilcannia to Menindee was completed in 2008. The work undertaken to analyse the complex movement of water and the full development of a model for this reach is the subject of a separate report [DWE, 2008], the following is a summary of salient points.

The river and floodplain inflows to the reach are very adequately defined by the two streamflow gauging stations located on the Darling River and Talyawalka Creek. There are no other tributary inflows. The outflow from the reach is defined as the inflows to Lake Wetherell and the floodplain flow that by-passes the Lake and exits the reach in the effluent creeks of the Talyawalka Floodplain at railway bridges of the Main Western Railway.

The data used for the calibration of this reach includes flow and storage records of varying lengths obtained at the following gauging stations and sites:
Inflows:-
Darling River at Wilcannia [Total Flow] -GSN 425002: (Length of Record [LoR] 1886-2004)
Darling River at Wilcannia [Main Channel]-GSN 425008: (LoR 1971-2004)
Talyawalka Creek at Barrier Highway -GSN 425018 (LoR 1971-2004)
Intra-reach flows:-
Talyawalka Creek at Kangaroo Water Holes (LoR 1998-1999)
Outflows:-
Darling River at Menindee Town -GSN 425001 (LoR 1881-1960)
Darling River at Weir 32 -GSN 425012 (LoR 1958-2004)
Main Weir (OIC*) flows -GSN 425034 (LoR 1967-2003)
Lake Pamamaroo (OIC*) inflows -GSN 425024 (LoR 1967-2003)
Lakes Wetherell & Pamamaroo (OIC*) regulator outflows (LoR 1967-2003)
Lakes Wetherell (OIC*) storage volumes (LoR 1967-2003)

Note (*) OIC are Officer in Charge daily read gate openings or levels converted to volumes by Operational rating tables.

Also used in calibration were a significant number of spot flow gaugings for a number of locations within the reach during the flood events of 1971,1974,1976,1990 & 1998. A schematic diagram of the reach, showing significant rivers and creeks, movement of floodplain flows and flow measurements sites is located at Figure 3.10.

Although the outflow locations have been identified the calculation of these outflows requires very careful assessment due to the impacts (ie impoundings, evaporative losses, releases and transfers) of Menindee Lakes. Also to be considered are the losses to terminal lakes and the extensive floodplains, as well as the considerable inaccuracies in measurement of outlows at Menindee (ie Weir 32) particularly during floodplain flows.

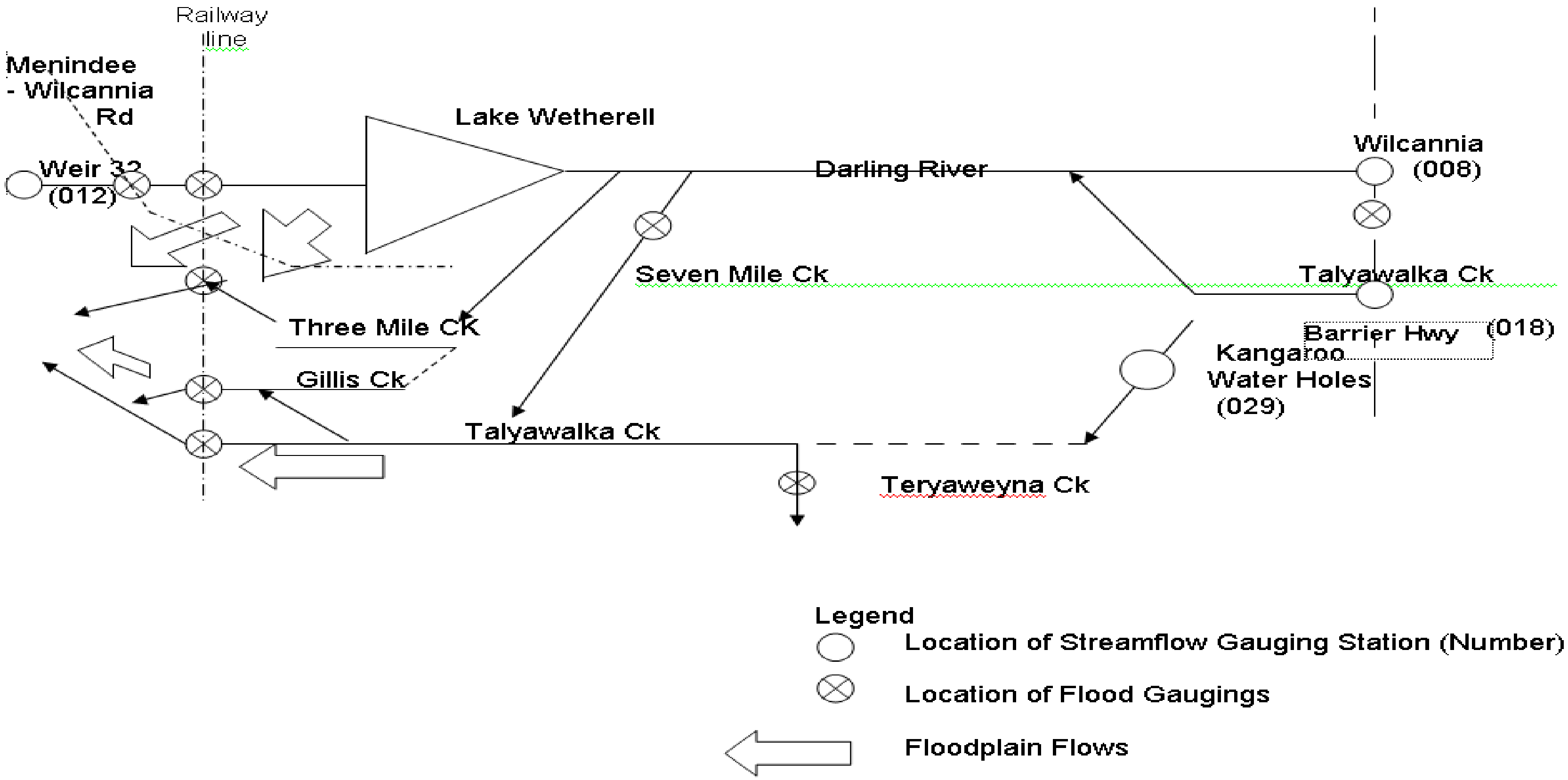


Figure 3.10 Schematic Diagram of Wilcannia – Menindee

Darling River 'in-bank' Seepage Losses

During 'in-bank' flow times (i.e. when flows are less than 15,000 ML/d and when there are no Main Weir releases), it was intended to define flows into Lake Wetherell using a 'back-calculated' approach. Although there is sufficient OIC data for purpose, the errors in the 'back-calculated' inflows appear so relatively large, erratic and unrealistic for such lengthy periods (see Figure 3.11), as to make them unsuitable for the purposes of daily calibration. Consequently flows at Wilcannia and Menindee, prior to the construction of Menindee Lakes Scheme, were utilised to define in-bank flow losses. These losses were later prorated, based on relative lengths, to define Wilcannia to Lake Wetherell losses.

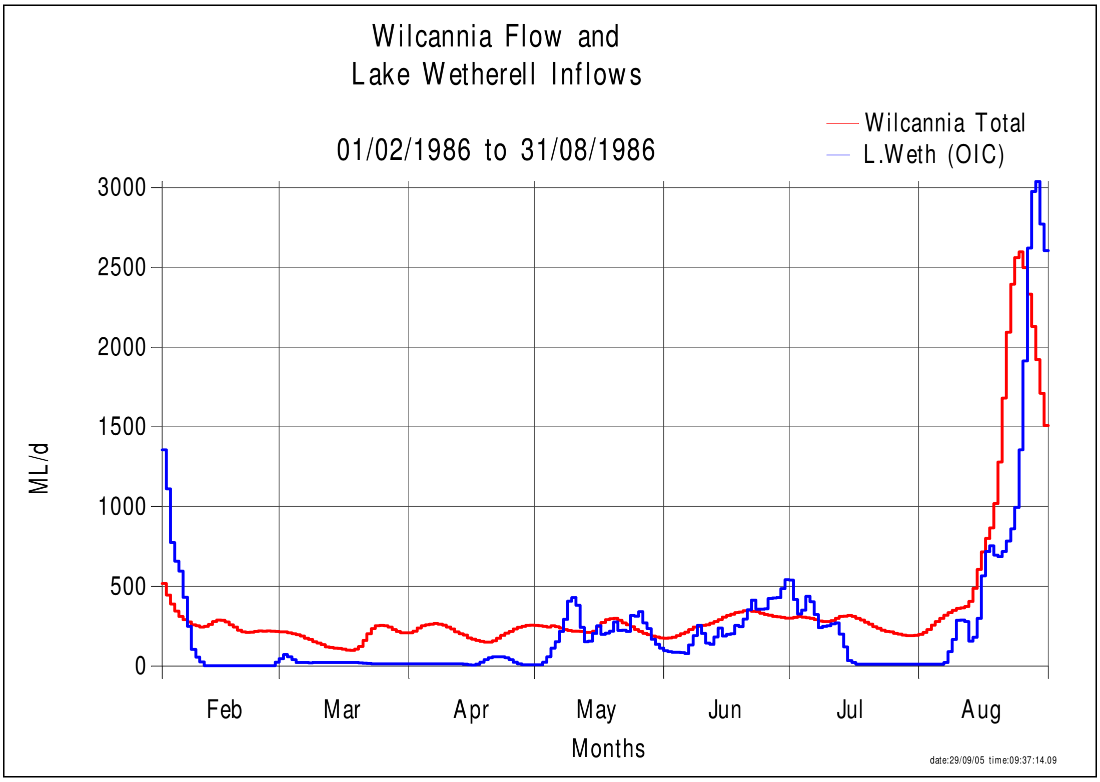


Figure 3.11 Comparison Wilcannia flows and 'back-calculated' Lake Wetherell inflows

Presented below are the results obtained from the calibrated 'in-bank' Wilcannia - Menindee model. Note unlike previous reaches, the model for this reach uses observed inflows. Flows less then 15,000 ML/d, on some 2100 days, were used for the calibration period (1927 – 1937), while the validation period (1937 – 1959) had some 2800 days of low flows. Figure 3.12 shows the daily flow frequency comparison for calibration period and

Figure 3.13 shows the time series of annual flow volume comparison for both periods, while Table 3.10 shows the quality of model fit achieved.

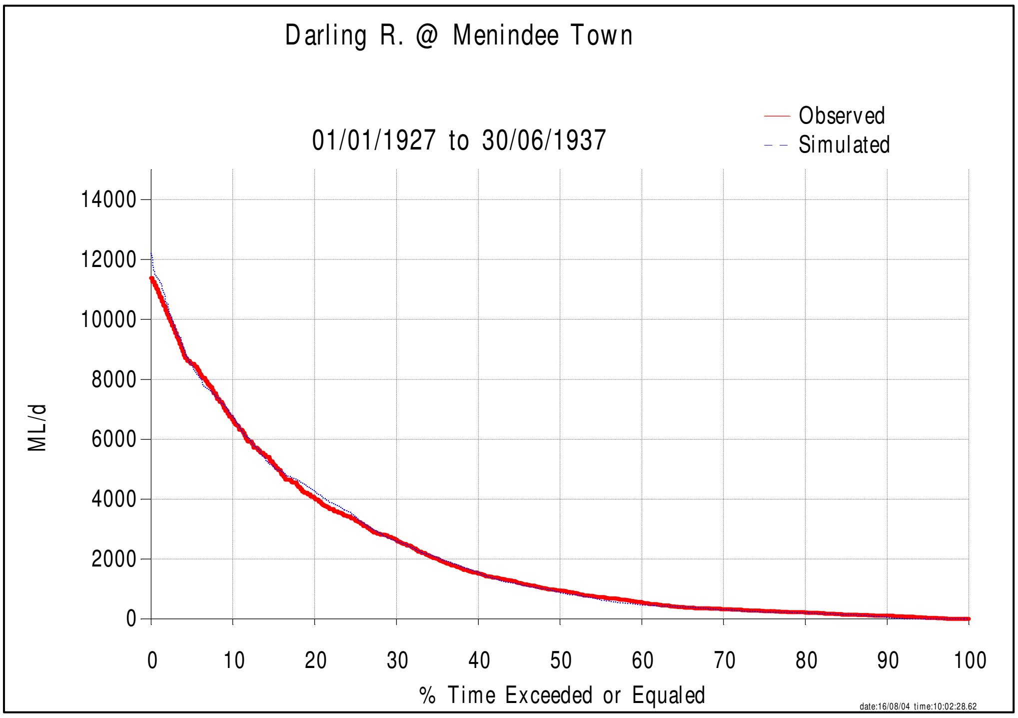


Figure 3.12 Darling River at Menindee – Daily Flow Frequency_Calibration Period

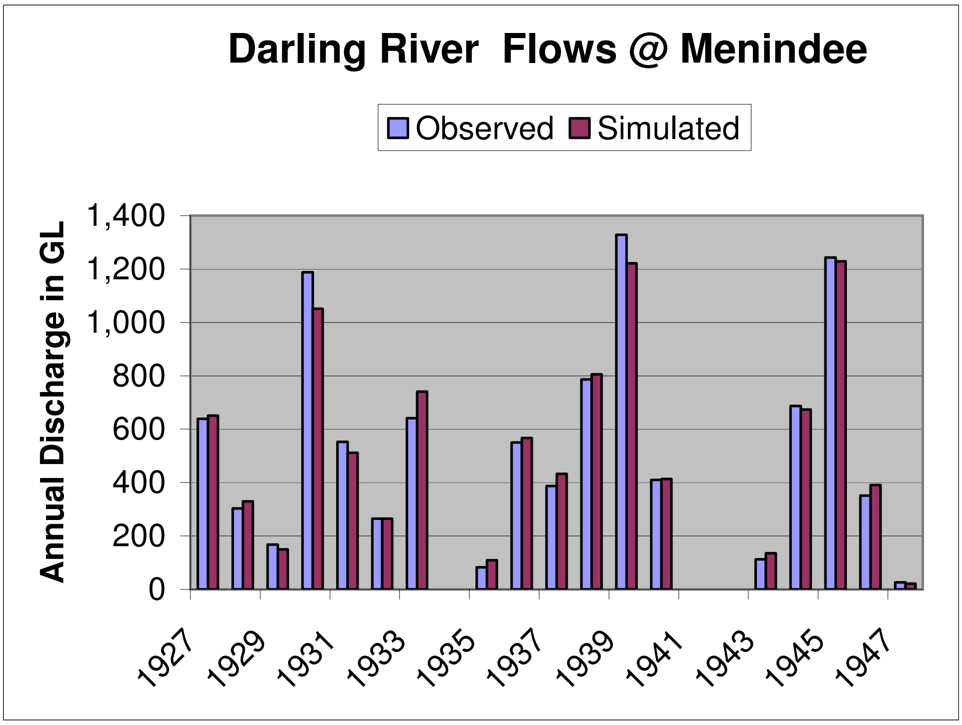


Figure 3.13 Darling River at Menindee – Annual Discharge Comparison

Table 3.10 Menindee – 'In-bank' Flow Calibration Quality Indicators(#) for Flows <15,000 ML/d during the period 1927 - 1959

PRIMARY FOCUS	***QUALITY INDICATOR***	***SUB-ASPECT***		***QUALITY RATING GUIDELINES (See Appendix Appendix E for details)***	***AVERAGE FLOWS FOR RANGE***
		Definition	***Apparent Error (AE)***		***OBSERVED / SIMULATED (ML/D)***
FLOW FREQUENCY REPLICATION (ranked daily flows)	VOLUME RATIO (vr) Where "vr" = 100 * (Simulated / Observed) Expressed as a %	'In-bank' Calibration range (0 – 15,000 ML/d)	AE = ("vr" – 100) -0.2%	Very High	2,185 2,365
		Lowest flow range from 60%ile (480 ML/d) to 100%ile (0 ML/d)	AE = ("vr" – 100) -7.5%	High	130 170
		Mid flow range from 20%ile (27,000 ML/d) to 60%ile (480 Ml/d)	AE = ("vr" – 100) +1.6%	Very High	1,500 1,495
		Higher flow range from 0%ile to 20%ile (,000 ML/d)	AE = ("vr" – 100) +0.1%	Very High	6,980 6,875
FLOW TIME SERIES REPLICATION	Daily flow time series – line of best fit: r^2	"r^2" coefficient of determination, (or the degree of scatter around the line of best fit)	AE = 100 * (1- r^2) 4.1%	Very High	-
	Annual flow time series: Assembled reach calibration stages: CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD +6.7%	Very High	9,721 (1) 9,697 .

Notes:-

Annual comparison in GL/yr

(#) See Appendix E for methodology of calculating the quality assessments

To define losses during over-bank flow times (i.e. greater then 15,000 ML/d) requires careful assessment of:

- Talyawalka Creek flows which pass Kangaroo Water Holes gauging station (425029);
- Seven Mile Creek and its associated floodplain which offtakes from the Darling River about half way between Wilcannia and Menindee; and
- releases from Lake Wetherell.

Effluent flows from Darling River

For Talyawalka and Seven Mile Creek there are sufficient flood gaugings available with which to develop effluent relationships to describe flows entering the floodplain upstream of Lake Wetherell. However to ensure these relationships are robust, flows over the entire floodplain were evaluated. This approach makes use of the extensive streamflow gaugings available on Talyawalka Creek at Menindee Railway Bridge available for the 1971, 1974 and 1976 flood events. From these gaugings daily streamflows were correlated based on Darling River flows to produce a set of daily 'target' flows. Table 3.11 shows the match that was achieved between gauged and correlated flows.

Table 3.11 Comparison of Talyawalka Creek Flows at Railway Bridge

Event	Number of Gaugings	Gauged Flows (GL)	Correlated Flows (GL)	Correlated Flows (% of Gauged)
1971	**9**	**85.8**	**94.9**	**111 %**
1974	**18**	**193.3**	**185.7**	**96 %**
1976	**7**	**133.7**	**124.1**	**93 %**
All	**34**	**413.2**	**407.9**	**99 %**

The effluent function for Seven Mile Creek offtake plus floodplain losses were developed simultaneously so that the simulated flows matched the 'target' flows during the calibration period (03/01/1971 – 31/12/1979). The results of the completed flow calibration are shown in Table 3.12, while Figure 3.14 shows a comparison of daily flows for the 1974 flood event.

Table 3.12 Comparison of Talyawalka Creek Flows

Event Date	**Corl. Flows @ Rly. Bdge.**	**Sim. Flows @ Rly. Bdge.**		**Sim. Contribution from Seven Mile Creek.**	
	Vol. (GL) *[Peak Discharge] (ML/d)*	**Vol. (GL)**	**As % Corl. Flow (%)**	**Vol. (GL)**	**as % Corl. Flow (%)**
15/12/70-31/07/71	733 ***[16,000]***	595	81%	442	60%
15/01/74-15/06/74	836 ***[20,000]***	783	94%	615	73%
13/01/76-29/06/76	1367 ***[24,000]***	1458	106%	1209	88%

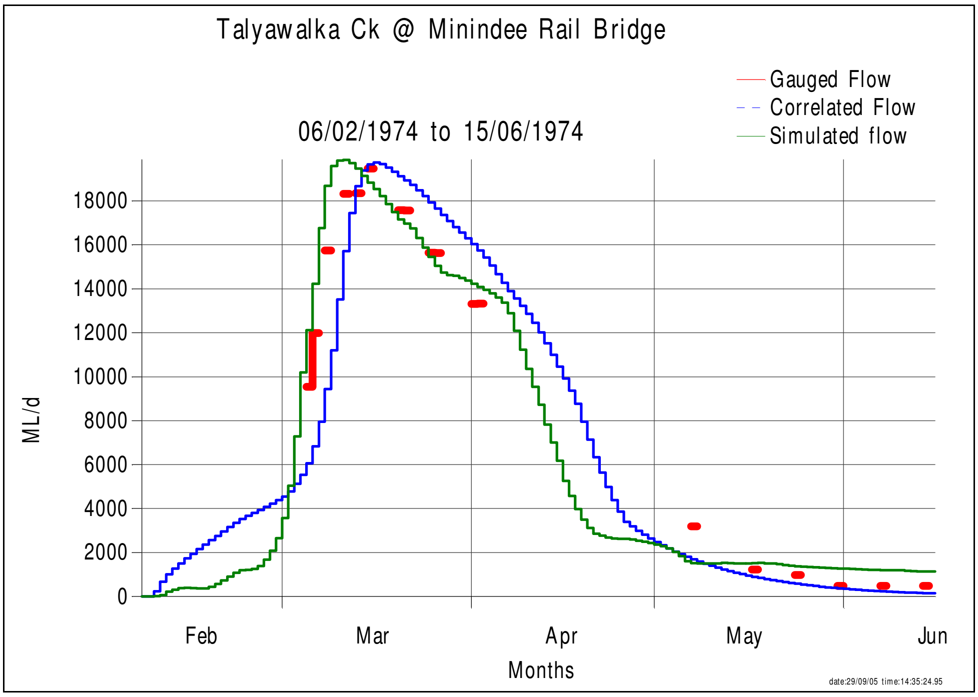


Figure 3.14 Comparison of Gaugings and Talyawalka Creek Flows (1974 Event)

Releases from Lake Wetherell

Although the evaporative problems for OIC 'back-calculated' inflows are relatively insignificant during over-bank flow times, the OIC calculated releases from Lake Wetherell have been shown, through gaugings, to have considerable inaccuracies with a tendency to overestimate outflows. Also the streamflow gauge (Darling River at Weir 32) which has the potential to provide accurate estimates for the majority of the outflows (i.e. Main Weir releases) is at times under measurement. This occurs during periods when releases are transitioning from main channel flows to floodplain flows (i.e. outflows in the range from 20,000 to 40,000 ML/d) and for all events post 1980 when outflows exceed 20,000 ML/d, as "total flows" are no longer being measured at Weir 32.

With no definitive set of 'target" inflows available it was decided to use the available information as an upper and lower bound. Table 3.13 shows the results obtained using all OIC data and a revision of Main Weir releases using Weir 32 data.

Table 3.13 Lake Wetherell - Inflows for flood events

Event Period	**Wilcannia Total Flow**		**'Back-calculated' Lake Wetherell Inflows**			
			OIC Based		**Revised using Weir 32**	
	Peak Discharge (ML/d)	**Event Volume (GL)**	**Event Volume (GL)**	**Lost Volume (% of Wilc.)**	**Event * Volume (GL)**	**Lost Volume (% of Wilc.)**
16/12/1970 – 29/07/1971(1)	**106,000**	**5,788**	**4,565**	**21.1**	**4,226**	**27.0**
15/01/1974 – 13/06/1974(2)	**149,000**	**6,450**	**5,156**	**20.5**	**4,843**	**24.9**
15/01/1976 – 29/06/1976(3)	**200,000**	**10,530**	**8,660**	**17.8**	**7,038**	**33.0**
11/04/1990 – 23/01/1991(4)	**80,000**	**6,478**	**7,094**	**- 9.5**	**5,836**	**10.0**
16/07/1998 – 29/01/1999(4)	**104,000**	**6,882**	**5,057 #**	**26.5**	**4,334**	**37.0**

NB * These statistics include periods when observed flows at Weir 32 are:
Suspected to only be only partial floodplain flows [ie Only Main Channel for Period (1) 6/3 – 27/3/1971: Period (2) 25/1 – 14/3/1974: Period (3) 15/2 – 8/4/1976;
All Post 1990 Periods (Noted 4) exclude floodplain flow and as a consequence these 'lost' volume estimates will be an over-estimate.
OIC data missing, approx 600 GL has been included as an estimate

Presented below are the results obtained from the calibrated 'over-bank' Wilcannia - Menindee model and again this model uses observed inflows.

Table 3.14 compares the results obtained for the 8 'over-bank' events between 1971 and 1998. This table shows simulated inflows are consistently less then OIC 'back-calculated' inflows, while being consistently greater then the revised 'back-calculated' inflows. This is consistent with the conclusions drawn, in that, the OIC method of 'back-calculation' appears to overestimate inflows whereas the revised 'back-calculated' method is an under-estimate due to lack of consistent total flow measurement at Weir 32. The overall 'over-bank' water balance shows that simulated flood flows are 94% of OIC and 109% of revised 'back-calculated' estimates.

Table 3.14 Comparison of Lake Wetherell Inflow Flood Events

Event Period	Simulated Inflows		Simulated as Percentage of Back Calculated Inflow	
	Peak Discharge (ML/d)	**Event Volume (GL)**	**OIC Method (%)**	**Revised Method (%)**
13/01 – 25/07/1971	**65,000**	**4,409**	**100**	**102**
22/01 – 13/06/1974	**80,000**	**4,706**	**92**	**98**
25/01 – 28/06/1976	**125,000**	**7,203**	**85**	**104**
20/03 – 21/08/1977	**32,000**	**3,566**	**91**	**110**
23/08 – 13/11/1984	**36,000**	**2,260**	**98**	**137**
30/04 – 25/09/1989	**31,000**	**3,614**	**105**	**150**
26/04 – 14/11/1990	**50,000**	**6,421**	**93**	**114**
08/08 – 14/12/1998	**70,000**	**4,759**	**97**	**114**

Figure 3.15 shows a favourable comparison of 'back calculated' and simulated inflows for 1976 flood event.

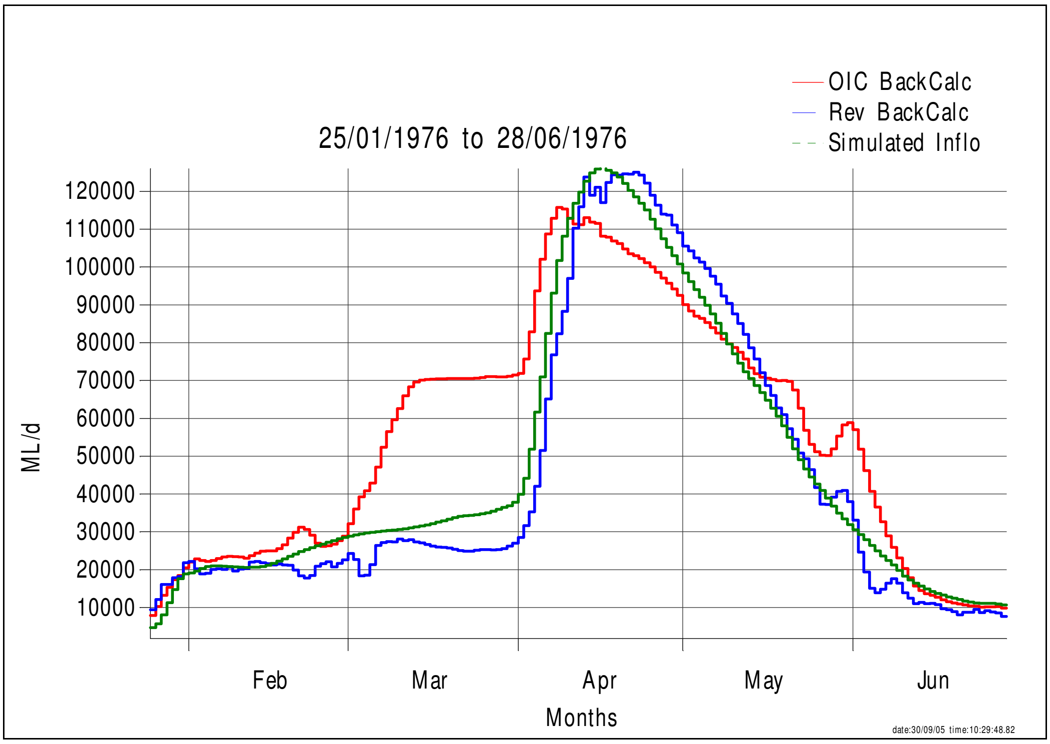


Figure 3.15 Comparison of Lake Wetherell Flood Inflows (1976 Event)

3.2.2.5 Adjustment for 1956 Floods

Following a review of the combined outflows (i.e. Lake Wetherell inflows plus Talyawalka Creek at Railway Bridge) from the model by MDBA in 2008 it was decided because of the significance of the volume involved, to develop a method to add extra flows during the 1956 floods to those simulated by the model. The work undertaken and the methodology adopted is the subject of a separate report [MDBA, 2008]. Monthly inflows from May, 1956 to December, 1956, for Natural & Current and Climate change scenarios were developed. A uniform daily pattern was applied to these monthly inflows.

Figure 3.16 shows the impacts of adding these extra daily flows at the Menindee Town Gauge (GSN 425001) during the 1956 flood.

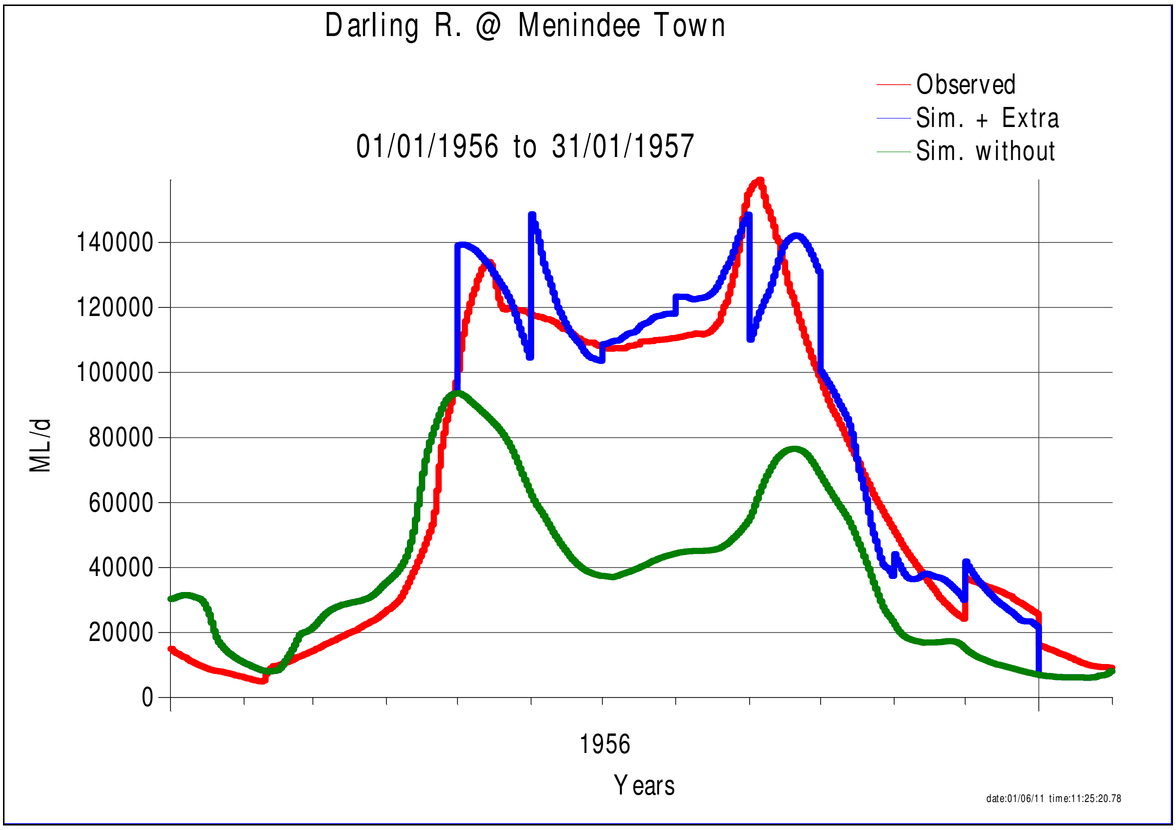


Figure 3.16 Comparison of 1956 Menindee Flood Event

3.3 IRRIGATION DIVERSION CALIBRATION

3.3.1 Background and methodology

It is worth noting that any achieved calibration can only be as accurate as the recorded diversions upon which it is based. As noted in section 2.6 these metered diversions had to be adjusted to offset the changes that occurred in the annual agreed pumping rates (i.e. conversion from pump rpm to discharge in ML/d) prior to 1999/2000. This change has caused an overall reduction of about 2% in the raw historical diversions. Also of interest, is a study currently underway to determine the full effects of changes in river heights on agreed pumping rates along the Barwon and Darling Rivers. Initial results from the study has shown that in some years, some irrigator's annual diversions may be understated by existing 'Time and Event' meters by over 20%.

The objective of this step was to calibrate the metered river diversions through adjustment of crop water demand and on-farm water management modules over the calibration period [DLWC, 1998[c]]. IQQM uses a soil moisture accounting model and net crop evapotranspiration rates to generate irrigation demands. These daily demands are supplied from the OFS which in-turn is replenished from river diversions, as well as floodplain and rainfall-runoff harvesting.

The calibration process utilises the flow calibration parameters (routing, losses and residual inflows) and observed irrigation crop and infrastructure data (i.e. crop areas planted and types, areas from which rainfall-runoff can occur, OFS and pump capacities). Appropriate rainfall and evaporation data is selected to drive the crop demand module. The IQQM modeller adopts potential crop factors based on factors contained in the literature [Allen, et. al., 1998] and [Doorenbos and Pruitt, 1984]. The parameters for the size of the soil moisture store are based on the root depth of cotton and irrigator experience, while rainfall interception loss is based solely on literature. Floodplain harvesting configuration (access and rate) is based on information provided by irrigators (See Section 2.8.5.2), as is, the configuration of OFS airspace for rainfall-runoff harvesting (See Section 2.8.4). The calibration parameters are the crop watering efficiency for each crop type and the rainfall-runoff harvesting efficiency, as well as, OFS seepage. The on-farm storage operation is also modelled at this step. This includes, for some irrigators the estimation of OFS airspace for floodplain harvesting configuration. Values for all of these parameters are adjusted until the simulated metered river diversions best match the observed data (Appendix E2). This is a complex process with all of the parameters interacting with each other and a number of iterations are required. This process is only applicable to the 30 individual large scale irrigators for which metered diversion and infrastructure data is available.

An appropriate calibration period must be selected for the diversion calibration. As IQQM has the facility to incorporate development changes over the calibration period (i.e. use of time series input parameters), it is more appropriate to use a period that has a range of climate and flow conditions then to settle for a short period near a particular development level. There must also be good quality, reach-by-reach diversion data available. Consideration of these issues resulted in a calibration period from 1995/96 to 2004/05 being selected. However because of changes to licence access conditions in 2000/01 two separate calibration models are required:

- 1988/89 to 1999/00: Annual accounting without carryover; Commence to Pump thresholds based on 'old' riparian requirement.
- 2000/01 to 2004/05: Annual accounting without carryover; Commence to Pump thresholds based on 'new higher' environmental requirements.

3.3.2 Crop Demands and Efficiency

The climatic data used to drive the crop water demands was selected as indicated in Sections 2.3.1 and 2.3.2.

The IQQM modeller estimates the potential monthly crop factors, size of the soil moisture store and rainfall interception loss based on factors contained in the literature [Allen, et. al., 1998] and [Doorenbos and Pruitt, 1984. The crop factors used for different crops are presented in Appendix F.

Crop efficiency refers to the volume of water that reaches the root zone of the crop compared to the amount of water released from the OFS. Table 3.15 shows the range of crop efficiencies that were fitted during the calibration. This range of values also conforms to the Guidelines for predicting crop water requirements [Doorenbos and Pruitt, 1984].

Table 3.15. Calibrated Crop Efficiencies

Irrigation Efficiency (Fraction)	Number of Irrigators
0.70	9
0.75	21

3.3.3 Rainfall Harvesting Efficiency

Rainfall harvesting or rainfall-runoff re-cycling efficiency defines that portion of runoff, caused by rainfall falling on an area that is able to be captured and returned to OFS for later use. In this process runoff can occur from cropped, fallow and adjacent areas. This efficiency is affected by both physical layout of property and on-farm management decisions (See Sections 2.8.5.3).

To assist with the definition of these efficiencies use was made of the “Qualitative Assessment of Irrigation Delivery Efficiency for Farms on the Barwon-Darling River”. This Assessment was completed by two representatives (Irrigator and Dep’t of Agriculture) of the IQQM Reference Group, who utilised information from the Development History Project (remote sensed scenes and interview information) to provide comments on the layout and any development of each property for the years 1993/94 and 1999/2000. This assessment provided an understanding of and an establishment of the relativity between irrigators, it was also of great assistance in the selection of parameter values. It also established that the area laid out to irrigation (developed area) was, in all but a few occurrences, the area from which rainfall harvesting could occur.

The range of efficiencies (0.0 – 1.0) fitted during the calibration process, are shown in Table 3.16. Those properties with the lowest efficiencies tended to be the less efficient layouts and/or relatively higher application rates.

Table 3.16. Calibrated Rainfall Harvesting Efficiencies

Rainfall Harvesting Efficiency (Fraction)	Number of Irrigators
0.0 to 0.25	4
>0.25 to 0.5	15
>0.5 to 0.75	8
>0.75 to 1.0	3

3.3.4 OFS Seepage

OFS seepage is used to represent any seepage losses that occur from these storages (Note: that OFS evaporation losses are calculated separately, utilising daily evaporation rates {See Section 2.3.2.1} and derived OFS water surface area). In the model, seepage which is expressed by a rate (mm/day) occurs from an area equal to the water surface area. The slight difference between the water surface area, as used by the model and the wetted area as occurs in reality, should not cause any significant errors.

Seepage rates ranging from 0.0 to 1.0 mm/day were used for 90% of all properties, Table 3.17 shows the range of values fitted in the calibration process. The three properties with the highest seepage rates (1.5 mm/day) have quite small OFS which could be either fairly poorly constructed or are natural billabongs.

Table 3.17. Calibrated OFS Seepage Rates

OFS Seepage (mm/day)	Number of Irrigators
0.0	14
>0.0 to 0.5	7
>0.5 to 1.0	6
>1.5	3

3.3.5 Calibration Results and Discussion

Results from the final three calibrated assembled models that were developed for diversion calibration (I:\IQQM\DARL\QUANQUAL\CALIB\EXTRACT\2010Recalib\Valley Models\Integrated Valley Model Forced area\clnp211s.sys & clnz21[bb & 1b].sys) are presented below. However, to protect the anonymity of individuals, only aggregated results are presented. Results for the four river reaches, as well as the total valley, have been supplied. Below are graphical and objective measures of the quality of model fit achieved. These measures of quality are based on the quality assessment guidelines described in Appendix E (DLWC, 1999).

Attached at Appendix G are full details of the aggregated behaviour of 'major' irrigators at the completion of the forced area calibration. Annual comparisons of metered diversions, and OFS behaviour plus details on floodplain and rainfall harvesting volumes are included to provide an overall picture of water usage

Figure 3.17 shows the modelled and observed total annual metered diversion volumes for the whole Barwon-Darling system. Table 3.18 summarises the objective measures of the quality of model fit achieved for all irrigators and for the four reaches.

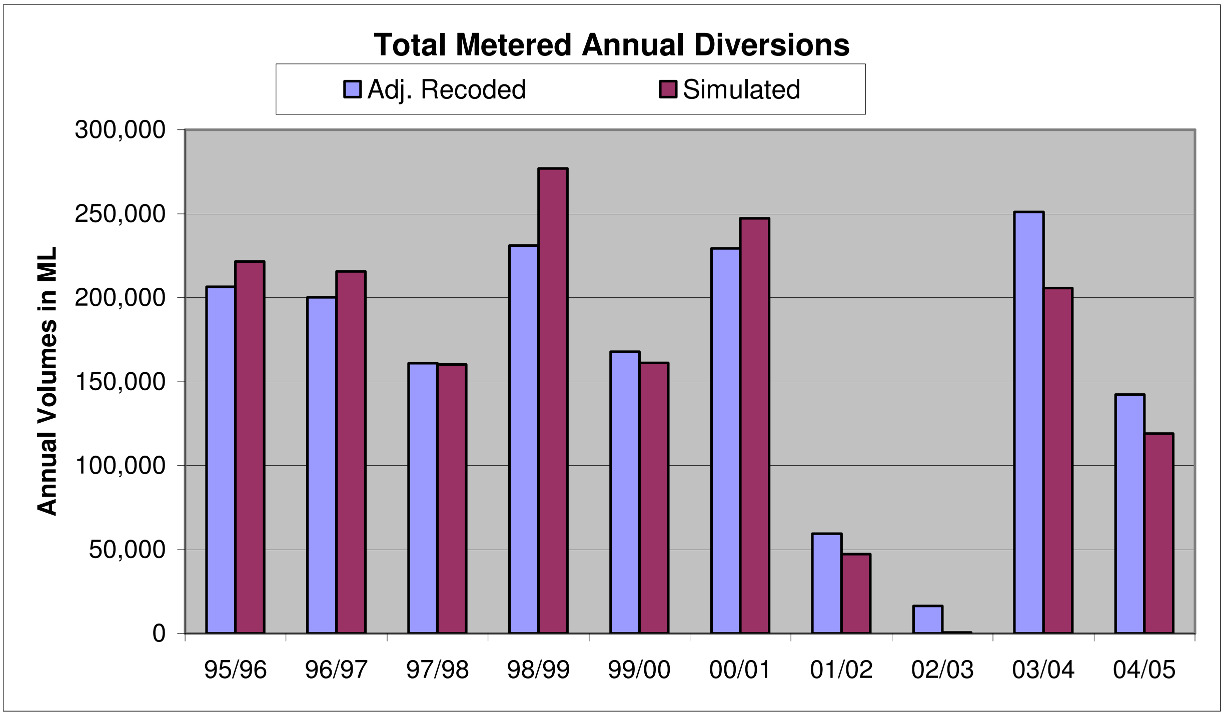


Figure 3.17 Total Valley – Adjusted Recorded and Simulated Diversions

Table 3.18. Diversion Calibration Quality Indicators(#) for period 1995/96 – 2004/05

SUBJECT		Observed	Simulated	Volume Ratio	Apparent Error	QUALITY RATING
Irrigator Group	Quality Indicator	GL	GL	%	%	
Whole System	Total Volume Comparison	1665	1645	98.8%	-1.2%	Very High
	Annual Time Series Match (CMAAD)	-	-	-	12.9%	High
Reach: Mungindi - Walgett	Diversion Volume Comparison	317	375	118.2%	18.2%	Low
	Annual Time Series Match (CMAAD)	-	-	-	27.5%	Very Low
Reach: Walgett - Brewarrina	Diversion Volume Comparison	412	413	100.4	0.4%	Very High
	Annual Time Series Match (CMAAD)	-	-	-	17.7%	Moderate
Reach: Brewarrina - Bourke	Diversion Volume Comparison	614	585	95.4	-4.6%	High
	Annual Time Series Match (CMAAD)	-	-	-	4.6%	Very High
Reach: Bourke - Wilcannia	Diversion Volume Comparison	322	272	84.3	-15.7%	Moderate
	Annual Time Series Match (CMAAD)	-	-	-	11.9%	High

Notes:

(#) See Appendix E for methodology of calculating the quality assessments

The results shown in Table 3.18 are good considering that:

- around 20 percent of the simulated water which was used on-farm during the calibration period is not metered (i.e. its floodplain and rainfall-runoff harvestings for which there's only some estimates for a few irrigators);
- the accuracy of the volumes in the OFS, as discussed in Section 2.8.2, particularly in the earlier years is very dubious; and
- the crop areas after 2000/01 are only irrigator estimates which are known to vary from actual (i.e. based on remote sensing information) by up to – 7% and + 9%.

Also the poor results for the Mungindi – Walgett and Bourke – Wilcannia reaches are caused by one large irrigator in each reach who obtains significant unmetered volumes from tributary inflows.

3.4 PLANTED AREA BEHAVIOUR

In the previous chapter planted areas for each 'major' irrigator were fixed to equal recorded values, whereas here the model calculates and simulates these areas. The planted area usually changes as a result of a number of factors including on-farm development, volume of water available in OFS, climate, and market conditions. Therefore matching the historical planted area is the most difficult process in model calibration.

The model utilises a number of parameters, which represent different aspects of irrigator's behaviour during their planting decision process. These include the crop mix, maximum summer or winter crop areas that they are prepared to plant and irrigators' risk rate or function.

3.4.1 Crop Mix

Over the 10 year period (1995 – 2005) most farms were mono-cropped with cotton and for those few farms who grew winter crops wheat was the dominate crop. However, even on these farms, cotton comprised well over 90 percent of all crops grown.

3.4.2 Maximum Areas

The maximum cropped area is derived based on the maximum area per crop type that an irrigator planted over the 10 year period. For about two thirds of the irrigators who didn't alter their area developed for cropping over this period then the maximum area per crop type was adopted. For those irrigators who altered their developed area over this period then a maximum crop area for each year of that development was defined.

3.4.3 Crop Planting Decision

Most irrigators take a planting risk, in that at planting time not all the water they need to grow the crop is stored in their OFS. The model utilises a nominated individual risk rate (i.e. expressed in ML/Ha) to define the planted area based on the stored volumes in OFS at planting date (i.e. 1st of October for summer and 1st of March for winter).

Although, both the irrigator's and the model's computation can be influenced by whether the soil is wet or dry at planting time, it was felt that there wasn't sufficient information available to develop a irrigator's response to its changing values.

Another factor that strongly influences a irrigator's planting decision is market considerations. However, this influence is not presently considered in the model, being a subject of possible further IQQM development.

An individual risk rate for each 'major' irrigator was developed based on observed behaviour in unconstrained years over the calibration period (i.e. 1995/96 – 2004/05). Details of the adopted methodology and an example of an irrigator worksheet to determine risk functions are attached at Appendix J. The risk rate, which is fixed for the entire calibration period, is the best estimate of risk that an individual has taken.

3.4.4 Behaviour Results and Discussion

The results of applying these individual risk functions are presented in graphical and tabular forms comparing the observed and simulated areas.

Figure 3.18 shows the modelled and observed summer (1st of February) total crop areas for the whole Barwon-Darling system. Table.3.19 summarises the objective measures of the quality of model fit achieved for each of the four irrigator groupings, as well as for the whole system. As previously, details of the quality assessments used in this calibration are outlined in Appendix E.

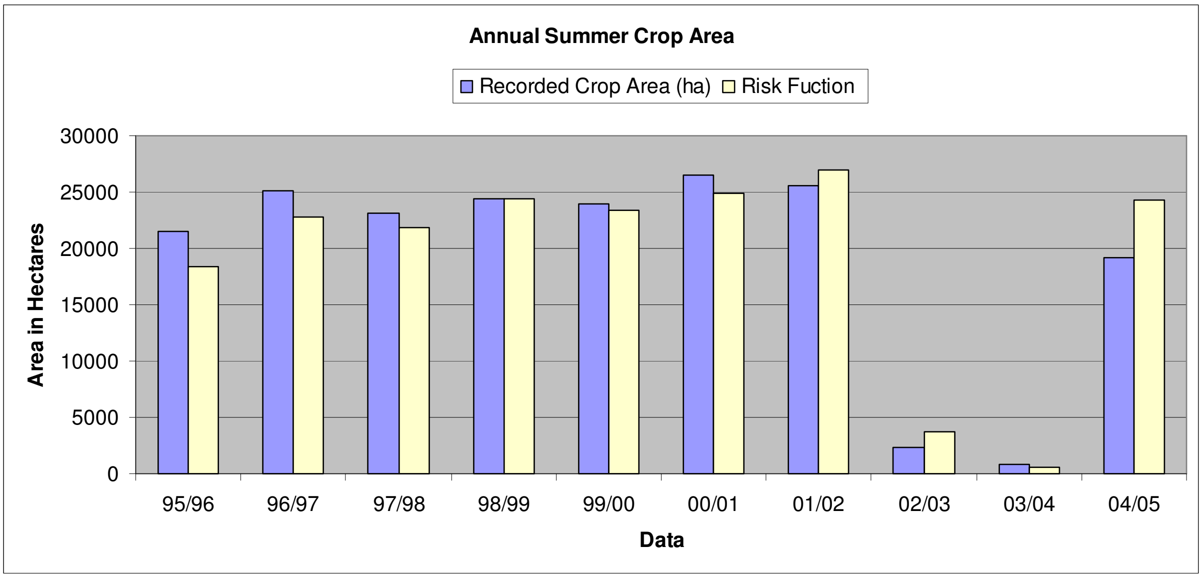


Figure 3.18 Barwon-Darling Valley –Observed and Simulated Cropped Areas

Table.3.19. Summer Area Behaviour Quality Indicators (#) for period 1995/96 – 2004/05

SUBJECT		Observed Average Annual Ha	Simulated Average Annual Ha	Area Ratio %	Apparent Error %	QUALITY RATING
Irrigator Group	**Quality Indicator**					
Whole System	Area Comparison	19,280	19,000	98.6%	-1.4%	Very High
	Annual Time Series Match (CMAAD)	-	-	109.7%	9.7%	High
Reach: Mungindi - Walgett	Area Comparison	5,970	6,017	101.5%	1.5%	Very high
	Annual Time Series Match (CMAAD)	-	-	126.1%	26.1%	Very Low
Reach: Walgett - Brewarrina	Area Comparison	4,000	3,930	98.0%	-2.0%	High
	Annual Time Series Match (CMAAD)	-	-	110.8%	10.8%	High
Reach: Brewarrina - Bourke	Area Comparison	5,970	6,069	101.1%	1.1%	Very High
	Annual Time Series Match (CMAAD)	-	-	109.6%	9.6%	High
Reach: Bourke - Wilcannia	Area Comparison	3,330	3,115	93.4%	-6.6%	High
	Annual Time Series Match (CMAAD)	-	-	110.2%	10.2%	High

(#) See Appendix E for methodology of calculating the quality assessments

The results shown in Table.3.19 are good considering that:

- model used an average risk rate for each irrigator over the entire calibration period while many irrigators exhibited significant fluctuations and a reduction trend in risk over the period. This trend is partially seen in Figure 3.18, with the simulated areas initially underestimating planted areas and then overestimating them in latter years;
- there are no observed OFS levels at planting date, therefore the risk function had to be based on OFS capacity. This assumption to use OFS capacity should give best results during that part of the calibration period that was average to wet period (i.e. 1996/97 – 2001/02); and
- the poor results for the Mungindi – Walgett reach can be attributed to one large irrigator who exhibited, at times, behaviour independent of available water.

Table.3.19 shows that for the whole system the apparent error in the comparison of crop areas over the 10 years is 1.4%, while a comparison in each year (i.e. CMAAD) had an apparent error of 9.7%. On an individual basis, the worst reach is Mungindi – Walgett even though the apparent area comparison error is only 1.5%, the annual time series match is very apparent error of 26.9%.

3.5 OVERALL MODEL CALIBRATION

In Sections 3.2 and 3.3, flow and irrigation demand calibration have been described. Depending on data availability, the individual parameters were calibrated for different time periods (i.e.1970-84; 1995/6-2004/05 etc). Now with adopted appropriate risk functions, these calibrated parameters are validated for a chosen common period (1995/6-2004/05). Although the chosen period may not permit an independent validation of crop areas (as this period was previously used for crop area behaviour), it was nevertheless used as there was no other periods with comprehensive data availability.

The tests of the overall quality of the model validation for the Barwon-Darling IQQM are an evaluation:

- of the degree of "impact" on the previously calibrated elements, and
- of selected key indicators.

3.5.1 Impact on Diversions

The impacts on diversions due to the introduction of individual irrigator crop area risk functions are compared with observed data in Figure 3.19 and in Table 3.20.

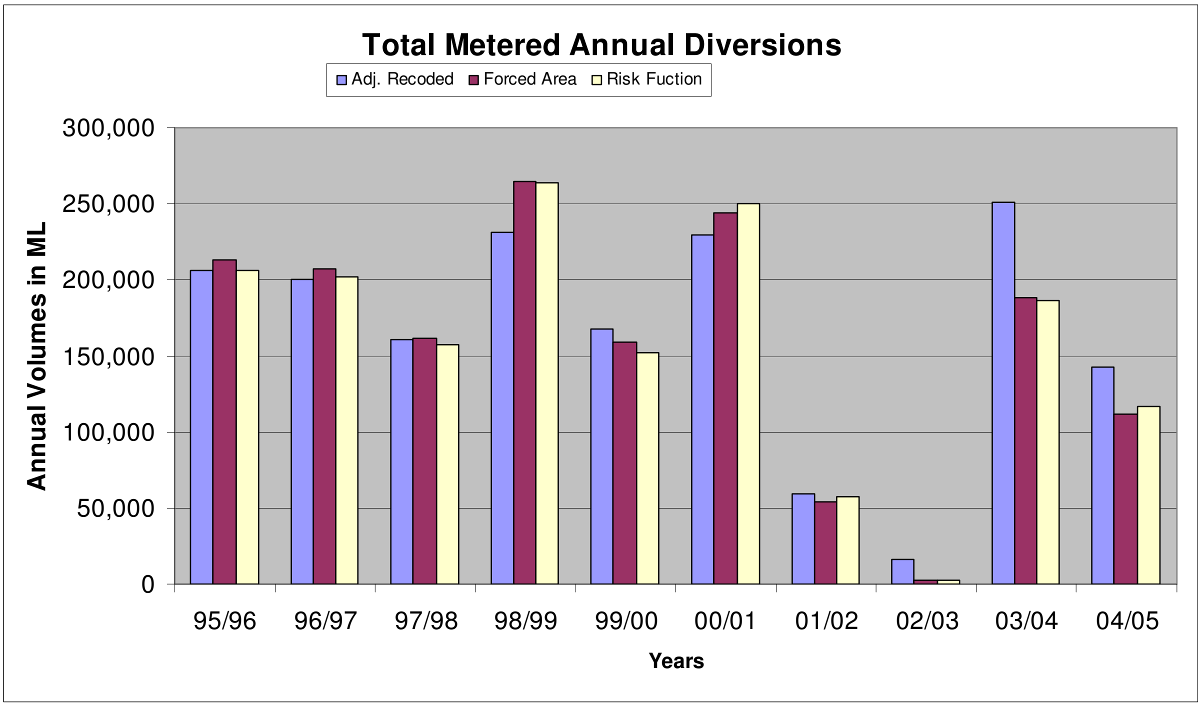


Figure 3.19 Barwon-Darling Valley – Adjusted Recorded and Simulated (Forced & Risk Function.) Diversions

Table 3.20. Comparison of Diversion Calibration Quality Indicators (#) (After Area Calibration) for period 1995/96 – 2004/05

SUBJECT of CHECK		Metered Diversion Volume Comparison		Annual T.S. Match
Impact on:-	Aspect	Overall Total (GL)	Diversion Ratio (Sim/Obs as %)	(CMAAD)
Whole System.	Old Value (*)	1,645	98.8%	112.9%
	New Value	1,595	95.8%	110.8%
(Obs. Div. 967 GL)	*New Quality Rating*	-	*Very High*	*Very High*
Reach: Mungindi – Walgett	Old Value (*)	375	118.2%	131.7%
	New Value	315	99.4%	132.6%
(Obs. Div. 180 GL)	*New Quality Rating*	-	*High*	*Very Low*
Reach: Walgett - Brewarrina	Old Value (*)	413	100.4%	117.7%
	New Value	412	100.0%	117.6%
(Obs. Div. 231 GL)	*New Quality Rating*	-	*Very High*	*Moderate*
Reach: Brew'ina - Bourke	Old Value (*)	585	95.4%	104.6%
	New Value	586	95.5%	107.6%
(Obs. Div. 376 GL)	*New Quality Rating*	-	*High*	*High*
Reach: Bourke - Wilcannia	Old Value (*)	272	84.3%	111.9%
	New Value	281	87.1%	104.5%
(Obs. Div. 180 GL)	*New Quality Rating*	-	*Moderate*	*Very High*

(#) See Appendix E for methodology of calculating the quality assessments

(*) As calculated in Diversion Calibration see Table 3.18 for previously achieved quality ratings

Key to Shading :-	No Shading = No Impact	Black = Worse by more than 2%	Grey = Better by more than 2%

Table 3.20 shows that overall there is very little change in the quality of diversion results through the introduction of the farmer's risk function. Detailed results from the integrated model are attached at Appendix G. This appendix shows annual observed and simulated metered diversions, crop areas and OFS behaviour. Together with simulated annual floodplain and rainfall-runoff harvested volumes for total system as well as individual reaches.

3.5.2 Impact on Streamflows

The quality of the fit achieved between the modelled stream flows and recorded data for the validation period (1995/96 – 2004/05), was little changed, except for low flow periods than that was obtained for the flow calibration period (1970-84). In view of the drier period and the increase in significance of simulated diversions, the calibration was still considered acceptable.

It was noted that there was little difference in modelled streamflows between the two integrated models (i.e. with or without risk function). A comparison of the modelled stream flows with the observed flows for each of the three reaches is evaluated below:

3.5.2.1 Mungindi to Walgett Reach

Figure **3.20** shows the daily flow frequency comparison over the validation period 1995/96 – 2004/05. This figure is presented in log scale for ease of visual identification of flows, however this scale tends to exaggerate the calibration achieved in low flows. It shows that there is very little change in the quality of flow calibration through the introduction of farmer's risk function. Figure 3.21 shows a comparison of the time series of annual flows and Table 3.21 shows the quality of model fit achieved for this location.

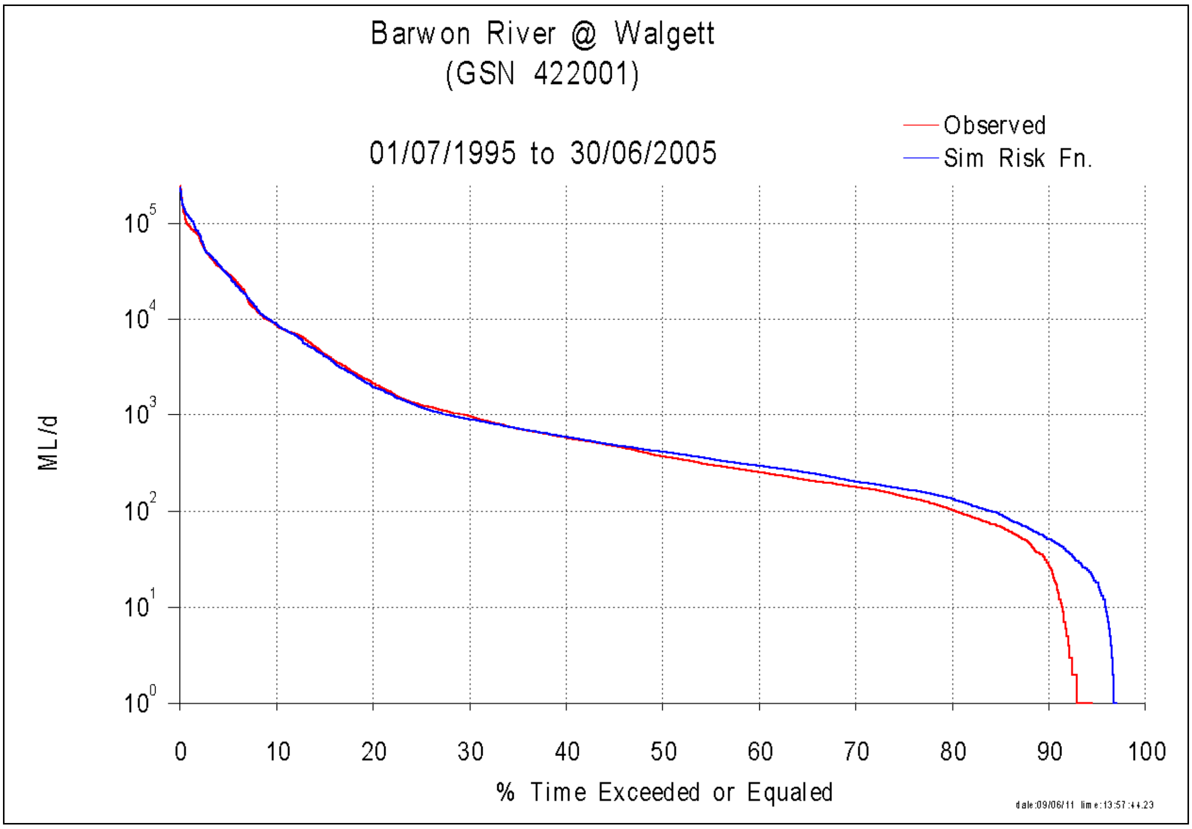


Figure 3.20 Barwon River at Walgett – Daily Flow Frequency

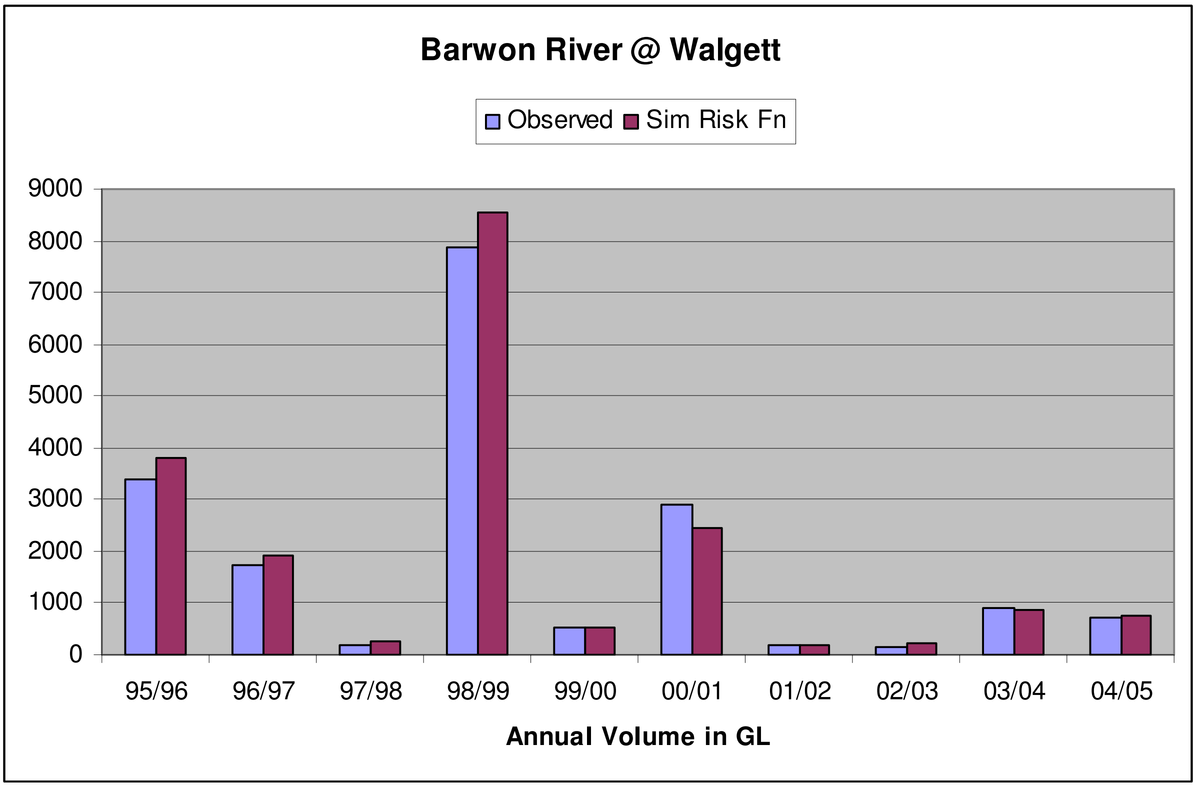


Figure 3.21 Barwon River at Walgett – Annual Discharge Comparison

Table 3.21. Walgett – Flow Calibration Quality Indicators(#) for period 1/7/1995 – 30/6/2005

PRIMARY FOCUS	***SUB-ASPECT***		***APPARENT ERROR (AE)***	***QUALITY RATING GUIDELINES***	***AVERAGE FLOWS FOR RANGE***
	Definition	***Period***	["vr" – 100]	***(See Appendix*** *Error! Reference source not found.* ***for details)***	***(OBSERVED) & SIMULATED (ML/D)***
FLOW FREQUENCY REPLICATION (ranked daily flows) VOLUME RATIO (vr) Where "vr = 100 * (Simulated / Observed) Expressed as a %	**Whole flow range**	Calibration (1)	**-0.4%**	**Very High**	(8,800) 8,765
		Validation (2)	**4.2%**	**Very High**	(5,100) 5,300
	Low flow range from 80%ile to 100%ile	Calibration (1)	**11.5%**	**Moderate**	(140) 155
		Validation (2)	**42.8%**	**< Very Low**	(35) 50
	Mid flow range from 10%ile to 80%ile	Calibration (1)	**0.7%**	**Very High**	(3,195) 3,220
		Validation (2)	**3.8%**	**Very High**	(1,140) 1,095
	High flow range from 0%ile to 10%ile	Calibration (1)	**0.9%**	**Very High**	(54,500) 54,000
		Validation (2)	**4.9%**	**Very High**	(42,800) 44,900
FLOW TIME SERIES REPLICATION					
Daily flow time series	"r^2" coefficient of determination, (or the degree of scatter around the line of best fit)	Calibration (1)	**2.2%**	**Very High**	
		Validation (2)	**9.2%**	**High**	
Annual flow time series	CMAAD – Coefficient of Mean Absolute Annual Differences	Calibration (1)	**4.4%**	**Very High**	(3,212) (3) 3,201
		Validation (2)	**10.5%**	**High**	(2,745) (3) 3,445

Notes:-

(#) See Appendix E for methodology of calculating the quality assessments
(1) As calculated in Flow Calibration period 1970-1984 (Observed 80%ile 330 ML/d; 10%ile 15,100 ML/d)
(2) As calculated in Validation period 1995/6-2004/5 (Observed 80%ile 102 ML/d; 10%ile 8,550 ML/d)
(3) Average annual comparison in GL /yr

Table 3.21 shows that overall there is very little change in the quality of flow calibration through the introduction of farmer's risk function. However, it shows that overall the flow calibration is of a lower quality during the validation period.

3.5.2.2 Walgett to Bourke Reach

Figure 3.22 shows the daily flow frequency comparison over the validation period 1995 – 2000. This figure is presented in log scale for ease of visual identification of flows, however this scale tends to exaggerate the calibration achieved in low flows.

Figure 3.22 shows the time series of annual flow volume comparison and Table 3.22 shows the quality of model fit achieved.

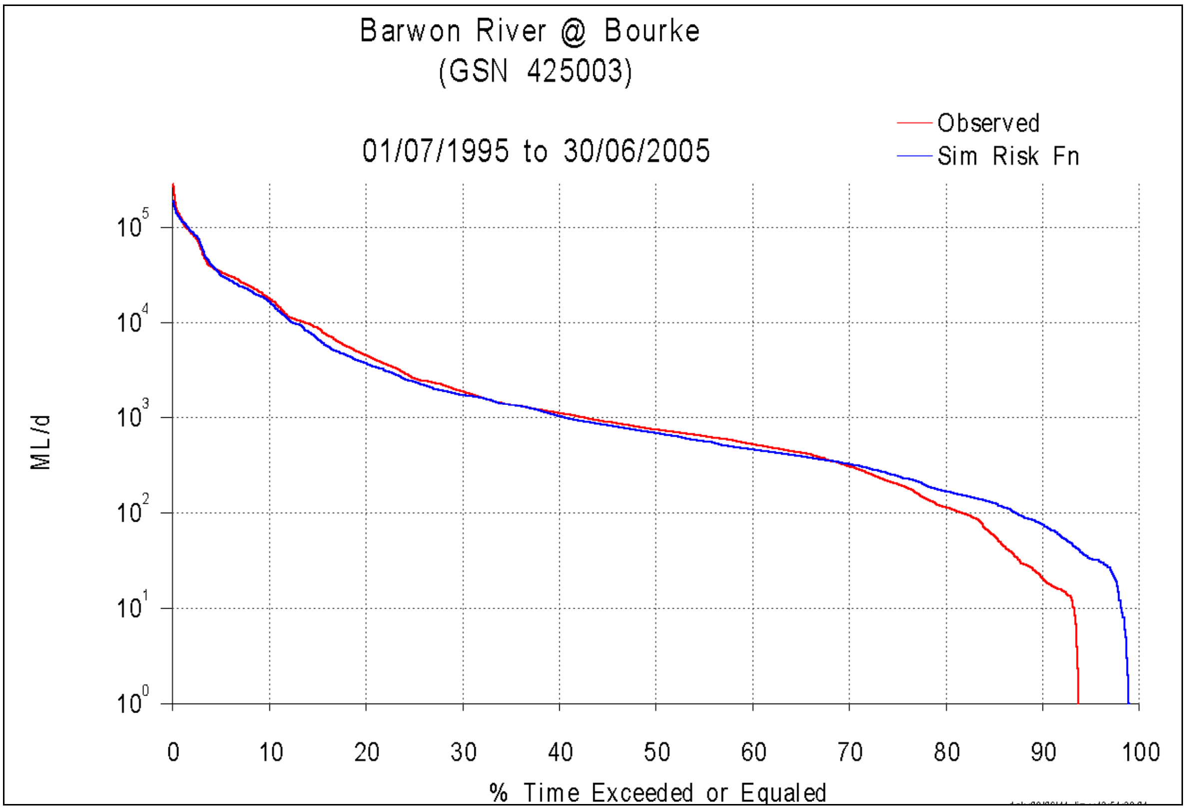


Figure 3.22 Barwon River at Bourke – Daily Flow Frequency

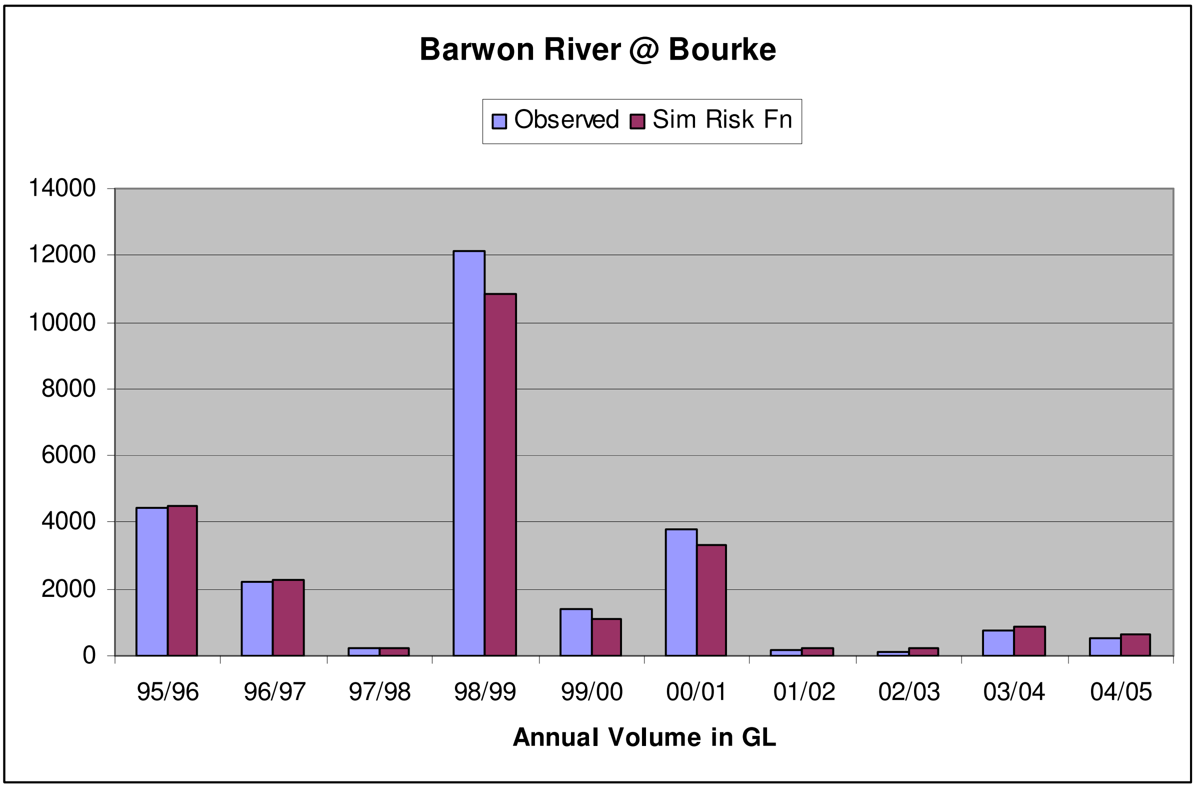


Figure 3.23 Barwon River at Bourke – Annual Discharge Comparison

Table 3.22. Bourke – Flow Calibration Quality Indicators(#) for period 1/7/1995 – 30/6/2005

PRIMARY FOCUS	*SUB-ASPECT*		*APPARENT ERROR (AE)*	*QUALITY RATING GUIDELINES*	*AVERAGE FLOWS FOR RANGE*
	Definition	*Period*	["vr" – 100]	***(See Appendix** Error! Reference source not found. **for details)***	***OBSERVED / SIMULATED (ML/D)***
FLOW FREQUENCY REPLICATION (ranked daily flows)	**Whole flow range**	Calibration (1)	**-5.3%**	**High**	(13,200) 13,900
		Validation (2)	**6.6%**	**High**	(7000) 6500
VOLUME RATIO (vr) Where "vr = 100 * (Simulated / Observed) Expressed as a %	**Low flow range** from 80%ile to 100%ile	Calibration (1)	**-40%**	**Very Low**	(165) 235
		Validation (2)	**-55%**	**Very Low**	(35) 75
	Mid flow range from 10%ile to 80%ile	Calibration (1)	**-2.7%**	**Very High**	(6,100) 6,300
		Validation (2)	**15%**	**Moderate**	(2200) 1900
	High flow range from 0%ile to 10%ile	Calibration (1)	**-6.7%**	**Very High**	(83,800) 89,400
		Validation (2)	**5%**	**Very High**	(54600) 52060
FLOW TIME SERIES REPLICATION					
Daily flow time series	"r^2" coefficient of determination, (or the degree of scatter around the line of best fit)	Calibration (1)	**3.6%**	**Very High**	
		Validation (2)	**6.6%**	**Very High**	
Annual flow time series	CMAAD – Coefficient of Mean Absolute Annual Differences	Calibration (1)	**8.3%**	**Very High**	(4,829) (3) 5,086
		Validation (2)	**10.1%**	**Very High**	(4,100) (3) 4,440

Notes:-

(#) See Appendix **Error! Reference source not found.** for methodology of calculating the quality assessments

1. As calculated in Flow Calibration period 1970-1984 (Observed 88%ile 250ML/d; 6%ile 39,000ML/d)
2. As calculated in Validation period 1995-1999 (Observed 80%ile 115 ML/d; 10%ile 17,900 ML/d)
3. Average annual comparison in GL /yr

Table 3.22 shows that overall there is very little change in the quality of flow calibration through the introduction of farmer's risk function. It also shows that at Bourke the flow calibration is good during both the calibration and validation periods.

3.5.2.3 Bourke to Wilcannia Reach

Figure 3.24 shows the daily flow frequency comparison over the validation period 1995 – 2000. Here too, the chosen log scale tends to exaggerate the calibration achieved in low flows.

Figure **3.25** shows a comparison of the time series of annual flows, and Table.3.23 shows the quality of model fit achieved.

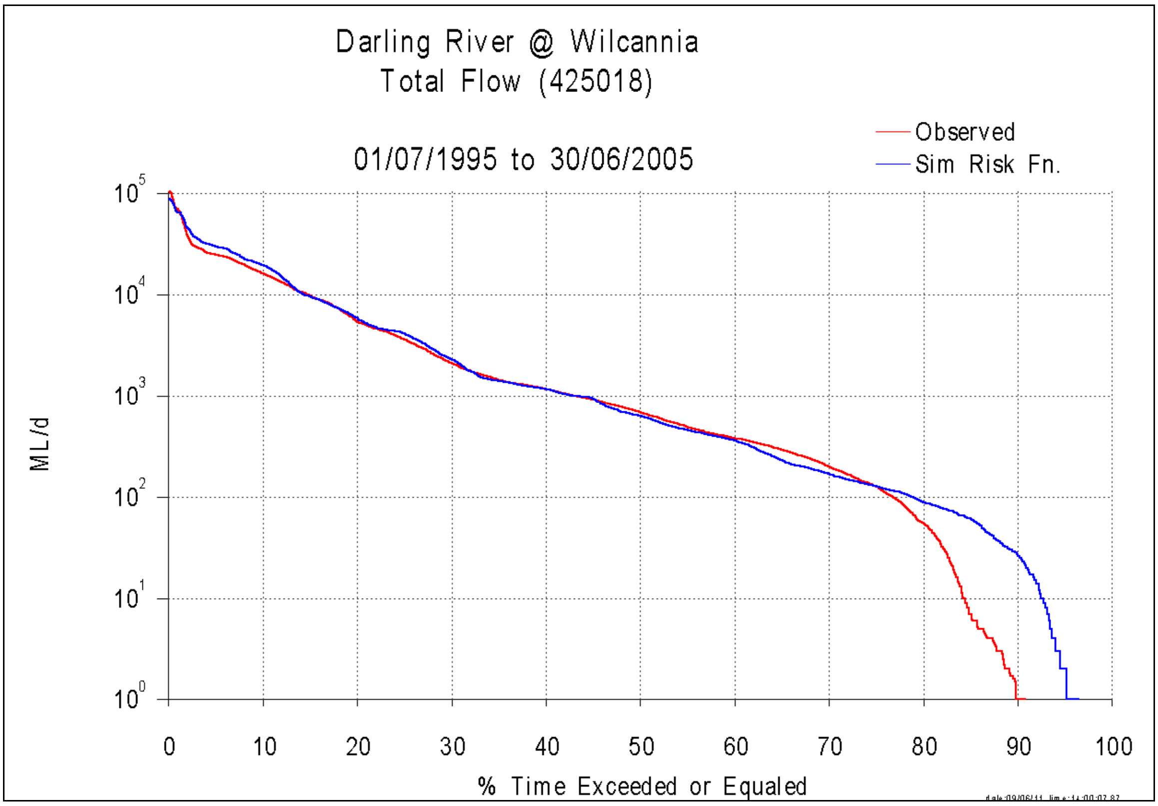


Figure 3.24 Barwon River at Wilcannia – Daily Flow Frequency

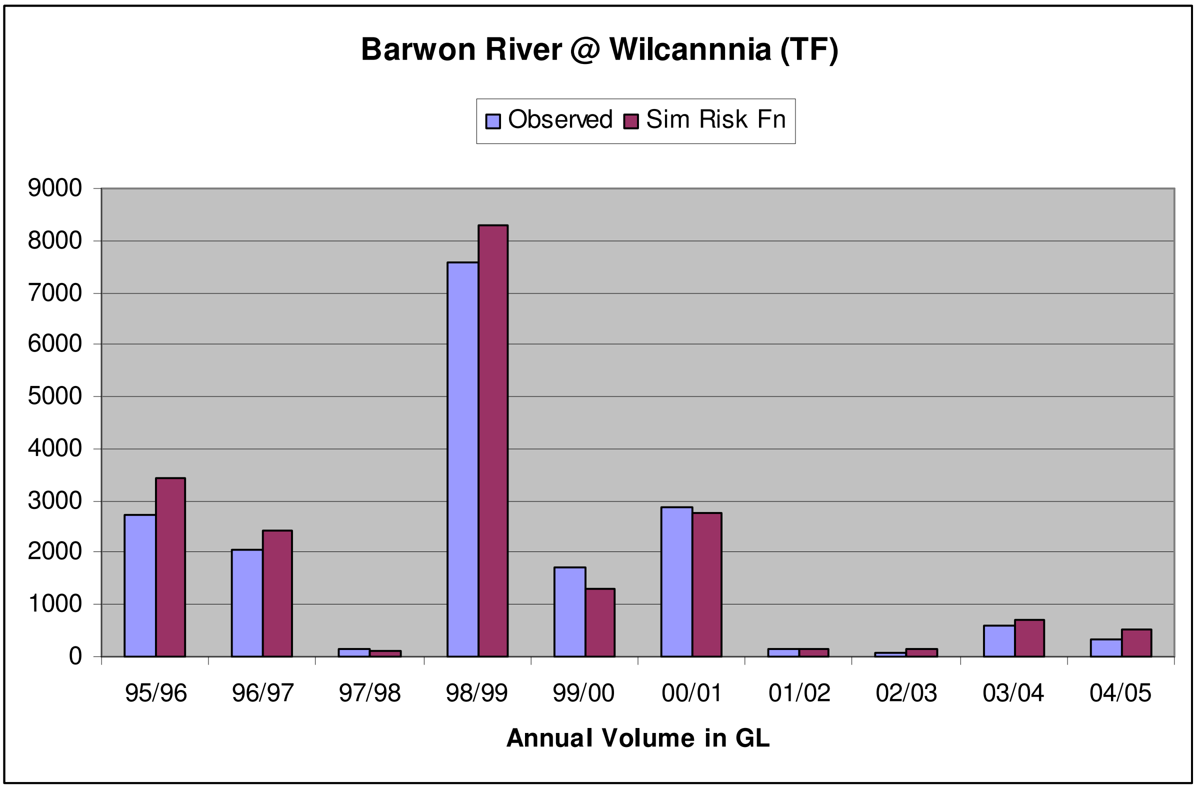


Figure 3.25 Barwon River at Wilcannia – Annual Discharge Comparison

Table.3.23. Wilcannia – Flow Calibration Quality Indicators(#) for period 1/7/1995 – 30/6/2000

PRIMARY FOCUS	***SUB-ASPECT***		***APPARENT ERROR (AE)*** ["vr" – 100]	***QUALITY RATING GUIDELINES*** ***(See Appendix*** *Error! Reference source not found.* ***for details)***	***AVERAGE FLOWS FOR RANGE*** ***(OBSERVED) & SIMULATED (ML/D)***
	Definition	***Period***			
FLOW FREQUENCY REPLICATION (ranked daily flows) VOLUME RATIO (vr) Where "vr = 100 * (Simulated / Observed) Expressed as a %	**Whole flow range**	Calibration (1)	**-5.0%**	**High**	(10,980) 11,540
		Validation (2)	**-6.8%**	**High**	(5000) 5300
	Low flow range from 80%ile to 100%ile	Calibration (1)	**-30.3%**	**Low**	(115) 150
		Validation (2)	**-73.2%**	**< Very Low**	(7.5) 29
	Mid flow range from 10%ile to 80%ile	Calibration (1)	**-9.2%**	**High**	(7,820) 8,550
		Validation (2)	**-3.1%**	**Very high**	(2400) 2500
	High flow range from 0%ile to 10%ile	Calibration (1)	**1.2%**	**Very High**	(74,500) 73,900
		Validation (2)	**-8.9%**	**High**	(33000) 36200
FLOW TIME SERIES REPLICATION					
Daily flow time series	"r^2" coefficient of determination, (or the degree of scatter around the line of best fit)	Calibration (1)	**5.0 %**	**Very High**	
		Validation (2)	**10.2%**	**High**	
Annual flow time series	CMAAD – Coefficient of Mean Absolute Annual Differences	Calibration (1)	**8.2%**	**Very High**	(4,011) (2) 4,212
		Validation (2)	**14.5%**	**High**	(2,850) (2) 3,580

Notes:-

(#) See Appendix E for methodology of calculating the quality assessments

(1) As calculated in Flow Calibration period 1970-1984 (Observed 88%ile 135ML/d; 8%ile 25,000ML/d)

(2) As calculated in Validation period 1995-1999 (Observed 80%ile 55 ML/d; 10%ile 16,100 ML/d)

(3) Average annual comparison in GL /yr

Table.3.23 shows that overall there is very little change in the quality of flow calibration through the introduction of farmer's risk function. It also shows that at Wilcannia the flow calibration results in a lower quality rating during the validation period.

3.5.3 Overall Quality Rating

The overall quality of the model calibration has been assessed using a combination of selected key indicators (Appendix E). The results of this evaluation are summarised in Table 3.24.

Table 3.24: Evaluation of overall quality of model calibration

ITEM	**Irrigation Diversions**		**Flow at Bourke**		**Max Summer Area**	
Apparent error in :	**V Ratio**	**CMAAD**	**V Ratio**	**CMAAD**	**V Ratio**	**CMAAD**
Indicator Value I	4.2	10.8	1.4	9.7	15	10.1
Very High	Very High	Very High	Very High	High	Moderate	Very High
Lower limit of QI: LL	0	0	0	7	10	0
Upper limit of QI : UL	5	10	3	15	20	15
Std lower limit of QI: SL	0	0	0	5	10	0
Std upper limit QI: SU	5	5	5	10	15	5
Standardised indicator: SI	4.2	5.4	2.3	6.7	12.5	3.4
Average Std Indicator: AI	5.7		No. of Calibration:NY			10
OVERALL QUALITY INDICATOR OI			3.9	Very High		

Although, two separate periods were used to calibrate some of the components of the Barwon-Darling IQQM (i.e. 1970-1984 for flow calibration), only the validation period (1995/96 – 2004/05) when all data was available has been included in Table 3.24. The adopted calibration / validation period length for climatic representativeness purposes (Appendix E) is 10 years.

According to Calibration Quality Rating Guidelines in Appendix E, the quality of calibration achieved in Barwon-Darling would be classified as 'very high quality', and consequently could be considered for the following uses, as listed in Table E.0.5, namely:

- Short term Cap Auditing;
- Long term Cap modelling;
- Long term analysis of management rule variations;
- Long term analysis of development variations;
- Long term analysis of infrastructure changes;
- Long term analysis of storage behaviour, yield and spilling frequency;
- Long term analysis of flow regimes and environmental flows at key locations.

4 1993/94 Development Conditions

4.1 OVERVIEW

The Barwon-Darling River Valley is a designated river valley under Schedule E of the Murray-Darling Basin Agreement (MDBMC, 2000), and is consequently required to be managed to ensure that diversions do not exceed those expected under 1993/94 levels of irrigation infrastructure and management rules (i.e. the MDBMC Cap). NOW uses the Barwon-Darling IQQM (DIRNR, 2005) to estimate this diversion limit and therefore provide an indication of the valley's compliance with the MDBMC Cap.

The previous chapters of this report have outlined how the IQQM has been configured and calibrated for the Barwon-Darling Valley. This chapter outlines how the IQQM has been further developed to perform a simulation of the valley with 1993/94 levels of development and tributary inflows. This chapter also outlines how the Cap scenario uses long term climatic conditions, as well as how it is used for short term Cap auditing, i.e. the Cap audit scenario.

4.2 CAP IN BRIEF

The Barwon-Darling River IQQM was used to simulate Cap conditions over the 113-year period from 1895 to 2009 to determine long term average annual diversions. For Cap auditing purposes under Schedule E, the model has been run for each of the water years from 1997/98 to 2009/10. The following assumptions were used to represent Cap conditions:

- Pump and OFS capacities as installed at the end 1993/94 irrigation season (i.e. winter, 30/06/1994);
- The crop mix as observed during the 1993/94 irrigation season;
- As the 1993/94 season and subsequent seasons were resource constrained and as there was also on-farm development during the 1993/94 season then the maximum planted areas and risk functions that were applicable for 1993/94 irrigation season had to be estimated using an assessment procedure as outlined in Appendix J ; and
- Management rules (i.e. access, transfers and entitlement volumes) applicable for the 1993/94 irrigation season.

4.3 CLIMATIC DATA

4.3.1 Rainfall

For the long term simulations, the rainfall stations selected based on the criteria outlined in Section 2.3.1 were extended using observed data. Any missing data was gap-filled to cover the intended simulation period (1895 – 2009).

4.3.2 Evaporation

As noted in Section 2.3.2.1 the evaporation data used in both the long-term simulations and in the calibration are synthesised long term pan evaporation data. This data was generated by a procedure that considers mean monthly pan evaporation and the variation of pan evaporation as a function of number of rain days in the each month. As explained in Section 2.3.2, four long-term rainfall stations were used for generation of evaporation data for the four geographic zones (Table 2.2).

4.4 FLOW DATA

4.4.1 Tributary Inflows

The observed data for the 18 tributary gauging stations that were utilised for calibration purposes are generally replaced with simulated flows for the long-term simulations. The fifteen simulated flows are produced by tributary IQQM's at Cap (1993/94) development levels for NSW tributaries and ROP development levels for QLD tributaries. Definition of the tributary Cap and ROP scenario models and details of other processes used to define inflows for those tributaries which do not have IQQM's (i.e. Little Weir River) are supplied in Appendix H.

4.4.2 Ungauged Tributary Inflows

In Section 3.2.2.1 the methodology to estimate "missing" tributary inflows during the calibration period was discussed. This adopted method effectively behaves like a revised streamflow rating curve that produces more water from the tributary once the tributary flow approaches bank full conditions. For the long term simulations the same combination of factoring of inflows and accompanying losses is used to produce additional inflows for the Barwon-Darling IQQM.

4.5 IRRIGATION INFORMATION

Where possible, observed data was used to configure the model's on-farm physical infrastructure, including pump capacities, area developed for irrigation and on-farm storages capacities and the emptying strategies, etc. Details on the sources of this "observed" data are given in Section 2.5.

The parameters of crop and rainfall harvesting efficiencies, together with OFS seepage rates, which were determined for 'major' irrigators during calibration period (1995–2005), were generally used in the Cap scenario. However, for about 5 'major' irrigators who significantly developed their properties between 1993/94 and the calibration period some changes to calibrated efficiencies were undertaken. To identify those properties were developments may have occurred an analysis of annual individual farm layouts was undertaken. This assessment was carried out by Irrigator and NSW Department of Agriculture Representatives on IQQM Reference

Group. They utilised the high resolution colour satellite imagery available from DHP for each year during summer cropping season from 1987/88 to 2000/01.

Although the assessment team only produced a “Qualitative Assessment of Irrigation Delivery Efficiency” paper, it is the basis of identifying irrigators who developed and how much to change efficiencies. Table 4.1 indicates the extent of changes made for the CAP model.

Table 4.1: Changes to Calibrated Efficiencies for Cap Model

Calibration Parameters Changed	No. of Irrigators Affected	Average Value after Calibration	Average Value Used for CAP
Crop Efficiency	5	0.80	0.74
Rainfall Harvesting Efficiency	5	0.74	0.56
OFS Seepage Rate	2	1.50 mm	1.05 mm

A full listing of the data and parameters describing the Barwon-Darling IQQM Cap scenario is included in Appendix I . (Note, only a reach summary, is supplied for ‘major’ irrigators to protect individual anonymity.)

4.5.1 Irrigation Entitlements and Access Conditions

The 1993/94 Cap scenario described in this report relates to the licence conditions (i.e. flow thresholds) and entitlements that were prevailing in the Barwon-Darling Valley for the end of 1993/94 irrigation season. Table C.0.1 details on a reach basis the licence conditions. The 1993/94 entitlements includes a small volume transferred from a ‘reach’ irrigator to a large ‘major’ irrigator.

4.5.2 Irrigation Extraction and On-farm Storage Infrastructure

The operational pump capacities for ‘major’ irrigators for the 1993/94 irrigation season were obtained from NOW’s 1995 - 2000 ultrasonic probings to determine pump capacity, while the DHP’s records were utilised to determine which pumps were actually installed in 1993/94.

From the DHP the installed 1993/94 ‘major’ irrigators’ OFS capacities (ML) and surface areas (ha) were obtained. In general the 1997 Hydrology survey information on OFS operating procedures for emptying and filling multiple storages was adopted for the Cap scenario. However a few irrigators provided information on changes to their procedures which caused an alteration to their modelled 1993/94 OFS operating procedures.

For ‘reach’ irrigators pump capacity and any OFS capacity was obtained from DHP 1994 data. Surface areas were estimated based on the assumption the OFS were 2 metres deep (i.e. similar to some of the small OFS of ‘major’ irrigators).

4.5.3 Crop Data and Planting Decision Determination

As noted from an examination of historical planted areas of ‘major’ irrigators (Table 2.8), variations in planted areas occurs from year to year. In the lowest year (2003/04) only 100 ha was planted in summer, while in 2000/01 a maximum of nearly 29,000 ha was planted. These variations in areas reflect ‘major’ irrigator’s response to resource constraints from year to year. This implies that for ‘major’ irrigators they should vary their planted areas from year to year for the whole period of simulation.

A risk function for ‘major’ irrigators that defines the relationship between the volume of water in their OFS and the area planted, together with area limits, was established for the 1993/94 levels of development. Details of how each of these parameters was defined follows below.

Minor irrigators (i.e. irrigators who individually grow areas less than 20 hectares and normally have no OFS) were treated in the Cap model as opportunists who will attempt to grow the observed 1993/94 areas each year and divert water to satisfy the crop demands.

4.5.3.1Area developed for irrigation

For ‘major’ irrigators the physical maximum area available for planting in the 1993/94 was 25,322 hectares. This area was obtained from the remote sensed scene of winter 1994, which was assessed as part of the DHP. While the developed area is sometimes an appropriate upper limit for the maximum area that can be planted, the need to rotate land on the farms and other operational features frequently limits actual planted areas to a smaller figure.

In the Cap model, this maximum area available for planting by a major irrigator is utilised to define:

- the maximum area that can be planted at any one time, also the combined maximum area where summer and winter crops overlap; and
- the area for on-farm rainfall-runoff harvesting.

No data is available for areas developed for irrigation by ‘reach’ irrigators, therefore maximum area planted is the sum of any winter plus summer cropped areas. The adoption of this area has no impact on rainfall-runoff harvesting as ‘reach’ irrigators do not undertake this process.

4.5.3.2Maximum cropped area

For ‘major’ irrigators the overall maximum summer cropped areas of 1993/94 was 19,400 hectares. However, in an unregulated system like the Barwon-Darling, the simplistic assumption that the maximum cropped area (under Cap conditions) should equal the maximum area irrigated up until 1993/94, cannot be made. This occurs because:

- some additional areas were still being developed for irrigation by ‘major’ irrigators during 1993/94 irrigation season and were not completed until winter 1994. Hence these ‘new’ areas could not be irrigated until later seasons; and
- also, even for those ‘major’ irrigators who had developed areas prior to 1993/94, there were sufficient constraints in available flows during this period to possibly limit the area planted for crops until at least 1996/97 season.

The IQQM Reference group developed a methodology to determine the Cap maximum cropping area for ‘major’ irrigators. This methodology utilises annual data (i.e. OFS capacity, area developed for irrigation and irrigated summer areas) available from the DHP and an analysis of steamflow data to determine if irrigators in a reach were possibly constrained by a limited volume of water in their OFS’s at planting date. Details of the adopted methodology and an example of an irrigator worksheet to determine maximum cropping area are attached at Appendix J. A reach summary of the 1993/94 areas developed for irrigation and the calculated maximum areas are shown in Table 4.2.

For ‘reach’ irrigators, the only available data is the 1993/94 cropped areas, these have been adopted as the maximum area.

Table 4.2 Areas Developed for Irrigation and Maximum Areas

Reach Description	Major Irrigators			Reach Irrigators	
	Developed Area (Ha)	Summer Maximum Area (Ha)	Winter Maximum Area (Ha)	Summer Maximum Area (Ha)	Winter Maximum Area (Ha)
Mungindi – Walgett	8,852	8,091	193	232	768
Walgett - Brewarrina	3,930	3,203	25	105	4
Brewarrina - Bourke	8,824	7,194	377	177	101
Bourke – Wilcannia	5,716	4,632	809	432	142
Mungindi - Wilcannia	**27,322**	**23,120**	**1,404**	**946**	**1,015**

4.5.3.3Minimum area

In severely resource constrained years there is likely to be no cotton areas planted by 'major' irrigators (i.e. cotton crops will not be planted unless there is water available to germinate the seed, about 2 to 3 ML/ha). For 'major' irrigators the same minimum area was adopted for all annular crops.

4.5.3.4Planting decision determination

To determine the planting decision of each 'major' irrigator under Cap conditions, the following process was considered appropriate, an individual irrigator will:

- determine the available resources based on the volume of water in their on-farm storage at the planting decision date; and
- use a risk function, based on that volume of water, together with maximum and minimum limits, to calculate the area that is actually planted.

Due to development and resource constraints around 1993/94, similar problems were encountered with the determination of appropriate risk functions as were previously with the determination of maximum areas. The IQQM Reference group developed a methodology based on reviewing irrigator's risk behaviour over a period of time, both before and after 1993/94 in order to produce an appropriate Cap risk function. Details of the adopted methodology and an example of an irrigator worksheet to determine risk functions are attached at Appenidix J. A reach summary of the 1993/94 risk functions are shown in Table 4.3. Note, although irrigators can grow a mix of summer and winter crops in IQQM there is only one summer and one winter risk function per irrigator.

Table 4.3: 'Major' Irrigators Cap Risk Functions

Reach Description	1993/94 Summer Risk Functions		
	Minimum (ML/Ha)	Maximum (ML/Ha)	Average (ML/Ha)
Mungindi – Walgett	0	9	3.7
Walgett - Brewarrina	4	9	6
Brewarrina - Bourke	0	10	5.4
Bourke - Wilcannia	0	4	2.6
	1993/94 Winter Risk Functions		
Mungindi – Walgett	0	0	0
Walgett - Brewarrina	1	1	1
Brewarrina - Bourke	0	0	0
Bourke - Wilcannia	0	0	0

4.5.3.5Crop mix

Even if the economic and social conditions remain unaltered, the need to rotate land on the farms and the variations in local climate affecting soil moisture at the planting decision date will lead to some changes in crop areas and mix from year to year. It was decided to investigate the crop mix over a few years around 1993/94 before determining the best crop mix to represent 1993/94 Cap conditions.

Major irrigators on the Barwon-Darling are predominantly cotton growers, and this crop would account for around 90 percent of the total cropped area. The remaining cropped area covers a number of other crops (e.g. summer and winter cereals, Lucerne etc). Although there has been some variation in the crop mix from year to year, the crop mix observed in the 1993/94 water year has been assumed to represent the Cap conditions. The adopted crop mix for each irrigator (i.e. both ‘major’ and reach) is held static for the duration of the simulation. Table I.0.1 shows the adopted 1993/94 crop mixes for ‘major’ and ‘reach’ irrigators.

4.5.3.6Floodplain Harvesting

In 1993/94, many ’major’ irrigators were able to harvest floodplain flows, Table C.0.1 details, on a reach basis, information on the flow thresholds when they gained access and the capacities (ML/D) by which they were able to harvest floodplain flows.

4.5.3.7Rainfall Harvesting

Information on the areas from which ‘major’ irrigators were able to harvest rainfall-runoff and the airspace that they keep in their OFS for that purpose are detailed in Table I.0.2 and Table I.0.3.

4.6 OTHER USERS

Other users include riparian, town water supplies, industrial and, stock and domestic use, currently there is little to no observed diversions available for any of these users. As their usage is likely to be negligible relative to irrigation, seepage and evaporation they have not been represented explicitly in IQQM.

4.7 GROUNDWATER ACCESS

Groundwater access and usage, other then from the Great Artesian Basin, is insignificant compared to surface usage. In this present IQQM Cap model no allowance was made for groundwater or groundwater interaction with surface water usage.

4.8 RIVER FLOW REQUIREMENTS

The North West river flow requirements (i.e. Unregulated Flow Plan) as detailed in section 2.2.7 are not included in the 1993/94 CAP model.

4.9 1993/94 CAP SIMULATION MODEL VALIDATION

The CAP model was re-calibrated during 2010, utilising 1995-2005 data, and the model parameters were revised accordingly. To assess the robustness of the CAP scenario, a simulation was performed over the period when irrigation development was closest to Cap conditions. Three seasons form 1993/94 to 1995/96 seasons were considered the most appropriate. Also of consideration is the reliability and sensitivity of the model to initial OFS volumes.

The observed and simulated results were compared for a range of data including; on-farm storage behaviour (at the end of season), metered diversions, and planted areas, as well as, flows at Walgett, Bourke and Wilcannia. The overall results are presented in Table 4.4, however it should be remembered that these results are the sum of 30 individual results some of whom may exhibit trends, opposite to those apparent in the Table.

Table 4.4: Key observed vs modelled parameters for 1993/94 – 1995/96

Parameter		***1993/94***	***1994/95***	***1995/96***
OFS volume (GL)				
(Start of season)	Modelled	92.5*	72.3*	112.5
	Observed	93.8*	62.1*	182.8
	Difference	-1.3	10.2	-70.3
	(%)	-1	16	-38
Summer Planted Areas (Ha)				
Total ('Major' Irrigators)	Modelled	15,900	17,150	20,100
	Observed	17,100	13,200	19,900
	Difference	-1,200	3,950	200
	(%)	-7	30	1
Metered Diversions (GL)				
	Modelled		83.2 *	218.6
	Observed		81.0 *	215.0
	Difference		2.2	3.6
	(%)		3	2
Flows (GL)				
Walgett:	Modelled	267.3	253.0	4320
	Observed	232.9	327.6	3404
	Difference	34.4	-74.6	916
	(%)	15	-23	27
Bourke:	Modelled	612.3	604.1	4212

	Observed	548.7	931.2	5080
	Difference	63.6	-327	868
	(%)	12	-35	21
Wilcannia End-of-system:	Modelled	481.4	543.2	3678
	Observed	419.6	779.4	2741
	Difference	61.8	-236.2	937
	(%)	15	-30	34

Notes * Partial Record only

4.9.1 Comparison of OFS Behaviour

Generally OFS behaviour data was the least accurate owing to general lack of real measurements (i.e. in many cases they are only estimates, possibly remembered up to years latter for either the “Hydrology Survey” or at least annually for the State Water’s annual survey). Also, OFS capacities were, in some instances, only approximately known.

At the beginning of 1993/94 the volume in actual and modelled OFS was almost the same but this was achieved by effectively “forcing” the model through the choice of the initial OFS volumes. Although it should be noted that this model run commences in 1991, with initial OFS volumes at about long term average conditions, but the restrictions in available flows together with the relatively large demand of the crops at 1993/94 levels lead to a general decrease in OFS volumes.

At the start of 1994/95 season the volume in modelled OFS was about 10 GL greater then the observed volumes. This difference in OFS volumes was largely driven by the lower modelled then actual cropped demands in the preceding season (i.e. difference in modelled cropped area is 1,200 Ha with a crop demand of 8 ML/Ha equates to around 10 GL).

At the start of 1995/96 season, two factors contribute to the 70 GL discrepancy between actual and modelled OFS volumes. Firstly, there is the over 40 GL increase in actual OFS capacity since 1993/94 and secondly there was the impact of the increased modelled crop demand of almost 4,000 Ha in the preceding season. Both of these factors combine, to produce a markedly lower modelled OFS volume.

4.9.2 Comparison of Modelled and Observed Summer Areas

When comparing the observed and modelled summer planted areas over the 1993/94 -1995/96 period, there are two major factors that impact on the model’s ability, which is fixed at 1993/94 infrastructure levels, to reproduce observed crop areas:

1. observed growth in the area developed for irrigation that occurred during this period (i.e. from 26,300 ha to 29,600 ha, a 12% increase) and its consequent impact on cropped areas; and

2. overall impacts of the increase in observed OFS capacity (i.e. from 172 GL to 234 GL, a 37% increase) and the general decreases in the planting risks that occurred over the 3 year period.

An analysis of observed OFS volume in storage at planting date to cropped area, shows considerable fluctuations over the three year period but initially, the average risk was around 5 ML/ha increasing to around 9 ML/ha in 1995/96. However, some care needs to be taken with these figures, as not all irrigators were represented in all years and individual behaviours may vary considerably.

The model uses fixed risk functions for each individual irrigator with the highest risk being one hectare cropped per 2 megalitres of water stored at planting time (ie 2 ML/Ha) and lowest being 10 ML/Ha.

In 1993/94 modelled cropped area was some 7% (1,200 Ha) less then the observed area, despite storage capacities being almost equal. This would appear to indicate that the adopted risk functions are more conservative then what was actually occurred in 1993/94 but overall and individual year comparisons can be misleading. This was demonstrated in 1994/95 where a 16% increase (10 GL) in modelled to observed OFS volume caused a 30% increase (4,000 Ha) in the modelled to observed cropped areas (ie the same model risk functions would appear this time to be a lot more optimistic then what was actually occurred in 1994/95) .

The year 1994/95 would also appear to show an apparent contradiction in model results compared to 1993/94, where an approximate 20% reduction in overall storage volume causes a 7% increase in planted area. This would be impossible with a constant risk function, however what the overall results do not show was that there was a substantial redistribution of OFS volumes amongst individual irrigators who had substantial differences in their cropping risks and hence it can and did occur.

The year 1995/96, demonstrates the significance and variations that occur in the cropping risks. It shows that the significant increase in infrastructure (i.e. increase in OFS capacity from 190 to 230 GL and developed irrigated area from 26,000 to 30,000 Ha) as well as other factors, has lead a to an overall reduction in the cropping risk that irrigators are prepared to take. In this year, despite the observed OFS volumes being some 70 GL greater then the modelled volume of 112 GL, the planted areas are virtually the same.

4.9.3 Comparison of Modelled and Observed Diversions

When comparing the observed and modelled diversions, there are three major factors that impact on the model's ability to reproduce observed diversions and they are the:

1. differences between observed and modelled infrastructure, as noted above;
2. differences between observed and modelled crop demands (i.e. crop areas), also as noted above; and

3. lack of observed diversion data, 1995/96 was only year when all irrigators had diversion meters for the full year and hence the recording system was fully operational.

In 1995/96 modelled diversions closely match observed, within 2%, and although this comparison was very good and was expected due to the very similar modelled and observed crop areas, there are still some potential problems. These problems are seen in the differences in OFS volumes, where the modelled OFS volume increases by 68 GL but observed OFS volume only increases by 26 GL, resulting in a difference of 42 GL which is equivalent to almost 20% of the observed diversions. However as 1995/96 had considerable flood flows and moderate rainfalls, the model has estimated over 50GL of floodplain diversion and 20 GL of rainfall harvesting, therefore there is considerable scope for alternate non-metered sources to supply the missing 42 GL which is only, at best, an estimate.

4.9.4 Comparison of Modelled and Observed flows

The major differences between modelled and observed flow volumes are in higher flow periods. These differences have come about due to the factoring of tributary inflows and not from differences in modelled diversion of water. Without better information on high flows from tributaries this difference can not be overcome.

4.9.5 Conclusion

The above analysis and results demonstrates the difficulties when running a CAP scenario with fix development in 1993/1994 for a period of variable development in the Barwon Darling.

4.10 1993/94 CAP SIMULATION MODEL RESULTS

4.10.1 Summary of the Cap Scenario Results

The summary results for the 114 year IQQM Cap simulation are presented in Table 4.5. Figure 4.1 shows annual time series of total Barwon-Darling diversions. Barwon-Darling IQQM run number *BD007E.sqq* was used to simulate these results.

Table 4.5: Summary of the Long Term Cap scenario results

Summary Aspect	***Sub-aspect***	***Average Annual Figures (1)***	***Maximum Annual Figures***
Water Usage	Metered River (i.e. by 'major' irrigators)	190.3 GL	274 GL
	Un-metered River 'reach' irrigators	8 GL	10 GL
	Sub-Total (2)	**198 GL**	**284 GL**
	Floodplain Harvesting by 'major' irrigators	13 GL	48 GL
	Rainfall-runoff Harvesting by 'major' irrigators	13 GL	46 GL
	Total	**224 GL**	**378 GL**
Planted Areas	Summer Planted area by 'major' irrigators	20,640 Ha	22,000 Ha
	Summer Planted area by 'reach' irrigators	720 Ha	720 Ha
	Total	**21,360 Ha**	**22,720 Ha**
River Flows	Barwon River at Walgett	1,587 GL	14,020 GL
	Darling River at Bourke	2,230 GL	22,930 GL
	Darling River at Wilcannia (Total)	1,821 GL	16,911 GL

Notes:
(1) Long term average annual figures are based on the (01/07/1895 – 30/06/2009) period.
(2) This figure is used for long-term Cap assessment in Table 4.6

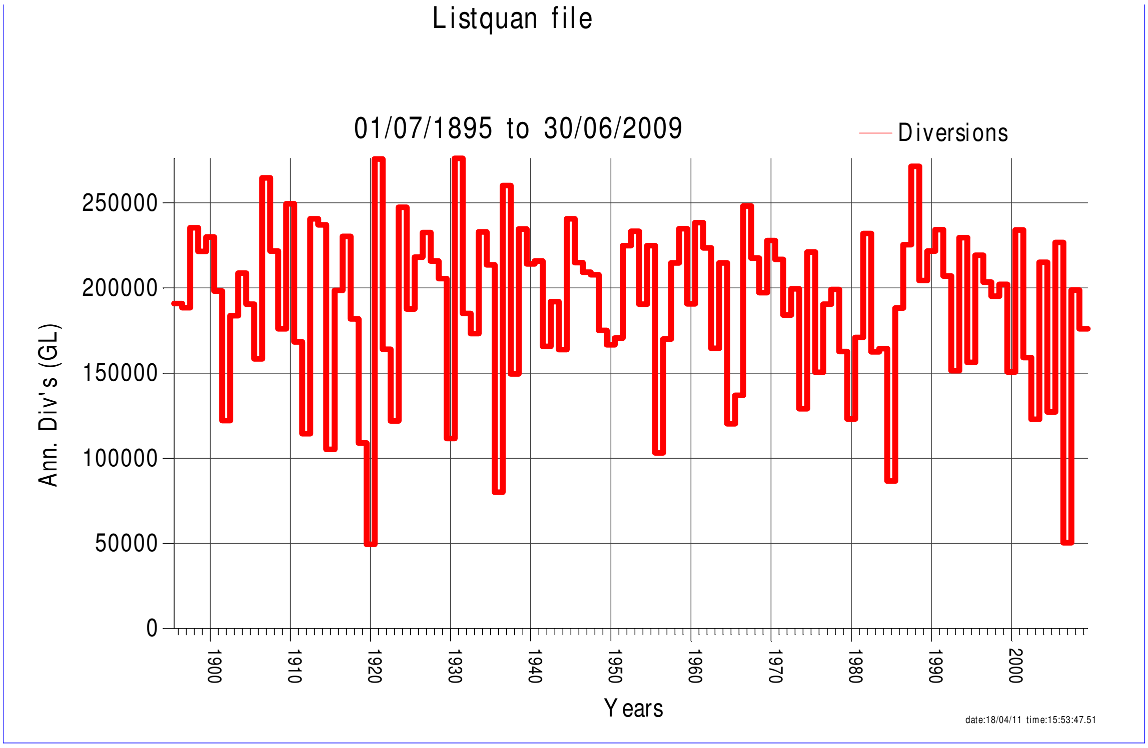


Figure 4.1 Cap scenario simulated total metered annual diversions

4.10.2 Cap audit (Schedule E accounting simulation)

To assess Cap performance in each valley designated in Schedule E of the Murray-Darling Basin Agreement (MDBMC, 2000), annual Cap simulations using the relevant IQQM are performed. In the Barwon-Darling Valley, the Cap simulation commenced at the start of the 1997/98 water year (July), with storage levels initialised at observed values. The IQQM then simulates continuously through subsequent water years using the observed climatic data as input and development and management rules fixed at 1993/94 levels. For this analysis observed tributary inflows are used.

To commence the Cap audit scenario, IQQM is started several weeks before the commencement of the 1997/98 water year, to allow for the river system to fill with water and to provide a better starting soil moisture store. Storage levels are set such that, at the commencement of the 1997/98 water year, they are equivalent to observed levels. This is known as hot-starting the model for the 1997/98 water year.

At the commencement of the simulation, IQQM will plant an area based on the resources available at the first available planting date (i.e. 1st of October). For those few irrigators on the Barwon-Darling who do grow winter crops, an inappropriate simulated winter planted areas will occur in the first year (1997/98).

Schedule E accounting for Cap compliance, as presented to the Independent Audit Group is presented in Table 4.6 below. Barwon-Darling IQQM run number *RC05D.sqq* was used to simulate these results.

Table 4.6: Barwon-Darling Valley preliminary Schedule E account

Water year	Total diversions (GL)	Cap estimate from IQQM (GL)	Difference (GL)
1997/98	198	167	-3.1
1998/99	233	227	-6.2
1999/00	175	151	-24.1
2000/01	246	241	-5.3
2001/02	76	119	43
2002/03	20	37	17.2
2003/04	268	184	-83.7
2004/05	157	114	-43.4
2005/06	157	190	33.1
2006/07	1	2	1.3
2007/08	210	160	-50.5
2008/09	149	161	12
2009/10	145	147	2.4
Total	**2035**	**1900**	**-135**
Long-term average Cap estimate:			198
20% of Long-term average Cap estimate (1):			40

Note: A negative difference represents a Cap exceedance, or debit.

The long-term average estimate used here does not include floodplain harvesting.

(1) The variation permitted before CAP compliance measures are required.

5 Improvement Plans

5.1 OVERVIEW

Maintenance of the Barwon-Darling IQQM is an ongoing process and includes updating the model for:

- New generic IQQM capabilities;
- Improvements to existing model capabilities, including bug-fixes;
- Further information becoming available to facilitate improved calibration;
- More time and resources to refine calibration.

In the development of the IQQM software, every effort has been made to ensure that all aspects of the software are operational as intended. However, should it become apparent that any part of the software is not operating appropriately, and resolution of the problem causes any change to the results of Cap simulation, the MDBA will be informed of the changes to the results and the reason why the changes have occurred.

For the Barwon-Darling Valley the following points outline the future enhancements that have been identified should further information, time or data become available.

5.2 PROCEDURES FOR STREAMFLOW CALIBRATION

5.2.1 Extended Streamflow Records

Since the outset of implementing the Barwon-Darling IQQM, it had been intended that the flow calibration of the individual reaches would be reviewed based on the availability of more recent and better quality streamflow data. It was envisaged that this upgrading process would occur on approximately a five (5) year cycle. However the flow calibration has not been updated since 2000.

The streamflow verification period which includes a portion of the recent drought (2002-2003) has demonstrated the inadequacies of modelled losses at low flows and during dry periods. However, reviewing the flow calibration is a large task because it involves the collection and analysis of flow data and diversion data for all reaches. Also, given the uncertainty of the accuracy diversion data (Section 5.3.1) and their relative significance at low flow times, it was decided to delay any re-calibration of streamflows until the “Mace” meter process had been completed.

5.2.2 Antecedent conditions based losses

The model currently applies “average” losses as a proportion of flow. These losses were derived to achieve water balance during the calibration period (1970 – 1984). The development of an alternative, such as losses that would incorporate antecedent conditions is being considered.

5.2.3 Ungauged tributary inflows during flood times

Better estimation of ungauged inflows from tributary streams will only happen if more accurate and total streamflow data can be obtained on the Barwon Darling River to allow a water balance approach to be adopted. It is unlikely that new gauging stations will be installed on these ungauged tributaries. However, given that there has been additional flooding since the ‘factoring’ of tributary inflows was first developed a detailed review using the additional flood flows should be undertaken within a reasonable time.

5.3 UPGRADES TO DIVERSION CALIBRATION

5.3.1 Metered Diversions

The collection of new metered data by the ‘Mace” meters will overcome many of the problems that are currently afflicting the present ‘Time and Event’ meters. When sufficient data has been collected and diversions have been calculated and reprocessed back until 1995/96 it will be possible to re-calibrate irrigation diversions.

5.3.2 On farm Storages

The direct measurement of storage water levels during winter months will enable a realistic assessment of seepage losses from storages. This would replace the current estimates which were developed during calibration with data.

Utilising new data from ‘Mace’ meters will provide an independent measure of storage capacities when many of these storages were re-filled during December 2007 – February 2008 after the recent drought finished. Additional monitoring of storage behaviour would also provide information on initial losses.

5.4 UPGRADES TO AREA CALIBRATION

Any improvement to area planted calculation relies on good reporting of irrigator practices and on farm water balance, as well as, accurate crop area data. As noted in Section 2.7, remote sensed crop areas have not been collected since 2000/2001 water year and a survey on irrigator practises have not been undertaken since 1997.

5.5 GENERAL UPGRADES

5.5.1 On-river weir modelling

Currently no on-river weirs are incorporated into the Barwon-Darling IQQM. This is because small on-river weirs have caused flow pulsing problem in the past. Recent code developments in IQQM have improved on-river weir modelling and we may need to investigate incorporating these weirs into the model, with appropriate testing and re-calibration.

The incorporation of constructed and natural weirs would be one way to introduce some initial loss of streamflow after a period of no flow. It may also be flexible and representative enough to provide reliable estimates of antecedent losses.

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Appendix A

Statistical information for the rainfall stations utilised on the Barwon-Darling River system are listed below.

Table A.0.1. Statistical Information for rainfall stations used

Rainfall (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Mungindi PO (52020)													
Mean	71	64	53	30	34	34	33	26	28	39	41	51	504
Median	47	38	37	19	24	29	22	18	20	31	31	40	510
Mogil Mogil (52019)													
Mean	74	56	48	35	36	35	36	28	27	35	43	51	504
Median	49	31	33	22	25	29	28	19	20	29	39	37	361
Collarenbri PO (48031)													
Mean	69	59	50	32	33	36	34	27	25	37	46	48	496
Median	40	37	33	22	23	29	24	18	17	31	35	36	486
Walgett PO (52026)													
Mean	65	57	42	32	39	37	32	29	28	39	40	40	480
Median	45	36	28	22	30	29	22	21	19	29	31	35	491
Brewarrina PO (48015)													
Mean	53	50	42	27	29	34	29	23	25	31	32	35	410
Median	30	29	23	12	21	24	23	16	15	22	21	23	396
Bourke PO (48013)													
Mean	42	42	37	25	28	27	23	21	20	27	28	31	351
Median	24	25	17	13	20	19	18	13	13	19	18	21	330
Wilcannia PO (46043)													
Mean	26	25	23	18	24	22	17	19	15	24	19	23	255
Median	10	13	11	9	18	17	14	13	9	16	11	11	245

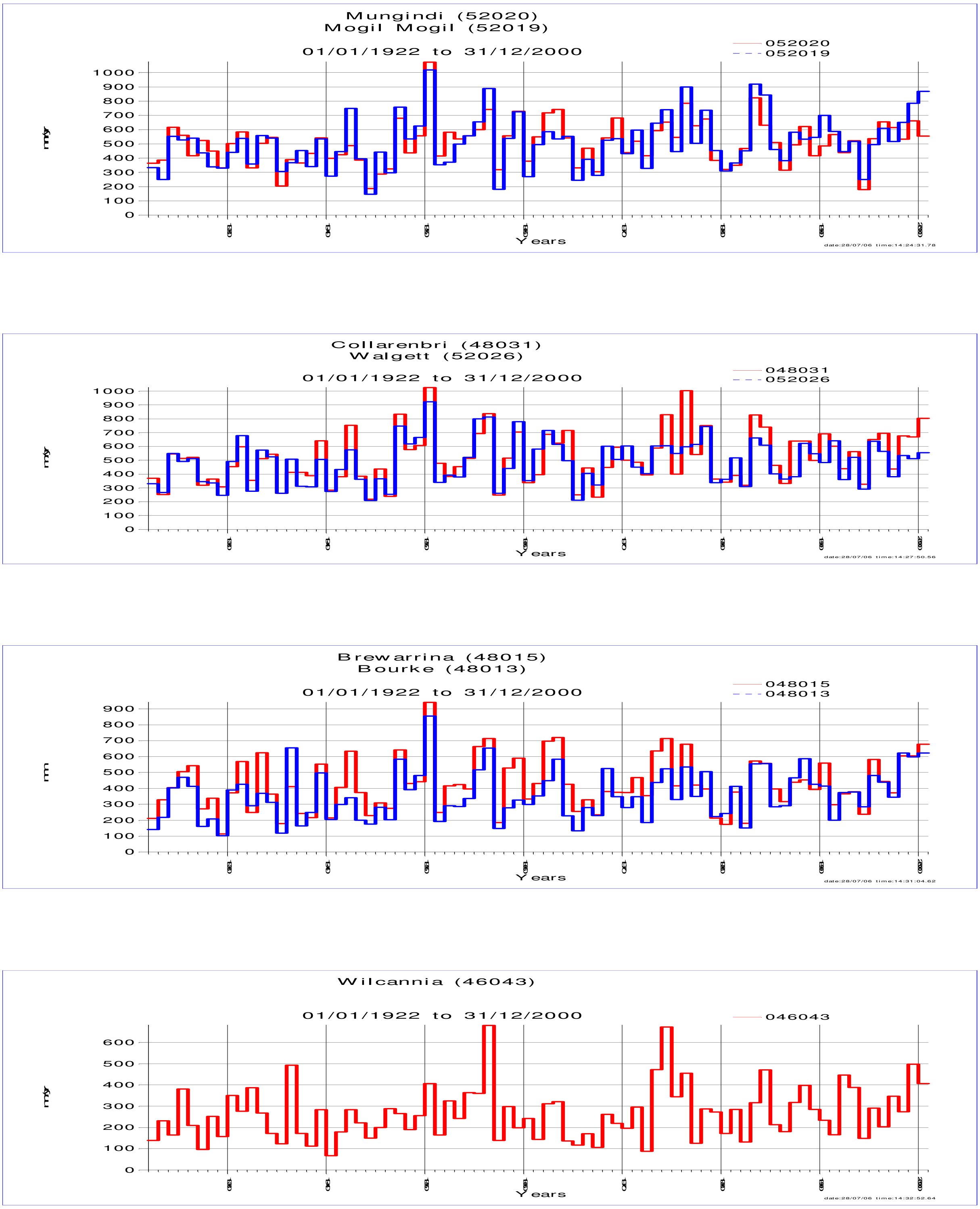
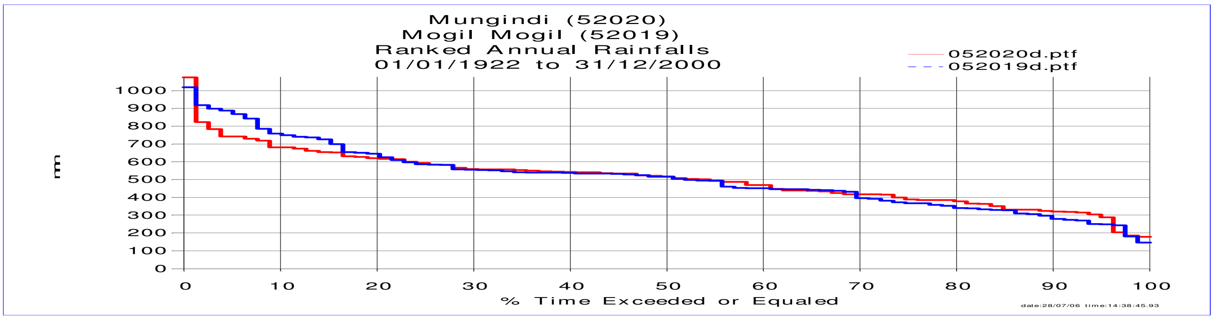
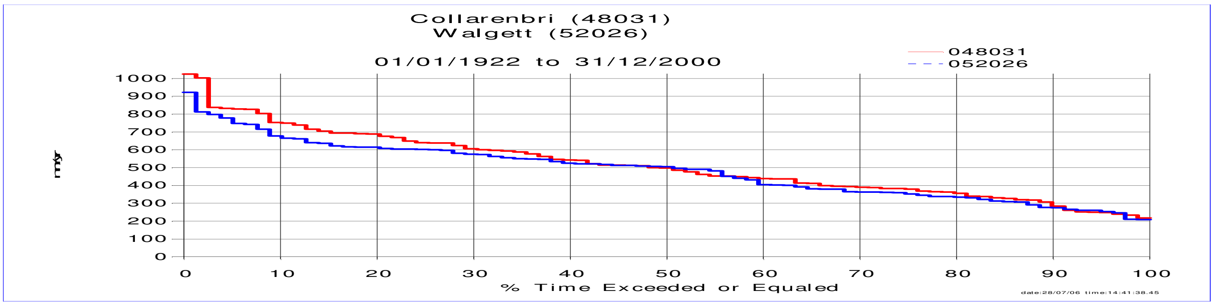
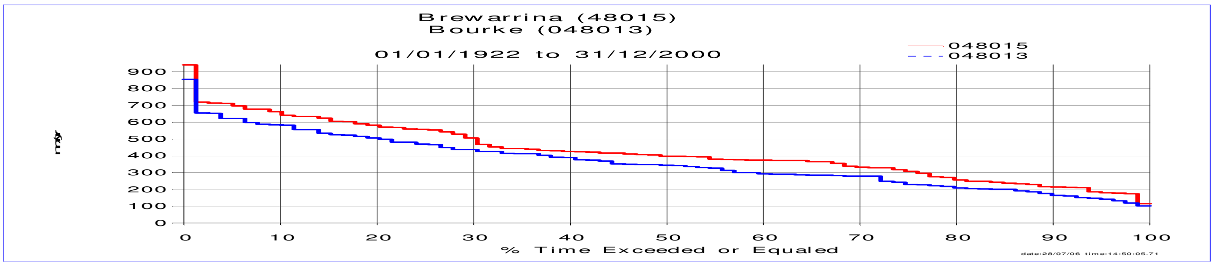


Figure A.0.1 Annual Rainfalls







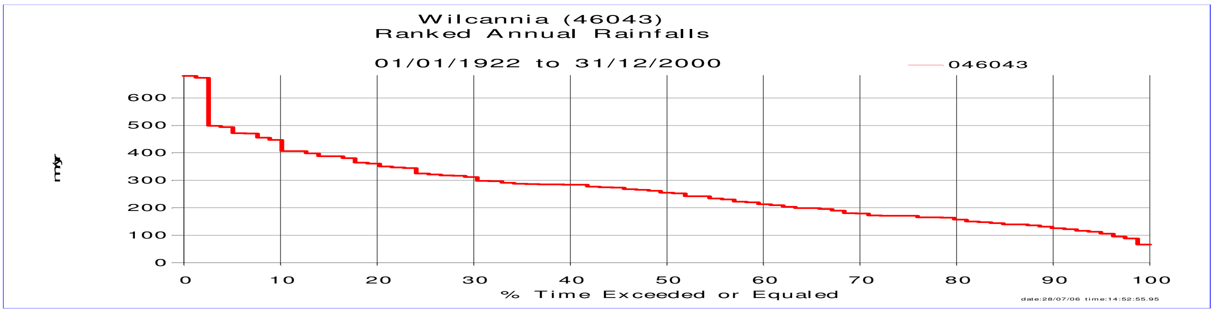


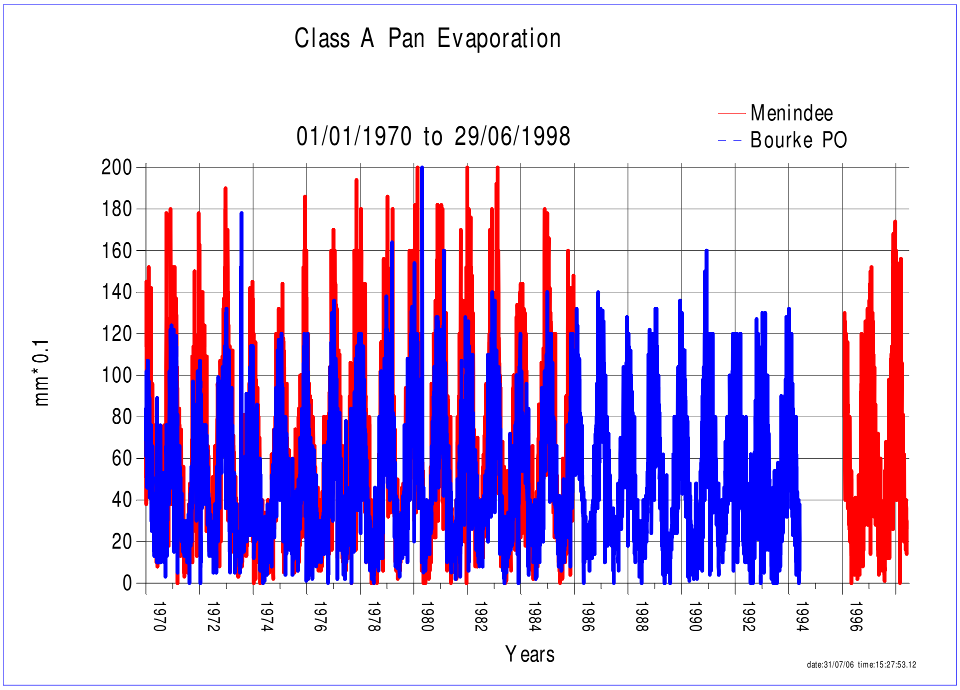
Figure A.0.2 Annual Rainfalls Ranked

Statistical information for the evaporation stations utilised on the Barwon-Darling River system are listed below.

Table.A.0.2. Average Observed (Class A Pan) Evaporation Rates

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mungindi(*)	8.2	7.5	6.3	4.5	2.8	2.1	2.1	3.0	4.4	5.9	7.6	8.5
Walgett	7.8	7.4	6.1	4.1	2.4	1.7	1.8	2.5	4.1	5.7	7.2	8.2
Bourke	8.3	7.4	5.9	4.1	2.5	1.9	2.0	2.9	4.2	5.9	7.5	8.6
Menindee	10.2	9.6	7.2	4.7	2.7	1.8	2.1	3.1	4.6	6.6	8.5	10.3

* Weighted mean of observed data at Boggabilla (53004), Moree (53048) and St George (43053)



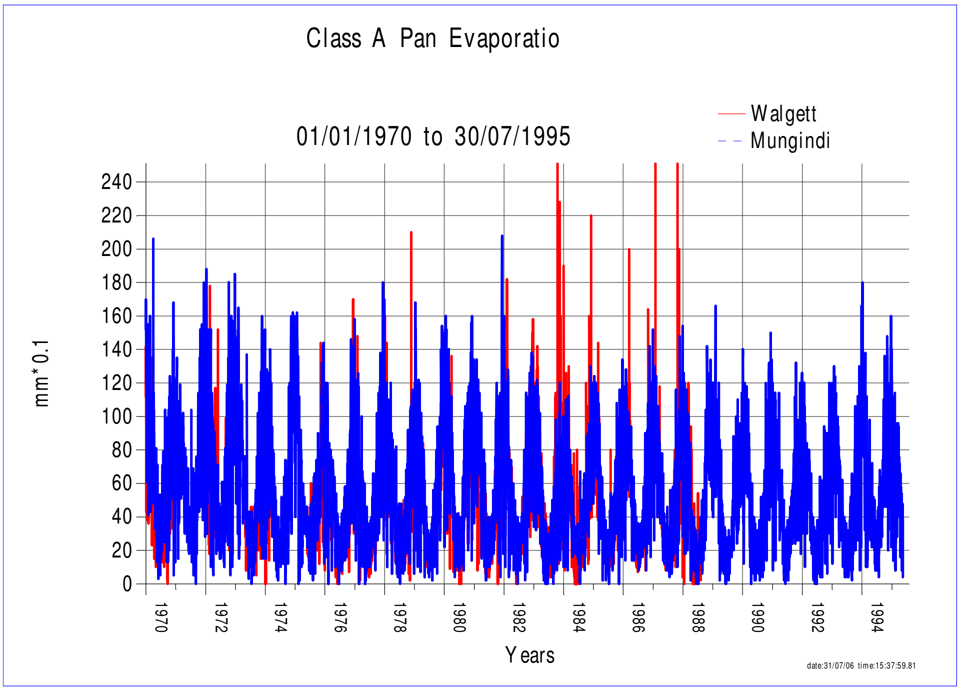


Figure A.0.3 Observed Annual Evaporations

Streamflow gauges utilised on the Barwon-Darling River system are listed below.

Table.A.0.3. Streamflow stations used for model calibration

Location	Station No (#)	Operation Period	Area sq.km	Usage in IQQM calibration
'Main River' Gauges				
Location	**Station No (#)**	**Operation Period**	**Area sq.km**	**Useage in IQQM calibration**
Barwon River @ U/S Pressbury Weir	416050	1987 - date	44100	Used for mainstream (in-channel) loss calibration
Barwon River @ Mogil Mogil	422004	1944 - date	64800	Used for mainstream (in-channel) loss calibration
Barwon River @ Collarenebri	422003	1944 - date	85500	Used for mainstream (in-channel) loss calibration
Grawan Creek @ Old Pockataroo	422018	1965 - date	N.A	Used for effluent flow relationship
Barwon River @ Walgett	422001	1886 - date	132200	Used for total flow loss calibration
Barwon River @ Brewarrina	422002	1892 - date	297850	Used for mainstream (in-channel) loss calibration
Cato Creek @ Brewarrina	422007	1947 - date	N.A	Used for effluent flow relationship
Darling River @ Bourke	425003	1880 – date	385000	Used for total flow loss calibration
Darling River @ Louth	425004	1954 - date	489300	Used for segmenting mainstream (in-channel) loss calibration
Darling River @ Tilpa	425900	1995 - date	502500	Used for segmenting mainstream (in-channel) loss calibration
Darling River @ Wilcannia	425008	1913 - date	569800	Used for mainstream (in-channel) loss calibration
Talyawalka Creek @ Barrier Highway (Wilcannia)	425018	1971 - date	N.A	Used for effluent flow relationship and for it's contribution to total flow loss calibration
Darling River @ Wilcannia (Total Flow)	425002	1886 - date	569800	Used for total flow loss calibration
Darling River @ Weir 32	425012	1958 - date	572000	Used for total flow loss calibration
Darling River @ Menindee Town	425001	1881 -1960	569600	Used for channel flow loss calibration

Location	Station No (#)	Operation Period	Area sq.km	Useage in IQQM calibration
'Inflow' Gauges				
Barwon River @Mungindi	416001	1889 - date	44070	Used to define inflows and for gap filling of Boomi @ Neewoora and relationship to derive flows for Little Weir River
Boomi River @ Neewoora	416028	1968 - 1994	N.A	Used to define inflows
Gil Gil Creek @Galloway	416052	1987 - date	N.A	Used to define inflows
Gil Gil Creek @Weemelah No. 2	416027	1968 - date	N.A	Used to gap fill Galloway
Moonie River @Gundabluie	417001	1945 - date	15810	Used to define inflows
Gwydir River @ Collymongle	418031	1970 - 1999	N.A	Used to define inflows
Gwydir River @ Millewa	418066	1988 - date	N.A	Used to gap fill Collymongle
Mehi River @ Collarenebri	418055	1980 - date	N.A	Used to define inflows
Mehi River @ Bronte	418058	1982 - 2001	N.A	Used to gap fill Collarenbri
Namoi River @Goangra	419026	1954 - date	36290	Used to define inflows
Pian Creek @ Waminda	419049	1972 - date	36290	Used to define inflows
Castlereagh River @ Coonamble	420005	1960 - date	8400	Used to define inflows
Marthaguy Creek @ Carinda	421011	1944 - date	6475	Used to define inflows
Macquarie River@ Carinda	421012	1926 - date	30100	Used to define inflows
Marra Creek @ Yarrawin	421024	1945 - 1977	N.A	Used to define inflows
Marra Creek @ Billybingbone Bdge	421107	1980 - 1997	N.A	Used to define inflows
Marra Creek @ Carinda Road	421097	1980 - date	N.A	Used to define inflows
Bogan River @ Gongolgon	421023	1942 - date	N.A	Used to define inflows
Bokhara River @ Bokhara (Goodwins	422005	1944 - date	N.A	Used to define inflows
Culgoa River @ D/S Collerina	422006	1944 - date	N.A	Used to define inflows
Narran River @ New Angledoon	422012	1959 - date	N.A	Used to define inflows
Narran River @ Wilby Wilby	422016	1964 - date	N.A	Used to define inflows
Narran Lake @ Storage Gauge	4220019	1982 - 1990	N.A	Used to define inflows

Warrego River @ Ford's Bridge	423001	1921 - date	60500	Used to define inflows
Warrego River @ Ford's Bridge byewash	423002	1921 - date	60500	Used to define inflows
Paroo River @ Willaro Crossing	424002	1975 - date	31000	Not used in IQQM

Table A.0.4. Flow statistics for streamflow stations used for model calibration

Station	Calibration Period (1970 – 1984)					Validation Period (1995 – 2000)					Remarks
	Percent of Period Recorded	Daily Flows (ML/d)				Percent of Period Recorded	Daily Flows (ML/d)				
		Average	Maximum	Minimum	Median		Average	Maximum	Minimum	Median	
Barwon River @ U/S Pressbury Weir (416050)	0%	-	-	-	-	99%	1173	60,207 (12/9/98)	0	139	Missing Calib. Per'd
Barwon River @ Mogil Mogil (422004)	96%	3,700	71,780 (24/5/83)	0	825	100%	3233	141,408 (9/9/98)	0	197	
Barwon River @ Collarenebri (422003)	94%	4,290	71,780 (24/5/83)	0	1,050	100	2629	118,200 (11/9/98)	0	274	Effluents Bypass
Barwon River @ Walgett (422001)	93%	8795	445,854 (24/2/76)	0	1,310	100%	5082	243,046 (15/9/98)	0	356	Total Flow
Barwon River @ Brewarrina (422002)	87%	7290	164,740 (23/1/74)	0	2,320	100%	6316	118, 508 (22/9/98)	0	669	Effluents Bypass
Darling River @ Bourke (425003)	93%	13470	529250 (8/3/76)	0	3750	99%	6629	229,776 (29/9/98)	0	688	Total Flow
Darling River @ Louth (425004)	76%	11200	227000 (6/3/76)	0	3600	96%	4946	140,650 (12/10/98)	0	578	Floodplain Bypass
Darling River @ Tilpa (425900)	0%	-	-	-	-	92%	4418	50,139 (11/3/96)	0	550	Missing Calib. Per'd
Darling River @ Wilcannia (425008)	93%	8795	68444 (5/4/76)	0	3810	99%	4351	43,418 (20/10/98)	0	688	Main Channel Only
Darling River @ Weir 32 (425012)	95%	7207	126,126 (22/4/76)	0	1740	100%	3054	46503 (29/10/98)	0	409	Sometimes Total Flow
Darling River @ Menindee Town*	99%	4493	40638	0	1463	99%	10822	159248	0	2129	

* Different Calibration and Validation period for Darling River @ Menindee Town as the guage was only operational between1881 to 1960.

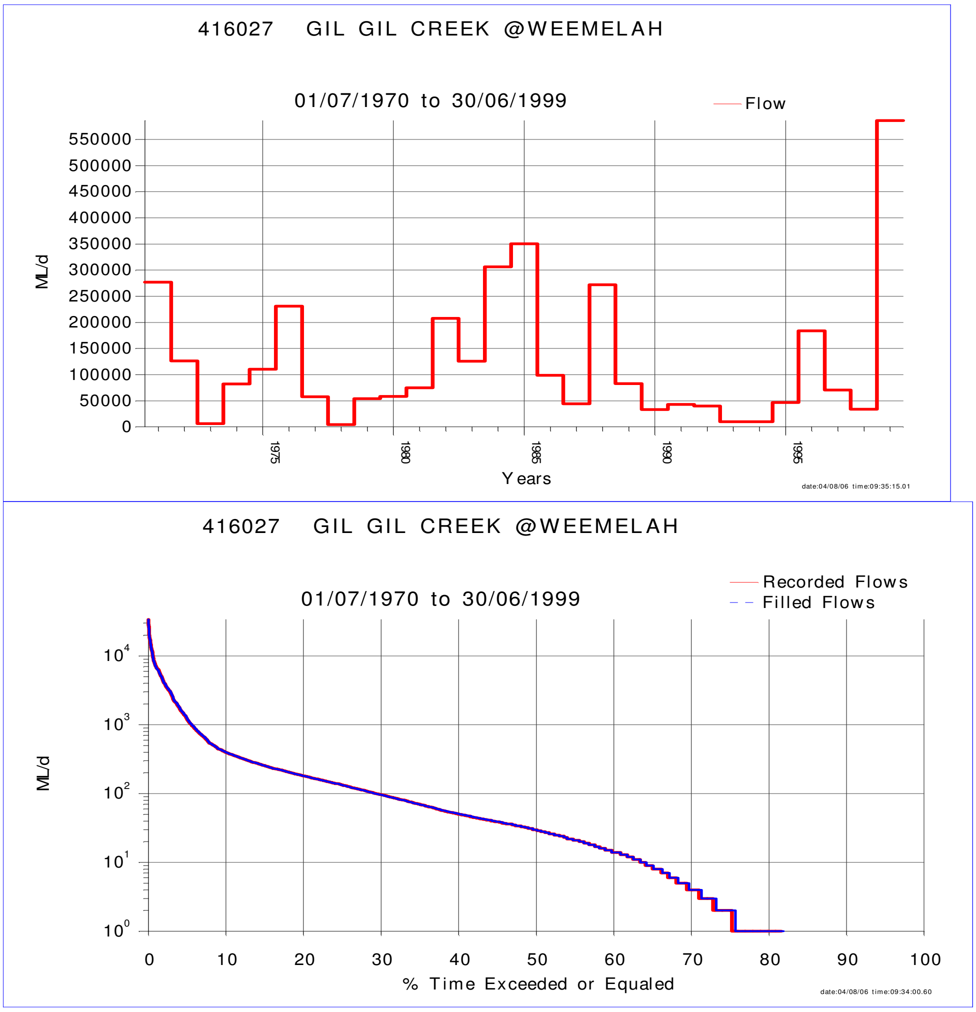


Figure A.0.4 Annual Flows and Ranked Daily Flows – Gil Gil Creek

Appendix B

Attached is sample of the data collected for each ‘major’ irrigation enterprise as part of the RMC’s Development History Project.

FARM

The Need for Agreement
An important part of this process is for both the irrigators and ourselves (project staff) to be confident that the data is correct.
In addition we need to ensure that information collected is kept confidential. In order to satisfy these requirements we are asking you to check the information on the following 166 pages and sign the declaration below.

Declaration:
I have checked the information presented on the following 166 pages and agree that it is an accurate representation of the recent history of development and water use on FARM:

Signed: . . . .

Name: (please print) . . . .

Date: . . . .

Please initial the bottom right of each page as well.

Current Owner: John Smith
Address:

Phone:
Fax:

Interview Details: Terry Brill and Catherine Hams interviewed owner on the 14th October 1999.

General Information:

The present irrigation development is approximately 888 ha and the storage area is 222 ha.
Irrigation commenced in the 1960's with mainly winter cereals grown. Soybeans were grown in the early 1980's and the first cotton crop was grown in 1982/83 season.
Farm's service center is Collarenbri.

Ownership History:

The family has owned Farm for a number of years and was the first to grow cotton.

Irrigation Licence (s):
The following table shows irrigation licences applicable to the Development. (D class licences and licences held for purposes other than irrigation are not included)

LICENSE	S O	METDIS	STATUS	EXPDATE	STREAM	CLASS	AREA	PURPOSE	QUOTA	FIRST	SURNAME	ADDRESS 1	ADDRESS 2	TOWN	PC	STD	PHONE
9SA10	640	40	AC	27/11/00	BARWON RIVER	B	243	IRRIGATION	5,645					Muningdi			
90SL03	642	40	AC	11/07/00	BARWON RIVER	C	162	IRRIGATION	1,430					Muningdi			

Year	Season	OFS Area (ha)	Developed Area (ha)	# of Fields Fallowed	Area Fallowed (ha)	% of Dev. area Fallowed	# of Fields being Developed	Area being Developed (ha)	Crop 1 - Type	Crop 1 - # of Fields	Crop 1 - Area (ha)	Crop 1 - Yield	Crop 2 - Type	Crop 2 - # of Fields	Crop 2 - Area (ha)	Crop 2 - Yield	Crop 3 - Type	Crop 3 - # of Fields	Crop 3 - Area (ha)	Crop 3 - Yield
1987	Winter	13	388	13	388	100		23		0	0	0.0		0	0	0.0		0	0	0.0
87/88	Summer	13	388	3	77	20		23	Cotton Upland	10	312	8.0		0	0	0.0		0	0	0.0
1988	Winter	13	412	13	412	100	1	25		0	0	0.0		0	0	0.0		0	0	0.0
88/89	Summer	13	412	5	139	34	1	25	Cotton Upland	8	273	7.4		0	0	0.0		0	0	0.0
1991	Winter	38	412	13	412	100	1	45		0	0	0.0		0	0	0.0		0	0	0.0
91/92	Summer	38	412	7	196	48	1	45	Cotton Upland	6	216	-2.5		0	0	0.0		0	0	0.0
1992	Winter	38	457	14	457	100	4	323		0	0	0.0		0	0	0.0		0	0	0.0
92/93	Summer	38	457	7	158	35	4	323	Cotton Upland	7	299	8.3		0	0	0.0		0	0	0.0
1993	Winter	38	698	17	698	100	1	83		0	0	0.0		0	0	0.0		0	0	0.0
93/94	Summer	38	698	15	631	91	1	83	Cotton Upland	2	66	8.7		0	0	0.0		0	0	0.0
1994	Winter	120	698	17	698	100	0	0		0	0	0.0		0	0	0.0		0	0	0.0
94/95	Summer	120	698	12	366	52	0	0	Cotton Up_dblskp	5	332	4.5		0	0	0.0		0	0	0.0
1995	Winter	120	698	17	698	100	0	0		0	0	0.0		0	0	0.0		0	0	0.0
95/96	Summer	120	698	6	190	27	0	0	Cotton Upland	11	508	6.2		0	0	0.0		0	0	0.0
1996	Winter	120	698	15	668	96	0	0	Oats –irrigated	2	29	Unknown		0	0	0.0		0	0	0.0
96/97	Summer	120	698	4	82	12	0	0	Cotton Upland	13	616	8.2		0	0	0.0		0	0	0.0
1997	Winter	120	698	14	645	93	0	0	Wheat	3	52	2.2		0	0	0.0		0	0	0.0
97/98	Summer	120	698	5	90	13	0	0	Cotton Up_hail	4	296	5.7	Cotton Upland	6	221	8.0	Cotton In_hail	2	91	7.2
1998	Winter	120	698	17	698	100	0	0		0	0	0.0		0	0	0.0		0	0	0.0
98/99	Summer	120	698	11	317	46	0	0	Cotton Upland	6	380	7.8		0	0	0.0		0	0	0.0

On Farm Storages:

Year	Type	OFS 1 Name	Capacity (ML)	Type	OFS 2 Name	Capacity (ML)	Type	OFS 3 Name	Capacity (ML)
87/88				Turkeys Nest	Storage 2	400			
88/89				Turkeys Nest	Storage 2	400			
89/90				Turkeys Nest	Storage 2	400	Turkeys Nest	Storage 3	1050
90/91				Turkeys Nest	Storage 2	400	Turkeys Nest	Storage 3	1050
91/92				Turkeys Nest	Storage 2	400	Turkeys Nest	Storage 3	1050
92/93				Turkeys Nest	Storage 2	400	Turkeys Nest	Storage 3	1050
93/94	Turkeys Nest	Storage 1	3650	Turkeys Nest	Storage 2	400	Turkeys Nest	Storage 3	1050
94/95	Turkeys Nest	Storage 1	3650	Turkeys Nest	Storage 2	400	Turkeys Nest	Storage 3	1050
95/96	Turkeys Nest	Storage 1	3650	Turkeys Nest	Storage 2	400	Turkeys Nest	Storage 3	1050
96/97	Turkeys Nest	Storage 1	3650	Turkeys Nest	Storage 2	400	Turkeys Nest	Storage 3	1050
97/98	Turkeys Nest	Storage 1	3650	Turkeys Nest	Storage 2	400	Turkeys Nest	Storage 3	1050
98/99	Turkeys Nest	Storage 1	3650	Turkeys Nest	Storage 2	400	Turkeys Nest	Storage 3	1050

Pumps:

Date	River pump (s)						Lift Pump 1					
Year	Number	Size (Inches)	Size (mm)	Brand	Type	Capacity (ML/Day)	Number	Size (Inches)	Size (mm)	Brand	Type	Capacity (ML/Day)
1998/99	R1	26	650		China	Unknown	2	14	350	Covill	Unknown	
1998/99	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1998/99							1	26	650		China	
1997/98	R1	26	650		China	Unknown	2	14	350	Covill	Unknown	
1997/98	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1997/98							1	26	650		China	
1996/97	R1	26	650		China	Unknown	2	14	350	Covill	Unknown	
1996/97	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1996/97							1	26	650		China	
1995/96	R1	26	650		China	Unknown	2	14	350	Covill	Unknown	
1995/96	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1995/96							1	26	650		China	
1994/95	R1	26	650		China	Unknown	2	14	350	Covill	Unknown	
1994/95	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1994/95							1	26	650		China	
1993/94	R1	26	650		China	Unknown	2	14	350	Covill	Unknown	
1993/94	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1993/94							1	26	650		China	
1992/93	R1	26	650		China	Unknown	2	14	350	Covill	Unknown	
1992/93	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1992/93												
1991/92	R1	26	650		China	Unknown	2	14	350	Covill	Unknown	
1991/92	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1991/92												
1990/91	R1	26	650		China	Unknown	2	14	350	Covill	Unknown	
1990/91	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1990/91												
1989/90	R1	26	650		China	Unknown	2	14	350	Covill	Unknown	
1989/90	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1989/90	R3	16	400		Centrifical	Unknown						
1988/89							2	14	350	Covill	Unknown	
1988/89	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1988/89	R3	16	400		Centrifical	Unknown						
1987/88							2	14	350	Covill	Unknown	
1987/88	R2	12	300		Unknown	Unknown	3	12	300		Axil Flow	0.8
1987/88	R3	16	400		Centrifical	Unknown						

🟦 **Rows or cells coloured indicate an uncertainity with the data. If the information is correct please initial box or make the appropriate changes in the table.**

Slope:

Presently the average field slope for FARM is 1:1700. Before redevelopment of most fields excluding 20, 21 and 22 the average slope was 1:2200.

The redevelopment if individual fields is unknown at present however, if you wish to add this data to your information please attach it when sending back the original copy. The information needed is the field number and the year it was redeveloped and its approximate slope.

Floodplain Harvesting:

Farm has only used floodplain water to “top up” its storages. The opportunity to harvest approximately 500ML every three years is an option if needed but has not been necessary so far.

Appendix C

The licence conditions (as indicated by entitlements and threshold conditions) that are represented in IQQM for those Barwon-Darling irrigators that were active during 1993/94 are shown in Table C.0.1. The reaches shown in Table C.0.1 differ slightly from the 1991 Water Licensing Policy [DWR, 1991] in that the Presbury to Collarenebri reach has been subdivided at Mogil Mogil. Also the Wilcannia to Lake Wetherell reach has not been shown as there were no active licences in 1993/94.

Table C.0.1. 1993/94 Entitlements and Threshold Conditions

Reach	Licence Entitlements by Class					Access Conditions by Class			
	'Major' Irrigators			Reach Irrigators					
	A (ML/year)	B (ML/year)	C (ML/year)	A (ML/year)	B (ML/year)	A (ML/d @ Site)	B (ML/d @ Site)	C (ML/d @ Site)	FP (5) (ML/d In Reach)
Mungindi to Presbury	-	8,505	2430	65 (1)	6,915 (1)	690 @ Pressbury OR 650 @ Collar'i & 40 @ Pressbury OR 600 @ Walgett & 50 @ Collar'i & 40 @ Pressbury	810 @ Pressbury OR 760 @ Collar'i & 50 @ Pressbury OR 700 @ Walgett & 60 @ Collar'i & 50 @ Pressbury	1880 @ Pressb'y OR 1760 @ Collar'i & 20 @ Pressbury	10,500

Presbury to Mogil Mogil	-	-	4,500	605 (1)	-	-	760 @ Collar'i OR 700 @ Walgett & 60 @ Collar'i	1760 @ Collar'i OR 1630 @Walgett & 130 @ Collar'i	-
Mogil Mogil to Collarenebri		9,720	17,010	400	2,585	650 @ Collar'i OR 600 @ Walgett & 50 @ Collar'i	760 @ Collar'i & 50 @ Pressbury OR 700 @ Walgett & 60 @ Collar'i	1760 @ Collar'i OR 1630 @Walgett & 130 @ Collar'i	45,000
Collarenebri to Walgett		18,145		600	8,160	600 @ Walgett & 50 @ Collar'i	700 @ Walgett & 60 @ Collar'i (2)		10,000 – 26,000
Walgett to Brewarrina		32,975	113,250	755	3,300	600 @ Walgett & 460 @ Brew'na	700 @ Walgett & 550 @ Brew'na	800 @ Walgett & 574 @ Brew'na OR 1300 @Walgett & 950 @ Brew'na - 2500 @ Brew'na (3)	30,000 – 50,000
Brewarrina to Bourke	2,790	109,890	34,345	3,915	4,070	460 @ Brew'na & 350 @ Bourke	550 @ Brew'na & 390 @ Bourke OR 800 @ Culgoa (4)	4894 @ Bourke & Menindee Lakes > 907.8 GL (3)	30,000 – 60,000
Bourke to Louth		12,965	44,750	860	980	350 @ Bourke & 260 @ Louth	390 @ Bourke & 280 @ Louth	750 @ Bourke - 489 @ Louth (3)	50,000 – 70,000
Louth to Wilcannia		4,880		1,440	5,920	260 @ Louth & 123 @ Wilcannia	280 @ Louth & 123 @ Wilcannia		110,000

(1) Reach irrigators not limited by entitlements at 1993/94
(2) Not all irrigators limited by these entitlements or conditions
(3) C Class conditions differ between irrigators as they were set by Land Boards
(4) Notwithstanding condition that was routinely applied to this reach
(5) Flood Plain (FP) access thresholds are supplied as guide only as they are unique for each irrigator

New licence conditions (as indicated by revised threshold conditions and known as Environmental Flow Rules) came into effect on 15/09/2000 for most Barwon-Darling irrigators. Details of these ‘new’ threshold conditions and entitlements of those Barwon-Darling irrigators that were active during 2000/01 are shown Table C.0.2. The Wilcannia to Lake Wetherell reach has not been shown as there were no active licences in 2000/01.

Table C.0.2. 2000/01 Entitlements and Threshold Conditions

Reach	Licence Entitlements by Class					Access Conditions by Class			
	‘Major’ Irrigators			Reach Irrigators					
	A (ML/year)	B (ML/year)	C (ML/year)	A (ML/year)	B (ML/year)	A (ML/d @ Site)	B (ML/d @ Site)	C (ML/d @ Site)	FP (5) (ML/d In Reach)
Mungindi to Presbury		6,075	2,430	65	6,915	220 @ Pressbury	270 @ Pressbury	1500 @ Pressb’y	10,500
Presbury to Mogil Mogil			4,500		605		270 @ Press’y & 230 @ Mogil	1100 @ Collar’i	
Mogil Mogil to Collarenebri		12,525	17,010	505	605	190 @ Mogil & 165 @ Collar’i	570 @ Mogil & 500 @ Collar’i	1100 @ Collar’i	45,000
Collarenebri to Tarra		20,575			2,255		500 @ Collar’i & 430 @ Tara		10,000 – 20,000
Tarra to Walgett		2,292		335	3,310	100 @ Walgett & 165 @ Collar’i	900 @ Walgett		26,000
Walgett to Macquarie R		11,105	6,200		380	900 @ Walgett & 870 @ Boorooma (Macquarie)	1000 @Walgett & 870 @ Boorooma - 1300 @Walgett & 950 @ Boorooma OR 1250 @ Bourke & 1000 @Walgett & 870 @ Boorooma -		30,000 – 40,000

							4894 @ Bourke & Menindee Lakes > 907.8 GL (1)		
Macquarie R to Brewarrina		21,130	108,000	755	2,915	530 @ Geera & 460 @ Brew'na	870 @ Geera & 840 @ Brew'na	2500 @ Brew'na	50,000
Brewarrina to Culgoa		22,165	9,235				840 @ Brew'na & 760 @ Beemery (U/S Culgoa)	4894 @ Bourke & Menindee Lakes > 907.8 GL	30,000
Culgoa to Bourke	2,790	97,575	25,110	3,910	4,070	400 @ Warraweena (D/S Culgoa) & 350 @ Bourke	1330 @ Warraweena (D/S Culgoa) & 1250 @ Bourke	4894 @ Bourke & Menindee Lakes > 907.8 GL	50,000 – 64,000
Bourke to Louth		18,405	44,750	1,070	980	350 @ Bourke & 260 @ Louth	1250 @ Bourke & 1130 @ Louth	1610 @ Bourke - 1339 @ Louth (1)	50,000 – 70,000
Louth to Tilpa		4,880		1,030		260 @ Louth & 215 @ Tilpa	1130 @ Louth & 1010 @ Tilpa		110,000
Tilpa to Wilcannia		4,880		410	5,030	215 @ Tilpa & 123 @ Wilcannia	1010 @ Tilpa & 850 @ Wilcannia		

(1) C Class conditions differ between irrigators as they were set by Land Boards

(2) Flood Plain (FP) access thresholds are supplied as guide only as they are unique for each irrigator

Appendix D

In the following node-link diagrams, the nodes are labelled with a shape, due to space restrictions only those nodes describing a physical location are labelled with a description. Table D.0.1 shows a key to node shape as well as a description of the functions of these node types.

Table D.0.1. Node Types used in Barwon-Darling IQQM

Node type	Node name	Node key	Main purpose of the node
0.0	Straight		Dummy nodes used to output simulated flows at selected locations.
1.0	Tributary inflow		Allows water from tributaries to join the main river.
1.2	Pumped inflow		Allows water pumped or extracted by a 3.1type node to inflow into a river section i.e. it's the receiving end.
2.1	Head-water storage		Storage where water orders from 8.0 type node (Irrigator) are meet.
3.1	Demand		Fixed demand constrained by entitlement and/or access conditions, etc, diverts water to a 1.2 type node.
4.0	Effluent off-take		Diversion of flows into an effluent channel, as a function of river flow.
5.0	Effluent return		Return of unregulated effluent flows to the river
8.0	Irrigation demand		Node that determines irrigation demands, ordering and diversion calculations from a storage, utilises awater use debiting scheme.
8.3	Irrigation demand		Node that determines irrigation demands from unregulated streams.
11.0	Confluence		Confluence of two river sections.
12.0	Floodplain Lakes		Simulate the behaviour of lakes or depressions within floodplains which store water when overbank flows occur, can also return water to river once overbank flows cease.

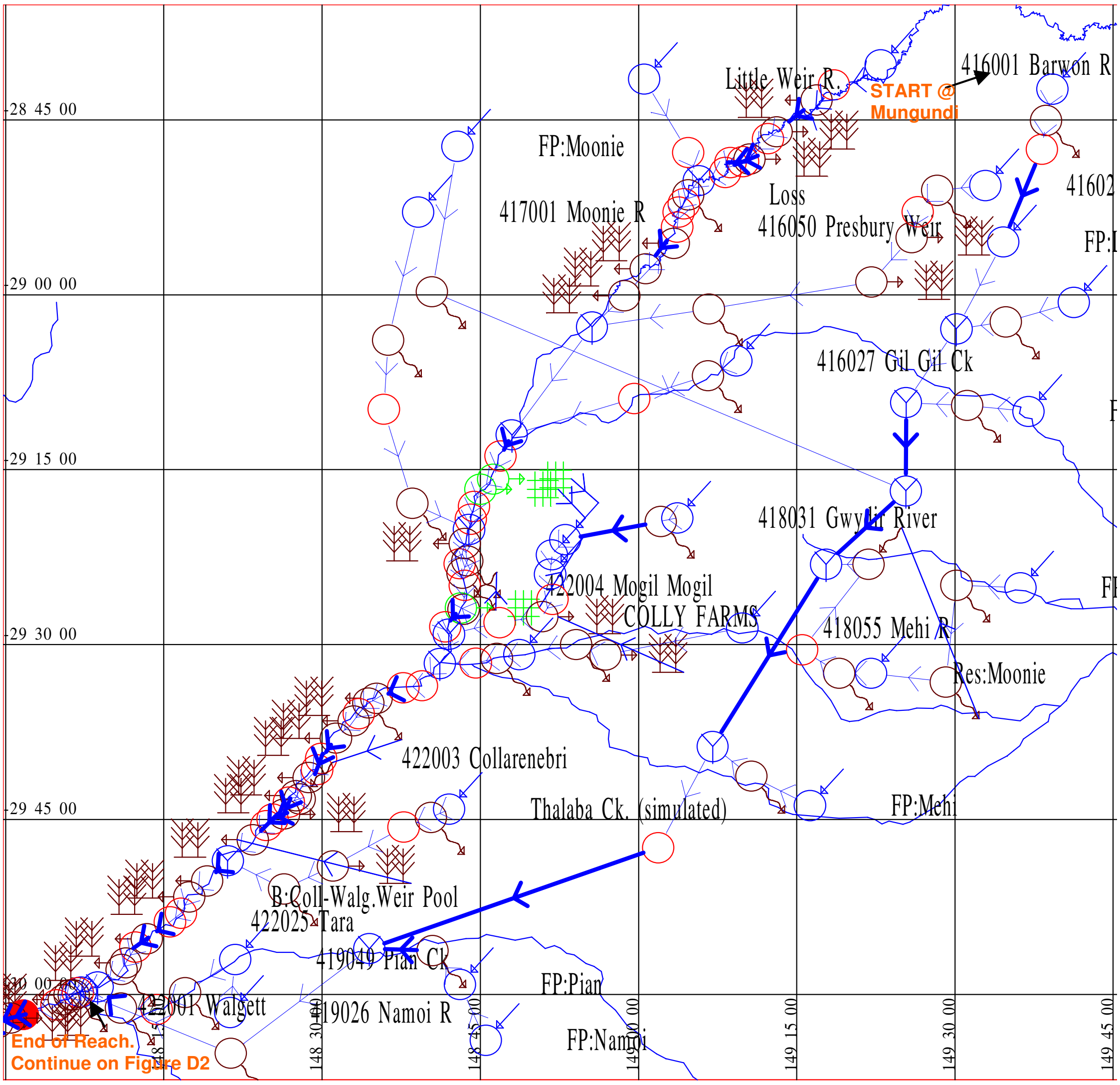


Figure D.0.1 Node link diagram showing the model between the guages located at Mungindi (416001) to Walgett (422001).

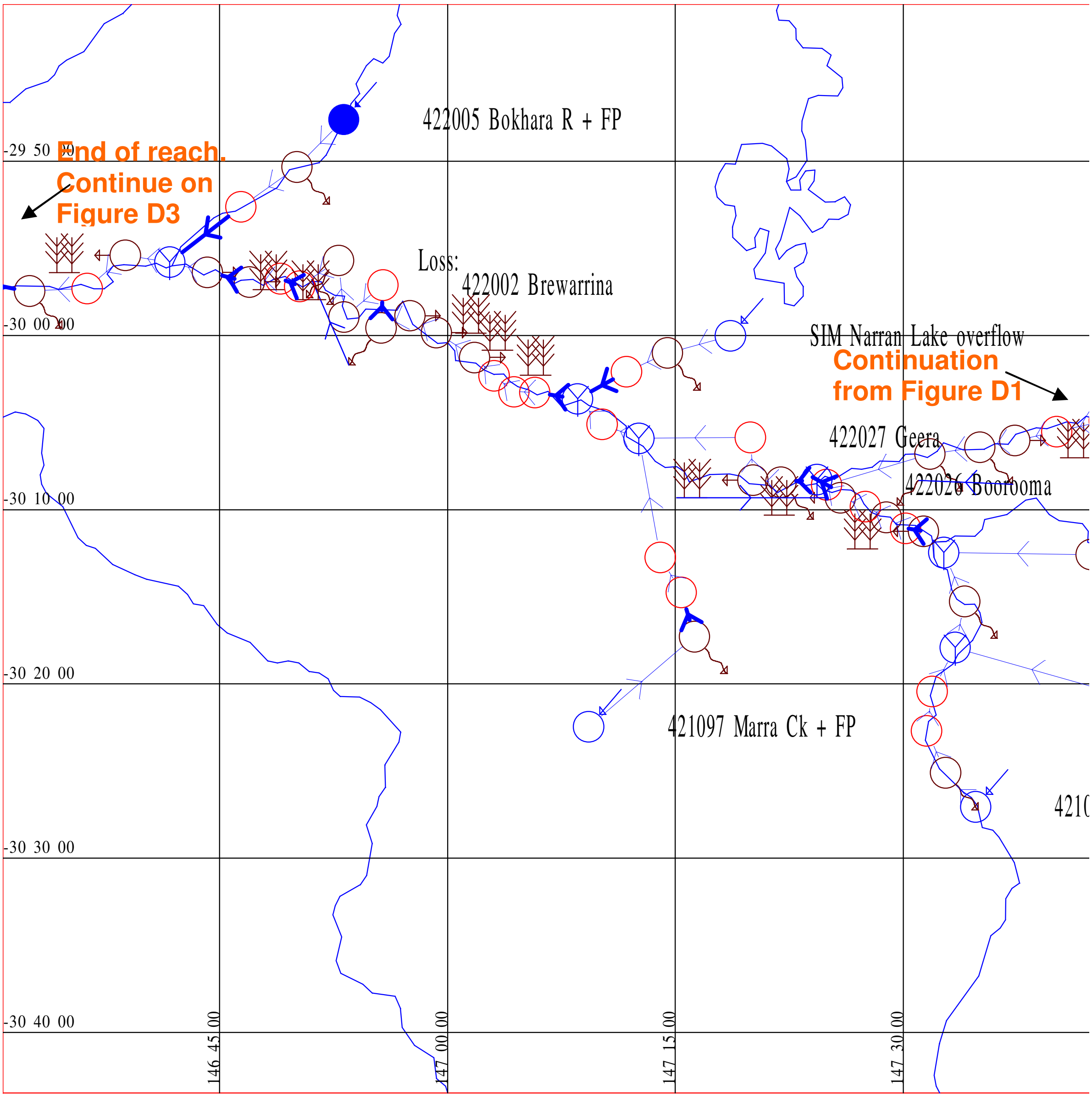


Figure D.0.2. Node link diagram showing the model between the guages located at Boorooma (422026) to pass Brewarrina (422002).

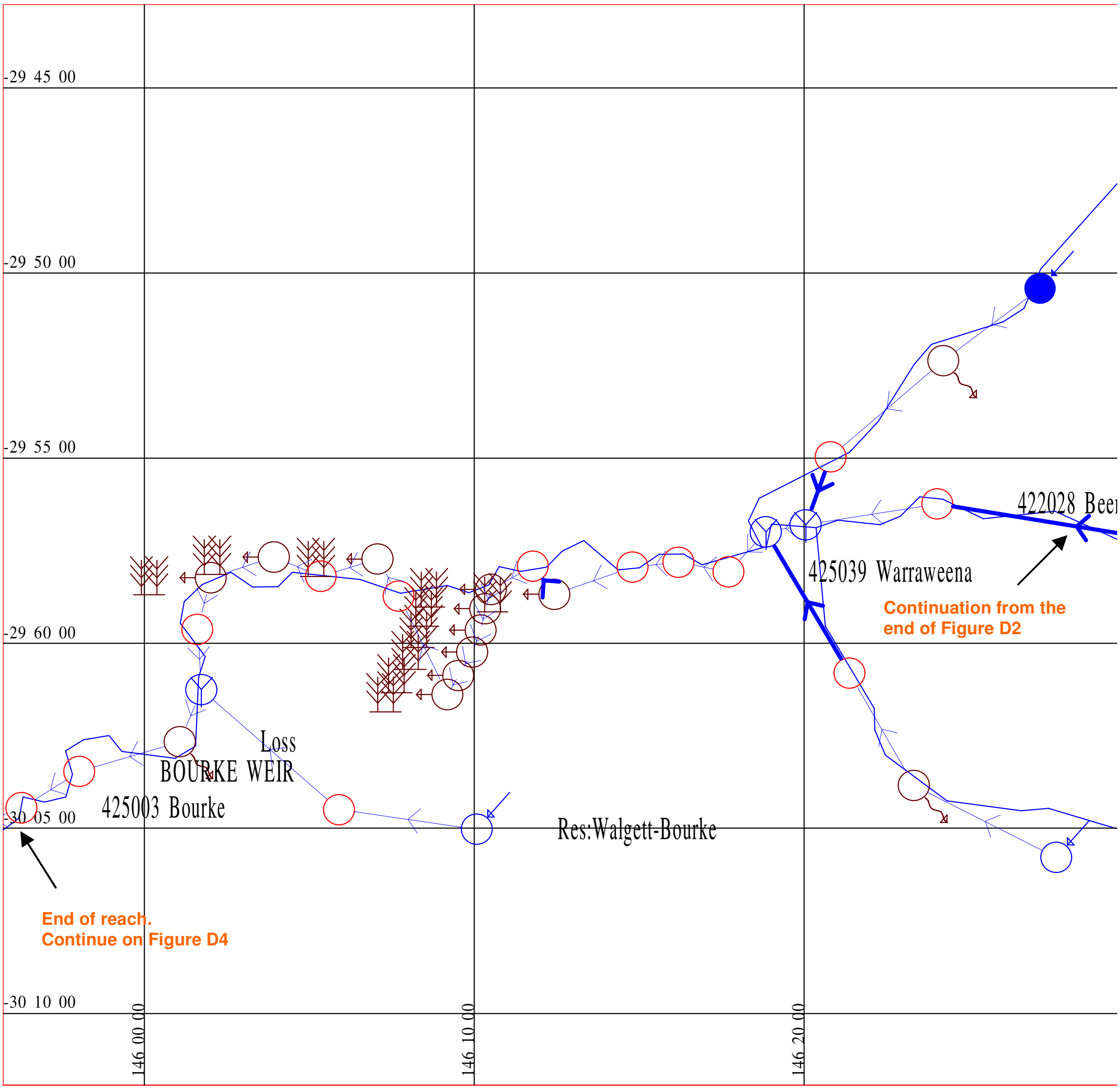


Figure D.0.3 Node link diagram showing the model between the guages located at Beemery (422028) to Bourke (425003).

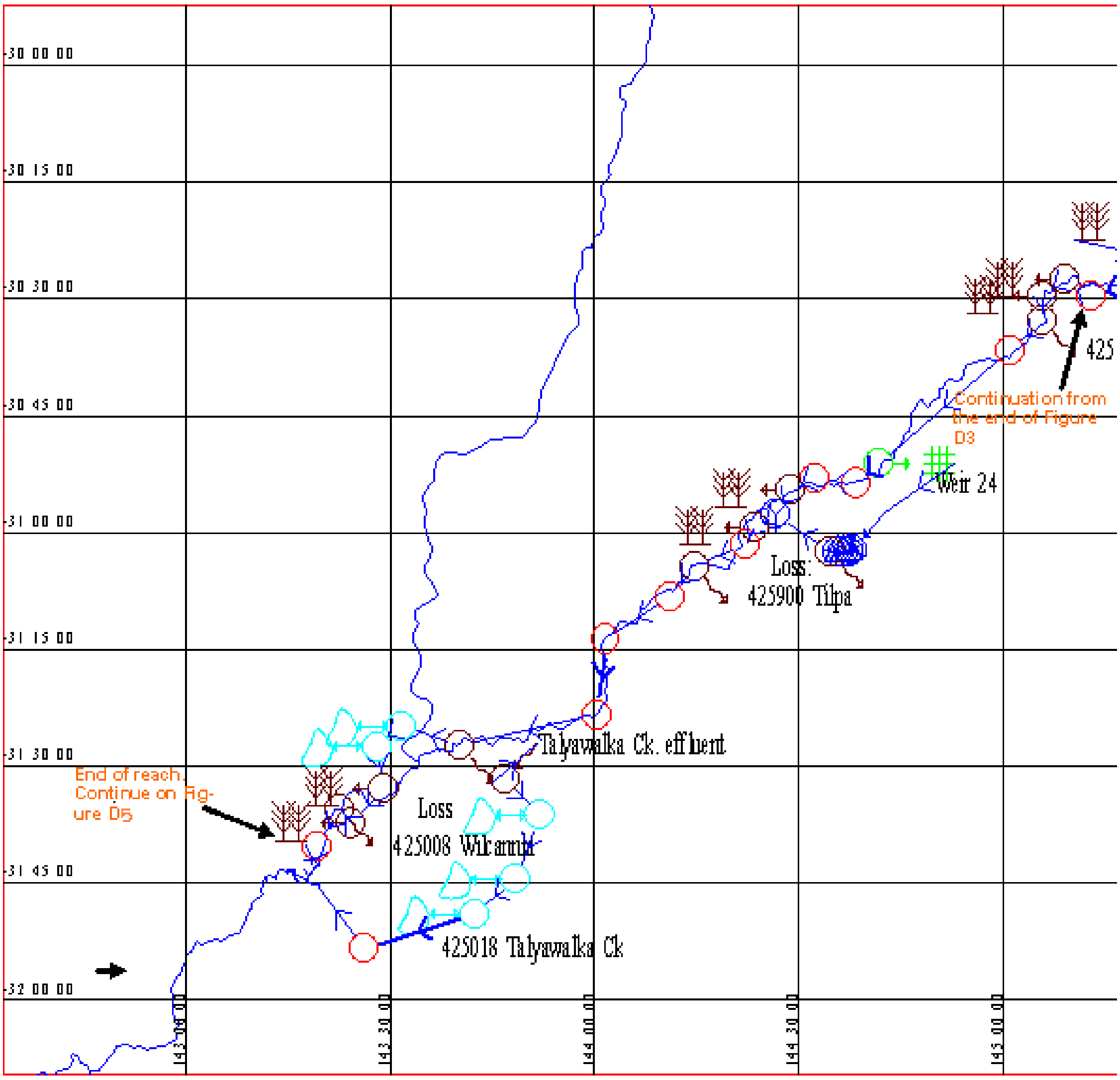


Figure D.0.4 Node link diagram showing the model between the guages located at Louth (425004) to Wilcannia (425008).

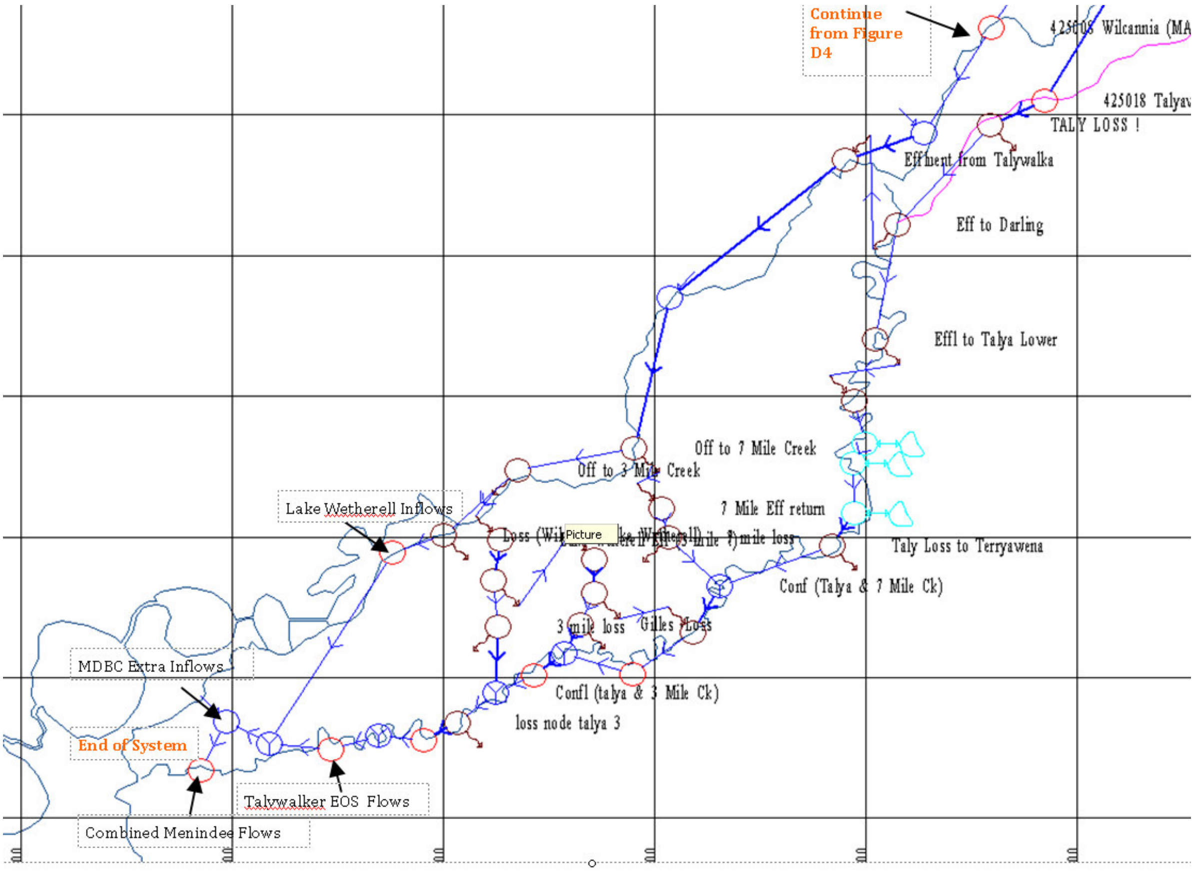


Figure D.0.5 Node link diagram showing the model between the guages located at Willcannia (425008) to Menindee.

Node	Node	Node	Location/description	Comments
no.	**type**	**Type(description)**		
1	2.0	Headwater inflow	416001 Barwon River @ Mungindi	
2	4.0	loss (fac. adj.)	factor adjustment :Barwon River inflow @ Mungindi	GT 65000 ML/d to Flood plain
3	0.0	observation	416001 Barwon River @ Mungindi (factored flows)	
4	8.3	irrigator	*Queensland 1*	
5	8.3	irrigator	*Queensland 2*	
6	8.3	irrigator	*Queensland 3*	
7	8.3	irrigator	***ALC***	
388	0.0	observation	observation (inflow for the first B.D irrigator)	
8	8.3	irrigator	***Coward-Comilaroy***	
10	0.0	observation	Comilaroy Weir	
162	0.0	observation	location of NS13A. Class irrigators	now redundant (because of ungrouping of irrigators)
169	0.0	observation	location of NS13B. Class irrigators	now redundant (because of ungrouping of irrigators)
11	1.0	inflow	Little Weir (416001, Barwon R.@ Mungindi used in estimation)	
12	0.0	observation	observe factored flows in Little Weir River	
14	11.0	confluence	Barwon River -Little Weir River confluence	
15	4.0	loss	loss:Mungindi gauge-Presbury weir	
375	0.0	observation	(was Infinite loss for revising the flows at Presbury)	now redundant (was used for testing)
376	0.0	observation	(was revised Presbury inflow)	now redundant (was used for testing)
16	0.0	observation	416050 Barwon River @ Presbury Weir	
17	8.3	irrigator	***Costello-Cubberoo***	
179	8.3	irrigator	***A Class:Mungindi Gauge-Boomi River confluence***	
180	8.3	irrigator	***B Class:Mungindi Gauge-Boomi River confluence***	
18	1.0	inflow	416028 Boomi River @ Neeworra	
19	4.0	loss (fac. adj.)	factor adjustment :Boomi River inflow	LT 14000 ML/d is multiplied by 1.5
20	0.0	observation	observe factored flows in Boomi River	
21	8.3	irrigator	***Anderson***	
22	8.3	irrigator	***Butler***	
23	4.0	loss	loss (Boomi River).	zero loss
299	11.0	confluence	Barwon River -Boomi River confluence	
24	1.0	inflow	416027 Gil Gil Ck.@ Weemelah	
25	4.0	loss (fac. adj.)	factor adjustment :Gil Gil Creek	unfactored
26	0.0	observation	observe factored flows in Gil Gil Creek	
27	11.0	confluence	Barwon River-Gil Gil Creek confluence	
399	0.0	observation	observe river flows upstream of Colly Farm	
314	3.1	3.1	**Colly-C Colly Farm (Balnabeen) C class Pumps**	
315	3.1	3.1	**Colly-Flood plain flow Colly pumping site (ICN)**	
181	0.0	observation	**Location A:Boomi-MM Weir Pool**	
186	0.0	observation	**Location B:Boomi-MM Weir Pool**	
28	1.0	inflow	417001 Moonie River @ Gundablouie	
29	4.0	loss (fac. adj.)	factor adjustment :Moonie River inflow	GT 20000 ML/d to Flood plain
30	0.0	observation	observe factored flows in Moonie River	
31	4.0	loss	loss:Moonie River	zero loss assumed
32	11.0	confluence	Barwon River -Moonie River Confluence	
171	0.0	observation	**Location A:MM Weir Pool**	
172	0.0	irrigator	**Location B:MM Weir Pool**	
35	4.0	loss	**loss:Presbury-Mogil Mogil**	
298	4.0	loss	Mogil Mogil effluent	
36	0.0	observation	422004 Barwon River @ Mogil Mogil	
297	5.0	Effluent Return	Mogil Mogil	
316	3.1	3.1	**Colly-B-Colly pumping site**	
37	0.0	observation	Banarway Weir	
38	1.0	inflow	418031 Gwydir River @ Collymongle -Gwydir monthly model	
39	4.0	loss (fac. adj.)	factor adjustment :Gwydir River inflow	LT 11000 ML/d is multiplied by 3.5 times
392	1.2	1.2	Colly 1B	
393	1.2	1.2	Colly 2G	
394	1.2	1.2	Colly 2B	
40	0.0	observation	upstream of Colly Farm	
395	8.3	irrigator	***Colly-Farms***	
396	0.0	observation	downstream of Colly Farm	
47	11.0	confluence	Barwon River-Gwydir River confluence	
43	1.0	inflow	Mehi R.@ Colly Farms N.B. Pumps u/s of gauge (418055 Mehi @ Co)	
323	8.3	irrigator	***Colly-Farms-Colly Central (Mehi)***	
44	4.0	loss	loss:infinite(As sim. flow is used for Colly which is u/s of gauge 418055)	
343	1.0	inflow	418055 Mehi R. nearr.Collarenebri	
344	4.0	loss (fac. adj.)	factor adjustment :Mehi River inflow	LT 5500 Ml/d is multiplied by 1.5 times
48	1.0	observation	observation for factored Mehi River inflow	
41	11.0	confluence	Barwon River -Mehi River confluence	
177	0.0	observation	obs.(was NS15A.IRR)	now redundant (because of ungrouping of irrigators)
178	0.0	observation	obs.(was NS15b.IRR)	now redundant (because of ungrouping of irrigators)

Node no.	Node type	Node Type(description)	Location/description	Comments
49	8.3	irrigator	***Tomkins-Coppingah***	
50	4.1	effluent	Grawan Creek at Old Pockataroo 422018	
51	8.3	irrigator	***McMillan***	
187	0.0	irrigator	**A:MM-Collarenebri**	
188	8.3	irrigator	***B:MM-Collarenebri***	
52	0.0	observation	422003 Barwon River @Collarenebri	
53	0.0	observation	Collarenebri Weir	
55	8.3	irrigator	***JMuller-Sunirra***	
54	8.3	irrigator	***Mansur-Lansdowne-Sunirra***	
56	5.0	Effluent return	Grawan Creek return	
57	0.0	observation	Collarenebri (Total Flow)	
58	8.3	irrigator	***Thompson-Callinan'***	
59	0.0	observation	Calmundi weir	
154	0.0	observation	obs.for 4G (Barwon)	
60	8.3	irrigator	***Hadley (4g-Barwon)***	
151	1.0	inflow	Thalaba Creek. (simulated)	
156	4.0	loss	loss to account for pooling	maximum loss of 360 Ml/d
157	0.0	observation	obs.for 4G (Thalaba)	
152	8.3	irrigator	***Hadley-4G (Thalaba Ck)***	
155	4.0	loss	loss:infinite	
153	11.0	confluence	Barwon River-Thalaba Creek confluence	
214	8.3	irrigator	***A Class irrigators:Coll-Walg.Weir Pool***	
215	8.3	irrigator	***B Class irrigators:Coll-Walg.Weir Pool***	
61	0.0	observation	Woorawardian Weir	
66	0.0	observation	422025 Tara (Barwon R. u/s Namoi Junction)	
62	8.3	irrigator	***Haire-Kalamos***	
64	0.0	observation	Breneger-Eumanbah	
63	8.3	irrigator	***Hogan-Wimbledon-Winooka***	
65	4.0	loss	loss:Collarenebri-Walgett	
67	1.0	inflow	419026 Namoi River @ Goangra	
68	1.0	inflow	419049 Pian Creek @ Waminda	
69	4.0	loss (fac. adj.)	factor adjustment :Namoi River & Pian Creek	GT 80000 ML/d diverted to FP
70	0.0	observation	observe (Namoi & Pian MC)	
71	4.0	loss	loss:Namoi River	zero loss
72	11.0	confluence	Barwon River-Namoi River confluence	
201	1.0	inflow	Flood plain flow:Barwon @ Mungindi	GT 65000 ML/d is multiplied by 2.5 times
221	4.0	loss (fac. adj.)	factor adjustment Flood plain flow:Barwon River @ Mungindi	
202	0.0	observation	observation	
203	1.0	inflow	Flood plain flow:Little Weir River	
204	1.0	inflow	Flood plain flow:Boomi River	
224	4.0	loss (fac. adj.)	factor adjustment Flood plain flow:Boomi River	
250	11.0	confluence	Flood plain flow-Boomi confluence	
205	1.0	inflow	Flood plain flow-GilGil Creek	
225	4.0	loss (fac. adj.)	factor adjustment Flood plain flow:Gil Gil Creek	
255	11.0	confluence	Flood plain flow-Gil Gil Creek confluence	
206	1.0	inflow	Flood plain flow:Moonie River	
226	4.0	loss (fac. adj.)	factor adjustment Flood plain flow:Moonie River	
260	11.0	confluence	Flood plain flow-Moonie River confluence	
207	1.0	inflow	Flood plain flow:Gwydir River	
229	4.0	loss (fac. adj.)	factor adjustment Flood plain flow:Gwydir River	
227	4.0	loss	Effl:Gwydir Flood plain flow	
190	1.0	inflow	Res:Moonie	
191	4.0	loss	loss:Res.Moonie	
192	0.0	observation	obs	
193	5.0	Effluent Return	Ret:Gwydir Flood plain flow	
265	11.0	confluence	Flood plain flow-Gwydir River confluence	
208	1.0	inflow	Flood plain flow:Mehi River	
228	4.0	loss (fac. adj.)	factor adjustment Flood plain flow:Mehi River	
270	11.0	confluence	Flood plain flow-Mehi River confluence	
209	0.0	observation	obs	
210	1.0	inflow	Flood plain flow:Namoi River	
211	1.0	inflow	Flood plain flow:Pian Creek	
231	4.0	loss (fac. adj.)	factor adjustment Namoi and Pian Flood plain flow	
275	11.0	confluence	Namoi River-Barwon River confluence	
212	4.0	loss	loss:Flood plain flow (Mungindi-Walgett)	
73	11.0	confluence	Floodplain flow - Barwon River confluence	
279	0.0	observation	obs (Walgett.tmp)	
213	4.0	loss	loss: Main stream	
189	8.3	irrigator	***A Class irrigators:Walgett Weir Pool***	
194	8.3	irrigator	***B Class irrigators:Walgett Weir Pool***	

Node no.	Node type	Node Type(description)	Location/description	Comments
74	0.0	observation	422001 Walgett (Barwon River)	
296	0.0	observation	(in bank flows assumed as 60000 ML/d)	
75	8.3	irrigator	***Fleming-Ulah***	
77	8.3	irrigator	***Smee-Mourabie***	
79	0.0	observation	obs. FP	
80	0.0	observation	***Silva-Mourabie West***	
81	0.0	observation	***Taunton-Byrnia***	
333	3.1	diversion	Diverts Murray B Class	
334	3.1	diversion	Diverts Murray FP	
335	1.2	receiving	Receives Murray B	
336	1.2	receiving	Receives Murray FP	
337	2.1	storage	Murray Dam	
338	0.0	observation	observation (d/s of Muarray Dam)	
339	8.0	irrigator	***Murray-Milrea***	
340	0.0	observation	observation (d/s of *Murray-Milrea*)	
341	11.0	confluence	Barwon River -Murray System Confluence	
83	0.0	observation	observation	
216	0.0	observation	***A Class irrigators:Walgett-Boorooma***	
217	8.3	irrigator	***B Class irrigators:Walgett-Boorooma***	
42	4.0	Loss	Effluent for Macq.back-up	
84	4.0	loss	Loss:Walgett-Macquarie Confluence	
377	0.0	observation	422026 Boorooma (Barwon R. u/s Macquarie Junction)	
85	1.0	trib. Inflow	421012 Macquarie River @ Carinda	
86	4.0	loss (fac. Adj.)	factor adjustment:Macquarie River @ Carinda	
87	0.0	observation	Macquarie River	
88	0.0	observation	observation Node	
89	1.0	trib. Inflow	421011 Marthaguy Creek @ Carinda	
90	4.0	loss	factor adjustment:Marthaguy Creek @ Carinda	
91	0.0	observation	Marthaguy Creek	
92	11.0	confluence	Macquarie-Marthaguy Confluence	
93	4.0	loss	Loss:Macquarie River	
94	1.0	trib. Inflow	425005 Castlereagh R.@ Coonamble	
95	4.0	loss (fac. adj.)	factor adjustment :Castlereagh River inflow	
96	4.0	loss	Loss:Castlereagh River	
97	11.0	confluence	Macquarie River-Castlereagh River confluence	
98	8.3	irrigator	***Saltglen***	
45	0.0	observation	obs.1 for Miralwyn Macq.flow	
46	5.0	Eff. Return	Macquarie back-up	
33	0.0	observation	obs.2 for Miralwyn Macq.flow	
99	8.3	irrigator	***Budvalt-Miralwyn (Macquarie)***	
100	11.0	confluence	Barwon River-Macquarie River confluence	
101	4.0	loss (fac. adj.)	Adj. for unguaged trib.(Mac)	
102	8.3	irrigator	***Budvalt-Miralwyn (Barwon)daughter node to 099***	
34	0.0	observation	422027 Geera (Barwon River d/s Macquarie Junction)	observation for flows u/s Miralwyn (Barwon River)
104	1.0	trib. Inflow	421097 Marra Creek.@ Carinda Rd.	
105	4.0	loss (fac adj.)	factor adjustment :Marra Creek inflow	
106	1.0	trib. Inflow	Marra Creek @ Billybingbone Bridge	
107	0.0	observation	obs.Narran River Inflow	
108	11.0	confluence	Barwon River-Marra Creek Confluence	
182	1.0	trib. Inflow	Narran Lake overflow (simulated)	
183	4.0	loss	Loss:Narran River	
184	0.0	observation	Narran River	
185	11.0	confluence	Barwon River-Narran Creek confluence	
329	0.0	observation	observation	
109	0.0	observation	*obs: Irri.Hertslet (dummy)*	
391	0.0	observation	*Hertslet*	
110	8.3	irrigator	***Clyde-Rumleigh***	
218	8.3	irrigator	***A Class irrigators:Boorooma-Brewarrina***	
219	8.3	irrigator	***B Class irrigators:Boorooma-Brewarrina***	
111	4.0	effluent	Cato & Tarrion Creek. effluent	
112	0.0	observation	422002 Brewarrina (Baron Ck)	
113	5.0	Eff. Return	Cato & Tarrion Creek. Return	
114	4.0	loss	Loss:Walgett-Brewarrina	
115	0.0	observation	Total flow at Brewarrina	

Node No.	Node Type	Node Type (description)	Location description	Comments
116	0	Observation	Brewarrina total flow	
317	9	Minimum flow	minimum flow at Brewarrina gau	
117	8.3	Irrigator	THOMPSON-Wirracanna	
118	8.3	Irrigator	CLYDE-Beemery	
124	11	Confluence	Barwon-Bokhara Confluence	
303	0.3	Time adjusted flow	D/S of Bokhara Conf	
195	8.3	Irrigator	A:Bre-Beemery	
196	0	Observation	B:Bre-Beemery	
125	4	Unregualted effluent	Loss:Brewarrina-Bourke	
126	0	Observation	422028 Beemery (Barwon R. u/s	
130	11	Confluence	Barwon-Culgoa Confluence	
251	11	Confluence	Barwon-Bogan Confluence	
292	0.3	Time adjusted flow	D/S of Bogan River Confluence	
134	0	Observation	425039 Warraweena (Darling R.	
222	0	Observation	Obs.(was NS19A.IRR)	Now redundant
223	0	Observation	Obs.(was NS19b.IRR)	Now redundant
120	8.3	Irrigator	BENNETT-Llandillo	
136	0	Observation	Bourke Town (Darling R.)	
313	9	Minimum flow	Minimum flow at Bourke Gauge	
137	8.3	Irrigator	GORDON-Carbuu	
139	8.3	Irrigator	GREEN-Barham Farm	
140	8.3	Irrigator	McINTOSH-Lodebar	
141	8.3	Irrigator	ENBROS-Ambalena	
142	8.3	Irrigator	MANSELL-Back O Bourke Fruits	
144	8.3	Irrigator	SIMPSON/DARLING FARMS-Allambi/	
145	0	Observation	Obs Node	
143	8.3	Irrigator	CLYDE-Latoka/Longmeadows	
147	0	Observation	Irri.Cronin	
220	8.3	Irrigator	A:Beemery-Bourke	
230	8.3	Irrigator	B:Beemery-Bourke	
148	0	Observation	Obs.	
294	11	Confluence	Darling-Residual Confluence	
289	0.3	Time adjusted flow	@ Bourke Gauge	
135	4	Unregualted effluent	Loss:u/s of Bourke	
149	0	Observation	Obs.	
302	0	Observation	425003 Bourke (Darling R.)	
234	0	Observation	Obs.(was NS20A.IRR)	Now redundant
237	0	Observation	Obs.(was NS20B.IRR)	Now redundant
238	0	Observation	Obs.	Now redundant
233	8.3	Irrigator	CLYDE-Janbeth	
398	8.3	Irrigator	THOMPSON-Prattenville	
235	8.3	Irrigator	NEWBURY (later CLYDE)-Ferguson	
350	0	Observation	425037 Weir 19A (Darling R.)	
236	8.3	Irrigator	CLYDE-Toorale (Darling)	
366	11	Confluence	Darling-Warrego Confluence	
304	0.3	Time adjusted flow	D/S of Warrego River.	
352	0	Observation	Weir 20A	
353	0	Observation	Weir 21	
354	8.3	Irrigator	A:Bourke-Louth	
242	8.3	Irrigator	B:Bourke-Louth	
355	4	Unregualted effluent	Loss:Bourke-Louth	
320	9	Minimum flow	minimum flow at Louth	
356	0	Observation	425004 Louth (Darling R.)	
158	3.1	Demand with fixed enviromental flow	Flood memory diversion	
357	0	Observation	Weir 24	
358	0	Observation	Obs.	
241	8.3	Irrigator	McCLURE-Kallara	
268	5	Effluent return	Talyawalka Ck.	
267	12	Floodplain	Lake Taly-1	
261	12	Floodplain	Lake Taly-2	
262	12	Floodplain	Lake Taly-3	

Node No.	Node Type	Node Type (description)	Location description	Comments
264	0	Observation	425018 Talyawalka Ck.@ Barrier	
13	4	Unregualted effluent	TALY LOSS !	
76	4	Unregualted effluent	Eff to Darling	
78	4	Unregualted effluent	Effl to Talya Lower	
253	0	Observation	obs node	
176	11	Confluence	Flood memory reach return	
288	0.3	Time adjusted flow		
243	8.3	Irrigator	A:Louth-Tilpa	
245	0	Observation	B:Louth-Tilpa	
359	4	Unregualted effluent	Loss:Louth-Tilpa	
160	0	Observation	425900 Tilpa (Darling R.)	
319	9	Minimum flow	minimum flow at Tilpa Gauge	
244	0	Observation	Irri.Crisp	
161	0	Observation	Darling d/s Paroo R.	
164	4	Unregualted effluent	Talyawalka Ck. effluent	
165	12	Floodplain	Lake Wongalara	
166	12	Floodplain	Lake Poopelloe	
239	8.3	Irrigator	A:Tilpa-Wilcannia	
240	8.3	Irrigator	B:Tilpa-Wilcannia	
167	4	Unregualted effluent	Loss:Tilpa-Wilcannia	
4	9	Minimum flow	minimum flow at Wilcannia Gaug	
168	0	Observation	425008 Wilcannia (MAIN -Darlin	
119	1	Tributary inflow	Residual 1	
138	5	Unregualted effluent return	Effluent from Talywalka	
146	1	Tributary inflow	Residual 2	
170	4	Unregualted effluent	Off to 7 Mile Creek	
198	4	Unregualted effluent	Off to 3 Mile Creek	
150	4	Unregualted effluent	Loss (Wilcannia-Lake Wetherell	
199	0	Observation	LAKE WETHERELL INFLOWS	
82	1	Tributary inflow	talywalka resi	
246	5	Unregualted effluent return	Eff from Taly	
247	12	Floodplain	ponding 1	
256	12	Floodplain	Ponding 2	
266	12	Floodplain	l jUNK	
232	4	Unregualted effluent	Taly Loss to Terryawena	
248	1	Tributary inflow	Dummy (7 Mile Creek)	
252	5	Unregualted effluent return	7 Mile Eff return	
282	4	Unregualted effluent	7 mile loss	
254	1	Tributary inflow	3 Mile residual	
257	5	Unregualted effluent return	Lake Wtherell Eff (3 mile ?)	
259	4	Unregualted effluent	3 mile bk	
103	4	Unregualted effluent	3 mile loss	
258	1	Tributary inflow	Gillis Residual	
263	5	Unregualted effluent return	3 Mile Effluent	
280	4	Unregualted effluent	Gillis bk	
249	4	Unregualted effluent	Gilles -Loss	
269	11	Confluence	Conf (Talya & 7 Mile Ck)	
281	5	Unregualted effluent return	Gillis eff return	
271	0	Observation	Obs node	
273	11	Confluence	Confl (talya & Gilles)	
272	0	Observation	Obs node	
274	11	Confluence	Confl (talya & 3 Mile Ck)	
283	4	Unregualted effluent	loss node talya 3	
276	0	Observation	Obs node	
277	11	Confluence	Conf (talya & talya)	
278	0	Observation	TALYWALKA EOS OUTFLOWS	
285	11	Confluence		
326	1	Tributary inflow	MDBC EXTRA INFLOW	
284	0	Observation	Combined Menindee Flows	

Appendix E

This Appendix describes the latest draft practice notes for assessing the quality of model calibration or validation – as outlined in Section 3.2.2 and 3.3.5.

They are based on rating the confidence that the model can be used to closely replicate both the time series and statistical distribution behaviour of the real system, under a specified set of development conditions. These quality rating guidelines are presented for each significant quality indicator identified by senior modelling and operational staff.

The five categories used for expressing the quality rating of a particular indicator, or of the model as a whole, are:-

Very high confidence
- High confidence
- Moderate confidence
- Low confidence
- Very low confidence

The apparent error associated with each quality indicator is calculated and placed within one of the five quality ranges, to define the calibration quality in that indicator. The primary quality indicator used is generally the percentage (ratio) of the model simulated volume or area versus the actual recorded volume or area, over the entire period analysed. Supplementary to this indicator but of equal importance, is a new indicator of time series variability, called the coefficient of mean absolute annual differences (CMAAD) as described below:-

CMAAD = ∑Absolute value(Simulated-Observed) / ∑Observed %

Where the Simulated and Observed volumes or areas refer to the total amounts relevant to a particular water year or other time period

To define an overall model confidence, the quality of the observed data needs to be considered. However, as noted at the end of Chapter 1, objective means of determining measurement uncertainty and climatic representativeness are not readily available. In the interim period prior to such means being developed, these guidelines have incorporated the effects of these two sources of uncertainty by:
- Using record length as a surrogate for climatic representativeness;
- Formulating quality rating tolerance bands relevant to the known greater or lesser measurement uncertainty of the observed data. As an example planted area uncertainty's moderate confidence rating is for simulated areas within ±15% of observed, whereas to achieved the same confidence rating in diversion replication a match to within ±10% must be achieved – indicating the greater inherent measurement uncertainty allowed for in the planted area data.

- Formulating quality rating tolerance bands relevant to the known greater or lesser measurement uncertainty of the observed data. As an example planted area uncertainty's moderate confidence rating is for simulated areas within ±15% of observed, whereas to achieve the same confidence rating in diversion replication a match to within ±10% must be achieved – indicating the greater inherent measurement uncertainty allowed for in the planted area data.

Flow calibration quality indicators and ratings

Set out below are the latest draft practice notes for assessing the quality of model calibration achieved.

Table E.0.1. Comparing actual gauged with model simulated flows over a period

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT (see note 2)*		*QUALITY RATING GUIDELINES (See note 1)*
		Definition	*Apparent Error (AE)*	
FLOW FREQUENCY REPLICATION (ranked daily flows)	VOLUME RATIO (vr) Where “vr” = 100 * (Simulated / Observed) Expressed as a %	Whole flow range	AE = (“vr” – 100)	Very High: AE within ±4% High: AE within ±10% Moderate: AE within ±15% Low: AE within ±25% Very Low: AE within ±35%
		Low flow range from X%ile to 100%ile (see note 4)	AE = (“vr” – 100)	Very High: AE within ±5% High: AE within ±10% Moderate: AE within ±20% Low: AE within ±30% Very Low: AE within ±40%
		Mid flow range from Y%ile to X%ile (see note 4)	AE = (“vr” – 100)	Very High: AE within ±4% High: AE within ±10% Moderate: AE within ±15% Low: AE within ±25% Very Low: AE within ±35%
		High flow range from 0%ile to Y%ile (see note 4)	AE = (“vr” – 100)	Very High: AE within ±7% High: AE within ±15% Moderate: AE within ±25% Low: AE within ±40% Very Low AE within ±50%
FLOW TIME SERIES REPLICATION	Daily flow time series – line of best fit: r^2	“r^2” coefficient of determination, (or the degree of scatter around the line of best fit)	AE = 100 * $(1- r^2)$	Very High: AE within 7% High: AE within 15% Moderate: AE within 30% Low: AE within 45% Very Low: AE within 50%
	Annual flow time series: CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD (see note 3)	Very High: AE within 10% High: AE within 15% Moderate: AE within 20% Low: AE within 25% Very Low: AE within 30%

Notes:-

1. Where range specifications are not mutually exclusive, the range conforming to the maximum quality rating should be adopted. For assembled model
2. Unless explicitly stated, all indicator values should be calculated in absolute value terms
3. CMAAD = 100* ∑Absolute value(Simulated annual – Observed annual) / ∑ (Observed annual values)
4. The “X%ile” and “Y%ile” points should be defined from examination of the ranked flow-duration plot of daily flows over the calibration period. The “X%ile” point should be identifiable as the point of convexity on a log-scale plot, where the lower flow region of the curve starts to turn downwards (usually around the 70 to 90%ile zone). The “Y%ile” point should be similarly identifiable as the point of concavity on a log-scale plot, where the higher flow region of the curve starts to turn upwards (usually around the 5 to 10%ile zone).

Diversion calibration quality indicators and ratings

Table E.0.2. Comparing observed with model simulated diversions over a period

PRIMARY FOCUS	***QUALITY INDICATOR***	***SUB-ASPECT (see note 2)***		***QUALITY RATING GUIDELINES (see note 1)***
		Definition	***Apparent Error (AE)***	
Whole of Valley , and irrigator groups	VOLUME RATIO “vr” based on Total period metered diversions Where “vr” = 100 * (Simulated / Observed) Expressed as a %	Metered total	AE = (“vr” – 100)	Very High: AE within ±2% (5%) High: AE within ±5% (10%) Moderate: AE within ±15% (20%) Low: AE within ±25% (30%) Very Low: AE within ±35 (40%)
	Annual metered diversion time series comparison CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD (see note 3)	Very High: AE within 10% (15%) High: AE within 15% (20%) Moderate: AE within 20% (25%) Low: AE within 25% (30%) Very Low: AE within 35% (40%)

Notes:-

1. Where range specifications are not mutually exclusive, the range conforming to the maximum quality rating should be adopted. Initial percentages for areas forced to observed and bracketed ( ) when the areas are simulated.
2. Unless explicitly stated, all indicator values should be calculated in absolute value terms
3. CMAAD = 100* ∑Absolute value(Simulated annual – Observed annual) / ∑ (Observed annual values)

Planted crop area calibration quality indicators and ratings

Table E.0.3. Comparing observed with model simulated summer planted crop areas

PRIMARY FOCUS	***QUALITY INDICATOR***	***SUB-ASPECT (see note 2)***		***QUALITY RATING GUIDELINES (see note 1)***
		Definition	***Apparent Error (AE)***	
Whole of Valley, and irrigator groups	AREA RATIO Whole period total area ratio (ar): Where "ar" = 100 * (Simulated / Observed)	Overall % (ar)	AE = ("ar" – 100)	Very High: AE within ±3% High: AE within ±7% Moderate: AE within ±15% Low: AE within ±25% Very Low: AE within ±35%
	Annual cropped area time series comparison CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD (see note 3)	Very High: AE within 7% High: AE within 15% Moderate: AE within 20% Low: AE within 25% Very Low: AE within 35%

Notes:-

1. Where range specifications are not mutually exclusive, the range conforming to the maximum quality rating should be adopted
2. Unless explicitly stated, all indicator values should be calculated in absolute value terms
3. CMAAD = 100* ∑Absolute value(Simulated annual – Observed annual) / ∑ (Observed annual values)

Representativeness of calibration period

As noted in Chapter 1, the observed data quality should ideally be based on a combination of measurement uncertainty of the data, and the representativeness of the calibration period. At this stage, however, only record length is readily available, as an indicator of climatic representativeness, as presented in Table E.0.4.

Table E.0.4. Climatic representativeness classification guideline

PRIMARY FOCUS	***QUALITY INDICATOR***	***SUB-ASPECT***		***QUALITY RATING GUIDELINES***
		Definition	***Ideal value***	
RECORD LENGTH	Available "valid" data record length	Length for IQQM calibration (L)	10 years	Very High: L > 10 years High: 5.0 < L< 10.0 years Moderate: 2.0 <L< 5.0years Low: 1.0 <L< 2.0 years Very Low L < 1 year

Another aspect that should be considered by the modeller/analyst is whether or not the period adequately represents the degree of development that will be represented in the model for long term simulation purposes. For example does it include 1993/94, if the model is to be used for CAP simulation purposes. At this stage no explicit allowance for this aspect has been made, but it is mentioned here for completeness.

Overall model quality rating

There are a number of methods for evaluating the overall quality of a model calibration. The evaluation of a calibration should take into account the intended use of the model and appropriate indicators should be chosen. Given that the major use of IQQM to date is CAP compliance and scenario comparisons the following indicators have been chosen:

1) Total diversion match for the valley (Volume ratio and CMAAD)
2) Total planted area for the valley (Volume ratio and CMAAD)
3) Flow match at key gauging site (Mid range volume ratio and CMAAD)

These criteria have been chosen on the basis that they represent the major components of the model that will be used for evaluating various options. The first three criteria give a reasonable assessment of the mass balance validity of the model while the fourth criteria gives an indication of the suitability of the model for assessing environmental flow options. As each of these criteria is of equal importance they have been given an equal weighting in the overall assessment of the model.

Each of the eight indicators has an associated quality guideline that is described in the preceding tables. Each of the guidelines has five sets of confidence limits of various magnitudes. To be able to combine these criteria with equal weighting these indicators need to be transformed into a standard rating system as follows:

3) Very High 0%<=x<=5%
4) High 5%<x<= 10%
5) Moderate 10%<x<=15%
6) Low 15%<x<=20%
7) Very low 20%<x<=30%

The transformation for each indicator is carried out as follows:

$$SI_i = (I_i-LL_i)*(SU_i-SL_i)/(UL_i-LL_i) + SL_i \qquad \{Eq.\ F.1\}$$

Where: SI_i = standardised indicator of quality

I_i = quality achieved for the selected indicator

UL_i = upper limit of the confidence band that I lies between

LL_i = lower limit of the confidence band that I lies between

SU_i = standardised upper confidence limit of equivalent indicator confidence limit

SL_i = standardised lower confidence limit of equivalent indicator confidence limit

i = the indicator number

To obtain an overall quality indicator (OQI) each of the selected individual indicators are standardised and averaged using Eq. F.2.

$$\mathrm{AQI} = \sum_{i=1}^{k} \mathrm{SI}_i \; / \; k \qquad \{\mathrm{Eq.\ F.2}\}$$

Where: *AQI* = average of the quality indicators
k = number of contributing indicators to the overall indicator

This average quality indicator is then adjusted for climatic representativeness of the calibration period using Eq. F.3:

$$\mathrm{OQI} = \mathrm{AQI} * 3.0 * \mathrm{NY}^{-0.65} \qquad \{\mathrm{Eq.\ F.3}\}$$

Where: *OQI* = overall quality indicator
NY = number of years of calibration period

The adjustment for climatic representativeness (Eq. F.3) takes into account that indicators in the preceding tables have been formulated assuming a calibration period of approximately five years. This adjustment allows for a decrease in confidence with a shorter calibration period and an increase in confidence with a longer calibration period. In doing this we assume that calibration period length is a reasonable surrogate for climatic representativeness. If the calibration period does not contain dry and wet periods then this adjustment may not be appropriate.

The overall quality indicator can be used to determine appropriate uses for the model (Table E.0.5).

Table E.0.5. Appropriate uses for the model

POSSIBLE USE	***APPROPRIATE USES BASED ON OQI (*** *Eq. F.3)*				
	0 – 5 %	5 – 10 %	10 – 15 %	15 – 20 %	≥ 20 %
Short term Cap Auditing	✓				
Long term Cap modelling	✓	✓			
Long term analysis of management rule variations	✓	✓			
Long term analysis of development variations	✓	✓			
Long term analysis of infrastructure changes	✓	✓			
Long term analysis of storage behaviour, yield and spilling frequency	✓	✓			
Long term analysis of flow regimes and environmental flows at key locations	✓	✓	✓		
Simplified unregulated system modelling			✓		
Understanding flow regimes			✓		
Requires more data			✓	✓	
Requires further calibration					✓

Appendix F

The crop factors listed below are utilised in the Barwon-Darling IQQM and are found in File BD-new2.crp.

Crop	J	F	M	A	M	J	J	A	S	O	N	D
Sorghum '	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.81	0.81
"S.Oil-soy'	0.63	0.70	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56
'W.Oil '	0.00	0.00	0.00	0.40	0.66	0.85	0.85	0.65	0.38	0.00	0.00	0.00
'Cotton '	0.67	0.95	0.83	0.00	0.00	0.00	0.00	0.00	0.00	-0.31	0.29	0.38
'S.Pasture'	0.55	0.55	0.55	0.55	0.40	0.00	0.00	0.00	0.23	0.39	0.55	0.55
'Wheat '	0.00	0.00	0.00	0.45	0.50	0.60	0.49	0.49	0.49	0.30	0.10	0.00
'W.Cereal '	0.00	0.00	0.00	0.70	0.60	0.42	0.42	0.42	0.42	0.30	0.00	0.00
'S.Oil '	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.76	0.90	0.35
'Citrus '	0.38	0.38	0.38	0.37	0.35	0.35	0.32	0.34	0.35	0.35	0.37	0.37
'Lucerne '	0.55	0.62	0.62	0.35	0.00	0.00	0.00	0.00	0.00	0.39	0.55	0.55
'W.Pasture'	0.00	0.30	0.62	0.67	0.67	0.55	0.55	0.55	0.55	0.50	0.00	0.00
'P.Pasture'	0.55	0.55	0.55	0.55	0.30	0.30	0.30	0.30	0.38	0.50	0.55	0.55
'S.Vegies '	0.65	0.70	0.65	0.65	0.54	0.00	0.00	0.00	0.48	0.61	0.65	0.65
'W.Cer-Oat'	0.00	0.00	0.30	0.70	0.60	0.42	0.42	0.42	0.42	0.30	0.00	0.00
'Garlic '	0.00	0.00	0.00	0.00	0.40	0.50	0.60	0.60	0.60	0.60	0.40	0.00
'Stone Fr.'	0.67	0.67	0.62	0.50	0.00	0.00	0.00	0.00	0.43	0.52	0.63	0.67
'Citrus '	0.38	0.38	0.38	0.37	0.35	0.35	0.32	0.34	0.35	0.35	0.37	0.37
'Wine Grps'	0.70	0.61	0.42	0.00	0.00	0.00	0.00	0.19	0.52	0.70	0.70	0.70
'S.Cereal '	0.63	0.70	0.63	0.00	0.00	0.00	0.00	0.00	1.15	0.21	0.42	0.56
'Fallow '	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40

Note the negative crop factors for cotton in October prompt the model to fully saturate the soil store on the 1st of the month so mimicking actual practise.

Appendix G

This Appendix provides the aggregated reach behaviour of ‘major’ irrigators at the completion of the forced area calibration. These results demonstrate the overall quality of the ‘major’ irrigator calibration. Annual comparisons of metered diversions, crop areas and OFS behaviour are made in the attached reach irrigation summaries. Additional details on floodplain and rainfall harvesting volumes are also included to provide an overall picture of water usage

Integrated Risk Function
Models : Clnp214.sys and Clnz214.sys **Water Year 1/7 to 30/06, except 01/10/1995 - 30/09/1998 and 1/10/98 to 30/06/1999**
Mungindi - Walgett

		95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	Total	Average	Comments
Metered Diversions	**Adj. Recorded (ML)**	48,612	34,724	33,801	37,126	25,340	39,332	22,900	5,590	42,449	27,286	317,160	31,716	
	Total Simulated (ML)	46,244	25,964	35,835	47,777	28,978	54,037	28,412	455	27,391	20,308	315,403	31,540	One large Irrigator accounts for almost all of the difference
	Sim / Rec	*0.95*	*0.75*	*1.06*	*1.29*	*1.14*	*1.37*	*1.24*	*0.08*	*0.65*	*0.74*	*0.99*	*0.99*	
	Sim - Rec	*-2,368*	*-8,760*	*2,034*	*10,651*	*3,638*	*14,705*	*5,512*	*-5,135*	*-15,058*	*-6,978*	*-1,757*	*-176*	
FloodPlain Diversions	**Simulated (ML)**	4,445	2,035	0	3,491	0	6,088	0	0	10,926	476	27,461	2,746	
Total Diversions	**Simulated (ML)**	50,689	27,999	35,835	51,268	28,978	60,125	28,412	455	38,317	20,784	342,863	34,286	
Rainfall-Runoff	**Simulated (ML)**	8,672	5,978	7,884	13,492	14,764	21,623	4,780	1,721	18,853	11,116	341,106	34,111	
Crop Area	**Recorded (Ha)**	7,479	8,009	7,772	7,415	6,309	9,270	9,045	960	225	3,225	59,709	5,971	
	Simulated (Ha)	6,400	6,526	6,478	7,023	7,203	6,846	8,147	2,703	563	8,283	60,172	6,017	
	Sim / Rec	*0.86*	*0.81*	*0.83*	*0.95*	*1.14*	*0.74*	*0.90*	*2.82*	*2.50*	*2.57*	*1.01*	*1.01*	
On Farm Storage	**Recorded Init.OFS**	22,450	61,494	51,490	55,467	67,070	47,700	47,840	2,885	N/A	50,580	406,976	End of Year	
	Simulated Init. OFS	27,355	55,080	43,067	32,548	56,761	43,736	59,477	2,474	4,643	63,886	389,027	End of Year	
	Sim / Rec	*1.22*	*0.90*	*0.84*	*0.59*	*0.85*	*0.92*	*1.24*	*0.86*	*#VALUE!*	*1.26*	*0.96*		
Application Rate (excluding rainfall) ML/Ha		4.2	5.7	7.0	5.5	9.0	5.4	9.4	-1.8	-44.4	-94.2	5.7		

N/A - Information not available

Integrated Risk Function
Models : Clnp214.sys and Clnz214.sys **Water Year 1/7 - 30/6**
Walgett - Brewarrina

		95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	Total	Average	Comments
Metered Diversions	Adj. Recorded (ML)	41,570	49,015	21,249	70,419	49,200	57,935	9,975	4,630	72,064	35,849	411,906	41,191	
	Total Simulated (ML)	44,931	49,689	28,800	80,118	43,592	66,791	15,019	595	50,225	32,240	412,000	41,200	
	Sim / Rec	*1.08*	*1.01*	*1.36*	*1.14*	*0.89*	*1.15*	*1.51*	*0.13*	*0.70*	*0.90*	*1.00*	*1.00*	
	Sim - Rec	*3,361*	*674*	*7,551*	*9,699*	*-5,607*	*8,856*	*5,044*	*-4,035*	*-21,839*	*-3,609*	*94*	*9*	
FloodPlain Diversions	Simulated (ML)	14,271	2,794	0	7,979	0	0	0	3,657	8,395	0	3,709	371	
Total Diversions	Simulated (ML)	59,202	52,483	28,800	88,096	43,592	66,791	15,019	4,252	58,620	32,240	415,710	41,571	
Rainfall-Runoff	Simulated (ML)	3,452	1,049	2,117	5,160	4,563	7,003	1,204	693	1,535	1,149	27,924	2,792	
Crop Area	Recorded (Ha)	3,089	4,534	4,623	5,290	5,108	5,250	5,330	1,400	240	5,200	40,064	4,006	
	Simulated (Ha)	2,558	4,968	4,867	5,034	4,940	5,579	6,118	981	36	4,220	39,301	3,930	
	Sim / Rec	*0.83*	*1.10*	*1.05*	*0.95*	*0.97*	*1.06*	*1.15*	*0.70*	*0.15*	*0.81*	*0.98*	*0.98*	
On Farm Storage	Recorded Init.OFS	27,356	47,251	54,677	20,592	55,519	80,165	88,830	9,500	800	70,750	455,440	End of year	
	Simulated Init. OFS	28,051	55,406	50,933	34,204	71,882	66,624	64,301	12,883	604	42,060	426,948	End of year	
	Sim / Rec	*1.03*	*1.17*	*0.93*	*1.66*	*1.29*	*0.83*	*0.72*	*1.36*	*0.76*	*0.59*	*0.94*		
Application Rate (excluding rainfall) ML/Ha		*11.4*	*12.8*	*10.3*	*10.5*	*10.5*	*14.5*	*12.7*	*12.3*	*77.9*	*-67.6*			

Integrated Risk Function
Models : Clnp214.sys and Clnz214.sys **Water Year 1/7 - 30/6**
Brewarrina - Bourke

		95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	Total	Average	Comments
Metered Diversions	**Adj. Recorded (ML)**	87,991	80,795	84,316	71,050	59,492	85,778	18,915	4,610	90,302	50,076	633,326	63,333	
	Total Simulated (ML)	74,295	72,621	68,890	77,184	48,095	106,515	8,723	1,807	82,938	44,868	585,936	58,594	
	Sim / Rec	*0.84*	*0.90*	*0.82*	*1.09*	*0.81*	*1.24*	*0.46*	*0.39*	*0.92*	*0.90*	*0.93*	*0.93*	
	Sim - Rec	*-13,696*	*-8,174*	*-15,426*	*6,134*	*-11,397*	*20,737*	*-10,192*	*-2,803*	*-7,364*	*-5,208*	*-47,389*	*-4,739*	
FloodPlain Diversions	**Simulated (ML)**	8,054	302	0	2,345	0	2,894	0	0	653	765	15,012	1,501	
Total Diversions	**Simulated (ML)**	82,349	72,923	68,890	79,529	48,095	109,409	8,723	1,807	83,591	45,633	600,949	60,095	
Rainfall-Runoff	**Simulated (ML)**	6,730	3,091	5,730	10,262	15,643	7,171	2,036	279	1,273	3,523	55,739	5,574	
Crop Area	**Recorded (Ha)**	6,679	7,013	6,284	7,037	6,916	7,555	5,820	0	0	6,050	53,354	5,335	
	Simulated (Ha)	5,582	7,293	6,665	7,923	7,181	8,536	9,026	0	0	8,484	60,690	6,069	
	Sim / Rec	*0.84*	*1.04*	*1.06*	*1.13*	*1.04*	*1.13*	*1.55*	*0.00*	*0.00*	*1.40*	1.14	1.14	
On Farm Storage	**Recorded Init.OFS**	57,982	70,649	71,774	66,351	73,286	75,720	85,240	N/A	N/A	75,805	576807	End of year	
	Simulated Init. OFS	63,011	77,047	71,985	67,080	69,831	73,473	80,616	182	3	80,540	583767.6	End of year	
	Sim / Rec	*1.09*	*1.09*	*1.00*	*1.01*	*0.95*	*0.97*	*0.95*	*0.00*	*0.00*	*1.06*	1.01		
Application Rate (excluding rainfall) ML/Ha		*11.2*	*11.6*	*12.7*	*12.4*	*8.7*	*13.9*	*15.3*	*#DIV/0!*	*#DIV/0!*	*-75.5*	*2.7*		

N/A - Information not available

Integrated Risk Function
Models : Clnp214.sys and Clnz214.sys **Water Year 1/7 - 30/6**
Bourke - Menindee

		95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	Total	Average	Comments
Metered Diversions	**Adj. Recorded (ML)**	29,143	37,268	27,095	52,212	33,829	49,486	9,305	3,020	31,386	31,252	303,996	30,400	
	Total Simulated (ML)	46,633	48,190	40,462	51,096	34,558	32,377	6,210	0	29,059	18,757	307,340	30,734	
	Sim / Rec	*1.60*	*1.29*	*1.49*	*0.98*	*1.02*	*0.65*	*0.67*	*0.00*	*0.93*	*0.60*	*1.01*	*1.01*	
	Sim - Rec	*17,490*	*10,922*	*13,366*	*-1,117*	*729*	*-17,109*	*-3,095*	*-3,020*	*-2,327*	*-12,495*	*3,344*	*334*	
FloodPlain Diversions	**Simulated (ML)**	19,665	14,346	12,991	9,168	9,241	16,650	0	0	389	2,700	85,151	8,515	
Total Diversions	**Simulated (ML)**	66,298	62,536	53,452	60,264	43,799	49,027	6,210	0	29,448	21,457	392,491	39,249	
Rainfall-Runoff	**Simulated (ML)**	5,174	2,786	5,987	8,268	11,294	4,716	1,094	154	754	2,029	42,256	4,226	
Crop Area	**Recorded (Ha)**	4,059	5,000	3,755	4,001	4,883	3,800	4,060	0	400	3,360	33,318	3,332	
	Simulated (Ha)	3,850	4,055	3,829	4,393	4,028	3,948	3,738	0	0	3,290	31,131	3,113	
	Sim / Rec	*0.95*	*0.81*	*1.02*	*1.10*	*0.82*	*1.04*	*0.92*	*#DIV/0!*	*0.00*	*0.98*	*0.93*	*0.93*	
On Farm Storage	**Recorded Init. OFS**	38,083	37,875	40,682	40,247	43,064	33,800	36,600	N/A	1,200	34,020	305,571	End of year	
	Simulated Init. OFS	40,400	43,145	40,738	42,572	42,374	43,009	34,540	20	82	35,269	322,149	End of year	
	Sim / Rec	*1.06*	*1.14*	*1.00*	*1.06*	*0.98*	*1.27*	*0.94*	*#VALUE!*	*0.07*	*1.04*	*1.05*		
Application Rate (excluding rainfall) ML/Ha		*16.9*	*13.5*	*15.3*	*17.2*	*11.2*	*16.4*	*10.3*	*#DIV/0!*	*-12.5*	*-78.4*	*4.9*		

N/A - Information not available

Appendix H

The details of the tributary inflows used in the Cap scenario model are shown below.

Table H.0.1. Tributary Inflows for the 1993/94 Cap

Tributary	Location	Description of Inflows
Border Rivers Valley Contributions		
Barwon River	Mungindi (GSN 416001)	Simulated by Border Rivers (93/94) IQQM (Br0609U8.s7) Period of availability: 01/01/1890-30/06/2009. Stored in directory: *I:\IQQM\BRIV|QQ\Modruns\9394* (Dated 29/04/2011)
Little Weir River	End of System (GSN -)	Estimated by effluent flow relationship, established during calibration of Border Rivers IQQM [DLWC & QDNR,1998], and utilises the above simulated flows at Mungindi.
Boomi River	Neeworra (GSN 416028)	Simulated by Border Rivers (93/94) IQQM, as above
Moonie River Valley Contribution		
Moonie River	Gundablouie (GSN 417001)	Simulated by Moonie (ROP) IQQM [modelled flows supplied by QDNR] Period of availability: 01/01/1895-30/06/2009. Stored in directory: *I:\IQQM\DARL\QQ\GUI2010\Inputdata\Cap_Raw_data* (Dated 17/08/2010).
Gwydir River Valley Contribution		
Gil Gil Creek	Weemelah (GSN 416027)	Simulated by Gwydir (93/94) IQQM (DEV93413A _10.sqq) Period of availability: 01/01/1892-30/06/2011). Stored in directory *I:\IQQM\GWYD\QQ\CALIB\CAP-recal04\CAP Audit* (Dated 30/06/2009)
Gingham Watercourse	Return of flows to Barwon	Simulated by Gwydir (93/94) IQQM, as above
Gwydir River	Collymongle (GSN 418031)	Simulated by Gwydir (93/94) IQQM, as above
Mehi Diversions	Colly Central Farm	Simulated by Gwydir (93/94) IQQM, as above (Simulated Diversions from Mehi R by Colly Central Farm)
Mehi River	Collarenbri (GSN 418055)	Simulated by Gwydir (93/94) IQQM, as above
Thalaba Creek Contribution		
Thalaba	End of	Generated as outflows of a sacramento modelled catchment

Creek	System	(Thalaba.flm). Period of availability:01/06/1895-30/06/2010. Stored in directory: I Stored in directory: *I:\IQQM\DARL\QQ\GUI2010\Inputdata\Cap_Raw_data* (Dated 11/08/2010).
Namoi River Valley Contribution		
Pian Creek	Waminda (GSN 419049)	Simulated by Namoi (93/94) IQQM (NamoB2009b.sqq) (Cpwamda.raw) Period of availability: 30/09/1892-30/06/2009. Stored in directory *I:\IQQM\NAMOI\QQ\MODRUNS\9394\base* (Dated 09/08/2010)
Namoi River	Goangra (GSN 419026)	As above. (Cpgngra.raw)
Macquarie River (Including Castlereagh) Valley Contribution		
Castlereagh River	Coonamble (GSN 420005)	Observed flows extended by simulated flows using Castlereagh R. (Natural) IQQM (CastlF8.S62) Period of availability: 01/06/1895-30/06/2010. Stored in directory *I:\IQQM\DARL\QQ\GUI2010\Inputdata\Cap_Raw_data* as (C420005.flm) (Dated 17/08/2010) Note: As development in this valley is minimal the use of observed streamflows after 1993/94 is justified.
Marthaguy Creek	Carinda (GSN 421011)	Simulated by Macquarie. (93/94) IQQM (Macqc014.sqq) Period of availability: 01/07/1891-30/06/2009. Stored in directory *I:\IQQM\DARL\QQ\GUI2010\Inputdata\Cap_Raw_data* as (Cp_mgy14.raw) (Dated 11/02/2010)
Macquarie River	Carinda (GSN 421012)	Simulated by Macquarie (93/94) IQQM, as above
Marra Creek	Carinda Rd (GSN 421097)	Simulated by Marra R. (93/94) IQQM (Marra_6.S62)_ Period of availability: 01/01/1892-30/06/2009. Stored in directory: *I:\IQQM\DARL\QQ\GUI2010\Inputdata\Cap_Raw_data* as (Cp_mrr14.flm) (Dated: 12/08/2010)

		Utilises output from Macquarie (93/94)IQQM.
Bogan River	Gongolgon (GSN 421023)	Simulated by Bogan R. (93/94) IQQM (Boga694.SYS & Boga0234.SYS) Period of availability: 01/01/1892-30/06/2009 Stored in directory *I:\IQQM\DARL\QQ\GUI2010\Inputdata\Cap_Raw_data* as (Cp421023.flm) (Dated: 12/08/2010) Utilises output from Macquarie (93/94) IQQM as well as tributary (Sacramento) inflows from the upper Bogan River catchment which has minimal development.
Condamine-Balonne River Valley Contribution		
Narran River	Narran Lake Storage (GSN 422019); & New Angledool (GSN 422012)	Simulated by Condamine R. (ROP) IQQM [Modelled flows supplied by QDNR) Period of availability: 01/01/1895-30/06/2009. Stored in directory *I:\IQQM\DARL\QQ\GUI2010\Inputdata\Cap_Raw_data* as (312B-03.flm) (Dated 17/08/2010).
Bokhara River	Bokhara (GSN 422005)	Simulated by Condamine R. (ROP) IQQM, as above (312B-09.flm)
Culgoa River	Collerina (GSN 422006)	Simulated by Condamine R. (ROP) IQQM, as above (312B-14.flm)
Warrego River Valley Contribution		
Warrego River	Fords Bridge & Bywash (GSN 423001 & 423002)	Simulated by Warrego R. (ROP) IQQM [Modelled flows supplied by QDNR) Period of availability: 01/01/1892-31/12/1992. Stored in *I:\IQQM\DARL\QQ\GUI2010\Inputdata\Cap_Raw_data* as (Ford-RO.flm) (Dated 17/08/2010).

Appendix I

The following table detail the 93/94 Development conditions.

ITEMS	DESCRIPTION		COMMENTS
GENERAL			
Simulation Period	01/01/1922 to 30/06/2000		
Water Year	01/10 to 30/09		For Section Mungindi to Walgett
	01/07 to 30/06		For Section Walgett to Menindee
FLOW INFORMATION	*(Annual averages over simulation period)*		
Tributary Gauged Inflows *(GL/yr)*		3071	
Tributary Floodplain (Factored) Inflows *(GL/yr)*		192	
IRRIGATION INFORMATION			
Annual Volumetric Limit 'Major' Irrigators *(ML)*	Mungindi - Walgett Walgett - Brewarrina Brewarrina - Bourke Bourke - Menindee TOTAL	29,100 146,500 147,000 62,600 385,200	
Annual Volumetric Limit 'Reach' Irrigators *(ML)*	Mungindi - Walgett Walgett - Brewarrina Brewarrina - Bourke Bourke - Menindee TOTAL	19,330 4,060 7,980 9,200 40,570	
Accounting system	Annual accounting		Annual Limit with No carryover from one year to the next
Maximum irrigable (developed) area *(Ha)*	Mungindi - Walgett Walgett - Brewarrina Brewarrina - Bourke Bourke - Menindee TOTAL	9,206 3,930 8,824 5,715 27,675	(1)
Maximum irrigable area *(Ha)*	Mungindi - Walgett Walgett - Brewarrina Brewarrina - Bourke Bourke - Menindee TOTAL	8,226 3,228 7,586 5,441 24,481	
On-farm storage capacity *(ML)*	Mungindi - Walgett Walgett - Brewarrina Brewarrina - Bourke Bourke - Menindee TOTAL	55,800 29,100 63,600 42,500 191,000	
Pump capacity *(ML/d)* *(major irrigators)*	Mungindi - Walgett Walgett - Brewarrina	2,940(2) 2,080(3)	includes ? ML/d of pump capacity on:

	Brewarrina - Bourke 4,350 Bourke - Menindee 2,550 TOTAL 11,920	(2) Collymongle Lagoon and Thalalba Ck (3) Macquarie R
On-farm storage operation *(Major irrigators)*	Flood plain harvesting yes Pre-watering yes Rainfall runoff harvesting yes Airspace yes	Approx 2/3rds of irrigators All cotton crops See Table I.0.2.Adopte for details See **Error! Reference source not found.** for details
Average crop mix *(%)* *(major irrigators)*	Cotton 94.1 % Summer Cereals 0.1 % Wheat 3.6 % Other 2.2 %	See Table I.0.1.Adopte for details
OTHER EXTRACTIONS		
	All other uses	Not modelled explicitly
RIVER FLOW REQUIREMENTS		
Minimum flow requirements *(ML/d)*	Unregulated Flow Plan for the North-west Irrigator pumping embargoes for transmission of riparian and town water supplies	Not Modelled Not Modelled

Table I.0.1. Adopted crop mix for the 1993/94 Cap scenario

Reach	**Percentage of crop (%)**							
	Cotton	**Lucerne**	**Summer Cereal**	**Summer Pasture**	**Wheat**	**Winter Cereal**	**Pecans**	**Others**
‘Major’ Irrigators								
Mungindi - Walgett	99.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Walgett – Brewarrina	98.6	0.0	0.6	0.0	0.8	0.0	0.0	0.0
Brewarrina - Bourke	92.0	0.0	0.0	0.0	6.0	0.0	0.0	2.0
Bourke - Menindee	86.0	0.0	0.0	0.0	7.0	0.0	0.0	7.0
‘Reach’ Irrigators								
Mungindi - Walgett	0.0	9.6	14.0	0.0	75.8	0.6	0.0	0.0
Walgett – Brewarrina	0.0	29.3	24.5	38.3	0.0	0.0	0.0	7.8
Brewarrina - Bourke	0.0	40.3	45.0	0.0	3.8	0.0	0.0	0.0
Bourke - Menindee	0.0	23.0	56.0	0.0	8.0	0.0	0.0	12.0

Notes: # Weighted average based on planted area.

Table I.0.2. Adopted parameters for rainfall runoff harvesting in the 1993/94 Cap Scenario

Reach	**Rainfall Runoff Harvesting Areas (ha)**		
'Major' Irrigators	**Harvesting Area**	**Max. Crop Area**	**Harvesting Area as % of Max. Area**
Mungindi – Walgett	9205	6091	151
Walgett – Brewarrina	3930	3228	122
Brewarrina – Bourke	8823	7571	117
Bourke – Menindee	5715	5037	113
Overall	27674	21927	126

Table I.0.3. Adopted parameters for OFS airspace for the 1993/94 Cap scenario

Reach	**OFS Airspace for Rainfall-Runoff Harvesting**	
'Major' Irrigators	**(ML)**	**% of Total OFS**
Mungindi – Walgett	11200	20.0
Walgett – Brewarrina	5600	19.5
Brewarrina – Bourke	5400	8.5
Bourke – Menindee	6100	14.0
Overall	28300	15.0

Appendix J

Methodology to Define Crop Risk

As detailed in Section 3.4, individual irrigator risk functions were required to be developed in-order to mimic how irrigators decided on what area they crop for irrigation. The model utilises a nominated individual risk rate (i.e. expressed in ML/Ha) to define the planted area based on the stored volumes in OFS at planting date (i.e. 1st of October for summer and 1st of March for winter). Also required is a maximum area that can be irrigated at anyone time.

These functions and areas are based on existing information, however as there is no reliable information available on irrigator's stored volumes in their OFS at planting dates, then some further interpretation of the available data is required. It was decided to use of OFS capacity as a surrogate for stored OFS volumes during years when the OFS were likely to be full at planting date. A methodology, based on available streamflow in preceding seasons, was developed to define these possibly "full" (i.e. unconstrained) years.

Based on an analysis of individual irrigator's installed pump capacity and OFS capacity, it requires around 30 days of pumping to fill most OFS. This analysis was supported by the anecdotal information from irrigator representatives of the IQQM Reference Committee. Recorded streamflows were analysed against commence to pump licence conditions (ie thresholds at upstream and downstream streamflow gauges) for each river reach during the period between irrigation seasons (i.e. April to September, inclusive) to determine possible constrained years. In the Table J.0.1 these years are highlighted in yellow.

The IQQM Reference Committee of the RMC utilised the information contained Table J.0.1 the representative risk that each irrigator undertook for a defined, as well as maximum area they were prepared to crop.

Table J.0.1. Defining Crop Risk for Sample Irrigator

Sample Irrigator

	Year	OFS Capacity (ML)	Area Developed (Ha)	Area Irrigated in Summer Season (Ha)	% Area Cropped	OFS Capacity per Ha of Crop	Volume in OFS @ 1/07 %
	1987/88	400	388	312	80%	1.28	
	1988/89	400	412	273	66%	1.46	
	1989/90	1450	412	333	81%	4.36	
	1990/91	1450	412	349	85%	4.15	
	1991/92	1450	412	216	52%	6.72	
	1992/93	1450	457	299	65%	4.85	
Subject Year 1 →	1993/94	5100	698	66	10%	76.81	
	Winter 94	5100	698	na	na	na	
	1994/95	5100	698	332	48%	15.36	
	1995/96	5100	698	508	73%	10.04	
	1996/97	5100	698	616	88%	8.28	
	1997/98	5100	698	608	87%	8.39	
Subject Year 2 →	1998/99	5100	698	380	55%	13.41	
	1999/2000	5100	698	608	87%	8.39	
Subject Year 3 →	2000/2001	5100	698	421	60%	12.11	
	2001/2002	*5100*	*698*	*440*	*63%*	*11.59*	*90*
	2002/2003	*5100*	*698*	*160**	*#VALUE!*	*#VALUE!*	*20*
	2003/2004	*5100*	*698*	*0*	*0%*	*#DIV/0!*	*0*
Subject Year 4 →	2004/2005	*5100*	*698*	*?*	*#VALUE!*	*#VALUE!*	*?*
	2005/2006				*#DIV/0!*	*#DIV/0!*	
	2006/2007				*#DIV/0!*	*#DIV/0!*	
	2007/2008				*#DIV/0!*	*#DIV/0!*	

(Years highlighted in yellow are assumed to be resource constrained)

*(Information in Years highlighted in **ITALICS** are sourced from M Allens farmer surveys)*

* WHEAT GROWN **Risk @ Planting Date**

1. Max area irrigated for 1993/94 Model

616 in 1996/97 **4** **ML Water / Ha Crop**

2. Max area irrigated for 1998/99 Model

380 in 1998/99 **?** **ML Water / Ha Crop**

**** Owners of Sample Irrigator have indicated they wouldn't crop the big areas again.**

3. Max area irrigated for 2000/01 Model

421 in 2000/01 **10** **ML Water / Ha Crop**

4. Max area irrigated for 2004/05 Model

421 in 2000/01 **10** **ML Water / Ha Crop**