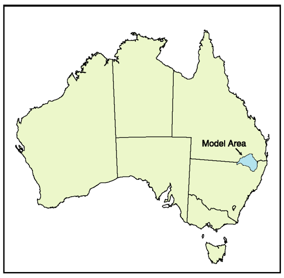
IQQM IMPLEMENTATION | CAP AUDIT MODEL

BORDER RIVERS VALLEY



IQQM Calibration and Configuration

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BORDER RIVERS VALLEY: IQQM Cap Implementation Report

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Executive Summary

What has initiated the work?	The MDBMC Cap requires that NSW develop a suitable planning tool to enable review of water use and sharing arrangements in the Border 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 Border Rivers IQQM status	This report summarises and documents the IQQM calibration, validation and model use for representation of Cap conditions in the regulated sections of the Border 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 all of the important features in the system, and closely replicates records of flow and water diversion behaviour. The secondary purpose is to demonstrate that the model can be successfully used to define the diversion Cap.
Model configuration includes all important features	Chapter 3 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 1987/88 – 1999/00 configures the model parameters	The MDBMC Cap requires that NSW develop a suitable planning tool to enable review of water use and sharing arrangements in the Border 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).
Calibration to 1987/88 – 1999/00 configures the model parameters	Chapter *3* also describes the model calibration procedure and results. Comparison is made in Chapter 4 between time series observed data and time series model simulated data using time series 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 calibration overall “High” CMAAD rating; • Diversion calibration ONA “V.High” CMAAD rating; SW “V.High” CMAAD rating; • Storage behaviour calibration overall “V. High” CMASDD rating; • Planted area calibration: overall “V.High” CMAAD rating; The Overall quality 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 Border Rivers System 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	Chapter 5 describes the Cap development conditions and management rules. These are configured into what NOW is defining as the 1993/94 Cap scenario.
Simulation of the Cap benchmark scenario	Chapter 5 also describes the use of the Border Rivers System QQM to simulate the NSW Border Rivers Cap scenario. Results are presented for: • the 120 year period from 1890 to 2010 inclusive, to estimate the long term Cap scenario average annual diversions; • the 1997/98 to 2010/11 period, to produce estimates of the Cap for auditing under the provisions of Schedule F of the Murray-Darling Basin Agreement.
Improvement suggestions	Chapter 6 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

Term	Description
Account Balance	This is the current amount of water an irrigator has access to for irrigation. It is calculated differently depending on whether the system uses annual accounting or continuous accounting. In annual accounting, it is a function of their water share, the AWD and the amount of water they have already diverted. In continuous accounting their balance is continuously updated based on inflow sharing and water diverted .
A Class General Security Licence	GS Licences with a transitional security (GS to HS) of supply. This was introduced in NSW Border Rivers on 10/11/1986. These licences are 60 ML for each GS licence, and are supplied with water after high security licence needs are fully satisfied and before the rest of GS licence entitlement is supplied. Total "A class" GS licences in NSW Border Rivers account for 20,880 ML.
Allocation Level	See AWD
Available Water Determination (AWD)	Available water determination (AWD) is the percentage of water share volume that general security irrigators can divert in the current water year. The first AWD announced at the beginning of each water year. The AWD will not decrease from this level over the course of the irrigation season however it may increase if there are significant dam inflows.
Allocation system	An allocation system is a group of river reaches ns on which all water users share the available resources declared as AWD. For a complex allocation system with more than one head water storage, where some water users have an access to only one of the Dams, AWD for the entire system is adopted as per the minimum of the AWDs for any of the allocation sub-systems under it.
Annual Accounting	A system where general security water users get an AWD of water each year. This system can be without carryover, where unused water at the end of the year gets re-socialised and distributed evenly between all users. Alternatively, it can be with carryover, where unused water at the end of the year remains in an irrigator's water share (up to a certain limit).
B Class General Security Licence	See "general security (GS) licenses"
Border Rivers Food and Fibre (BRFF)	The umbrella organisation for ten affiliated water users' associations with 450 members from Macintyre River, Dumaresq River and Macintyre Brook catchments in both NSW and Queensland.
Cap	The Murray Darling Basin Ministerial Council Cap on diversions 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 to simulate 1993/94 development conditions and management rules, with the simulation period commencing in 1997/98, to provide a cumulative target for the diversions that would have occurred under Cap conditions.
Cap Scenario	An IQQM that has been configured to simulate 1993/94 development conditions and management rules, witht the simulation period commencing in 1890, to estimatethe long term average diversions that would have occurred over the last 120+ years under these rules.
Carryover	
coefficient of determination	See "r^2"

Term	Description
coefficient of mean absolute annual differences (CMAAD)	A comparative statistic used to assess the match between simulated and observed annual values for model calibration. Further details are provided in (Appendix E.1).
coefficient of mean absolute monthly differences (CMAMD)	A comparative statistic developed used to assess the match between simulated and observed monthly values for model calibration. Further details are provided in (Appendix E.2).
coefficient of mean absolute storage drawdown deviation (CMASDD)	A comparative statistic developed used to assess the match between simulated and observed daily storage behaviour for model calibration. Further details are provided in (Appendix E.3).
continuous accounting	In a continuous accounting system water users have individual accounts that increase as inflows are shared and reduce as diversions are debited against the account. The accounts are operated continuously and are not reset at the start of water years . There are usually limits on the maximum amount the accounts can build up to and limits on the amount that can be used in a water year. Sate Water maintains separate accounts to manage year to year high security needs and transmission/operation losses. In addition a storage reserve is usually set aside to provide longer term security for high security water use. The Border Rivers Valley went to a continuous accounting system in the 2001/02 water year.
DECCW	NSW Department of Environment, Climate Change and Water: former agency with responsibility for water management from 2009-2011
DIPNR	NSW Department of Infrastructure, Planning and Natural Resoures: former agency with responsibility for water management from 2003-2005
DTIRIS	NSW Department of Trade and Investment, Regional Infrastructure and Services. A cluster of NSW Government Departments including DPI within which the NSW Office of Water (NOW) operates. The functions of NOW relevant to water management and modelling previously operated in DWR, DLWC, DIPNR, DNR, DWE and DECCW.
DLWC	NSW Department of Land and Water Conservation: : former agency responsible for water management prior from 1995-2003
DNR	NSW Department of Natural Resources: former agency responsible for water management prior from 2005-2007
DPI	NSW Department of Primary Industries: current agency within the DTIRIS cluster, within which NSW Office of Water has responsibility for water management since 2011
DWE	NSW Department of Water and Energy: former agency responsible for water management from 2007-2009
DWR	NSW Department of Water Resources: former agency responsible for water management prior to 1995
d/s	Downstream
Entitlement	See “water share”
Environmental Flow Rules (EFR)	A set of the river management operation rules aimed at increasing the environment’s share of river flows.
Flood-Plain Harvesting (FPH)	Water obtained by irrigators through pumping or directing inflows of water off the flood plain. This includes water:

Term	Description
	• 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) . . These diversions are not metered and therefore there is no FPH data available.
General Security (GS) Licences	Licences that are allocated water after high security licence needs are fully satisfied. These licences cover the great majority of irrigation licences both in terms of number and annual water share volume. In an annual accounting system AWDs are made each year to indicate the percentage of annual water share volume that can be supplied. In a continuous accounting system the annual water share volume is a function of usage in previous years and shared inflows this year.
High Security (HS) Licenses	Licenses that provide the highest reliability of water supply. Requirements for high security licenses are met in full before an AWD is undertaken for GS licences. These licenses are for relatively small volumes of water for town water supplies and permanent plantings such as orchards and vineyards.
Irrigator Planting 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 AWD, 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 stream flows or rainfall occurs.
IQQM	An Integrated Quantity and Quality river basin simulation Model developed by DNR since the early 1990s used to investigate water resources management issues in large river systems, with complex combinations of water regulation for irrigation and environmental requirements. It operates on a daily time-step.
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, a federal agency with responsibility for management of the water resources of the Murray-Darling Basin.
MDBC	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. Abolished with the establishment of MDBA in December 2008.
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.
NOW	NSW Office of Water, an agency within DITRIS.
Off-allocation diversion (OFA)	See Supplementary Water
Office-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 storages are large private storages constructed on an irrigator's property, and filled with water from diverted from different sources, including allocated water, supplementary access, floodplain harvesting, irrigation tailwater, and cropped area

Term	Description
	runoff. The stored water is subsequently used for irrigation.
OFS Airspace	The portion of an OFS that is left unfilled after access to supplementary water event so as to be able to capture any runoff from the cropped areas.
OFS Reserve	Irrigators that are far from headwater dams tend to hold an amount of water in their OFS to get through periods where they have underestimated their crop water requirements and travel times are too long to wait for additional regulated water to arrive.
On-allocation extraction	Water that is ordered by the irrigator from the dam to satisfy their crop water requirements or future management needs and diverted. This water is debited from the irrigators' water share for the year.
Pump Capacity	The maximum rate (ML/d) at which a pump at an irrigation node can divert water.
QDERM	Queensland Department of Environment and Resource Management.
QDNR	Queensland Department of Natural Resources (predecessor to QDERM).
Rain rejection	This occurs when ordered water in transit is not extracted from the river because rainfall that has occurred since it was released from the head-water storage. The water is not extracted from the river because either: • the rainfall has met the crop water requirements and regulated water in the river is no longer required. In a water use debit scheme the ordered water would not be extracted and would effectively become part of the system surplus; • the rainfall is ponding on the cropped area and needs to evacuated before the crops drown. In this situation, the irrigator may not have enough pumps to evacuate this water and access their orders in the river simultaneously. Therefore, even in a water order debit scheme, the ordered water would not be extracted and would effectively become part of the system surplus.
Rainfall Harvesting	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.
Resource Assessment	The process of calculating an AWD based on the current and predicted water resource availability and water requirements of all water users.
Sacramento Model	The Sacramento rainfall-runoff model is used to estimate long term stream flows 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 [DLWC, 1998[i]]. A long-term stream flow sequence can then be generated by inputting the

Term	Description
	long-term rainfall and evaporation. The model was developed by Burnash et al. [1973] in Sacramento California.
Supplementary Access Diversion	Previously known as off-allocation water. This is water that is diverted from the river during a Supplementary Access Period This water is not debited from the irrigators' water share for the year and is usually "billed" at a lesser cost.
Supplementary Access Period	A period when the river flow is in excess of the anticipated demands of the downstream users by a specified amount. The announcement of these periods may be subject to a number of other conditions such as equity, ease of access or environmental requirements.
On-river storage reserve	The amount of storage volume reserved or set aside for next year to ensure high security needs are met. The storage reserve is taken into account when calculating this year's AWD.
Tributary	An unregulated river that flows into a larger stream or water body.
Tributary Utilisation	The proportion of today's flow from a tributary that can be used to meet water orders.
Unregulated River	A river with no major storages by which flows are regulated.
u/s	Upstream.
Water Order Debit Scheme	An accounting scheme where irrigators' orders are debited against their water share volume, regardless of whether or not the water was diverted.
Water Share	Also referred to as "entitlement" or "license volume". This is the total amount of licensed water an irrigator has and remains static over time. In an annual accounting system, the water share is multiplied by the AWD to determine the water available in their account for the current water year.
Water Use Debit Scheme	In this accounting scheme the irrigators' diversions are debited against their water share volume.
Water Year	A continuous period (usually 12 months) starting from a specified month for water accounting purposes. In the Border Rivers Valley, the water years were as follows. • 1981/82 - 1985/86: 1st July to 30th June • transition 1986/871st July 1986 to 30th September 1987 • 1987/88 -:2007/08 : 1st October to 30th September • 2008/09-: current: 1st July to 30th June

Chapter 1: Introduction

1.1 Background

Water sharing and management plans and policies in NSW have long been supported by the analytical capabilities of water balance simulation models. The ability of these tools to see the likely outcomes of various policy scenarios provides the necessary information for stakeholders to decide on acceptable or optimal settings. Prior to the 1990s, monthly time step computer models were implemented in the major regulated river basins in NSW. These monthly models were suitable for investigating and developing the various water management and sharing policy initiatives of that time, focusing mainly on establishing the security of water supply for consumptive users.

During the 1990s several developments occurred in water management policies, including diversion limits under the MDBMC Cap [MDBMC, 1996], NSW Government Water Reforms intended to provide more water for the environment, and water quality management. These required the analysis of more complex water management arrangements and a water quality modelling capability. These changes required more model complexity, where representing the short term flow variability became increasingly more important.

In the late 1980s, prototypes of daily time step modelling software were developed, including the WARAS model [Lyall, 1986]. Building on many of the concepts within the WARAS model, the DWR started developing a more generalised and comprehensive river basin simulation model as a suitable tool to investigate water resources management issues. This modelling tool is called the Integrated Quantity Quality Model (IQQM).

IQQM operates at a time step of up to one day. Resource management issues such as sharing surplus flows and meeting, environmental flow requirements are beyond the capability of monthly time step models. The daily time step used in IQQM more realistically represents hydrologic processes in both regulated and unregulated rivers. IQQM can also simulate in-stream water quality constituents, such as salinity and nutrients. 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, 1998b].

1.2 Aim of Implementing IQQM in the Border Rivers Valley

IQQM has been implemented for the regulated part of the Border Rivers Valley from the headwater dams including Glenlyon, Pindari and Coolmunda to the outlet of the Border Rivers Valley near Mungindi. It also includes the major unregulated Weir River system.

The aim of this IQQM implementation is to establish a tool that can simulate daily hydrologic processes within a regulated river system over long (100+ years) time periods. A model such as this is required for the following purposes:

- Assess the impact of a range of policy scenarios, including accounting systems, environmental flow rules, water access rules, dam operations policies, levels of development, etc on the in-stream hydrologic regime and on long term variability of water availability for irrigation use.
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development, etc on the in-stream hydrologic regime and on long term variability of water availability for irrigation use.

- Estimate the long term average annual diversions for the NSW Border Rivers under a 1993/94 Development Conditions scenario, i.e. the Cap scenario.
- Compare on an annual basis observed irrigation diversions, to those modelled diversions that would have occurred under 1993/94 development conditions with the observed climatic inputs, i.e. the Cap scenario. This scenario is the basis of the MDBMC Cap auditing process.

1.3 IQQM Implementation

1.3.1 Procedure

The main steps for implementing the Border Rivers IQQM are as follows:

1. Configure and calibrate the model to reproduce historical observations of in-stream flow, storage behaviour, irrigation diversions and planted crop areas for the periods of record;
2. Apply Quality Assessment Guidelines (described in Appendix E) to report on how well the various components of the model are calibrated.
3. Configure for Cap scenario conditions, especially 1993/4 levels of development and management rules;
4. Validate the Cap scenario for a period considered representative of Cap scenario development conditions and management rules;
5. Simulate the long term Cap scenario for 100+ years to establish the long-term MDBMC Cap;
6. Simulate the short term Cap Audit scenario since 1997/98 to compare the Border Rivers Valley's performance relative to the MDBMC Cap.

1.3.2 Status

The model configuration, calibration and validation have now been completed. The long term simulation models have been prepared for the Cap Scenario and the Water Sharing Plan (WSP) scenario, and have been run for the period 1890-2011 period. The Cap Scenario is documented in Chapter 5: of this report.

1.4 Aim and Objective of this Report

This Border Rivers IQQM Cap Implementation report is intended to be used as a technical reference document. The aim of this summary report is to summarise the full calibration and configuration process into a single document to be presented to the Murray-Darling Basin Authority (MDBA) as a step in accreditation as part of the Cap Scenario approval process.

1.5 Scope of this Report

The scope of work covered in this report includes:

- Description of the Border River Valley including data availability(Chapter 2);

- Configuration and calibration methods of the Coolmunda, Pindari and Glenlyon sub-systems (Chapter 3);
- Calibration results for flow, diversions, storage behaviour, and planted area (Chapter 4)
- Configuration and simulation of the short term NSW Cap Audit scenario (Chapter 5);
- Outline of model improvement plans (Chapter 6);
- Details of the climatic and stream flow stations used in the model (Appendix A);
- Details of the model configuration (Appendix B);
- A Node link diagram showing major features affecting the water balance (Appendix C);
- Background to modelling the planting decision (Appendix D);
- Description of the quality assessment guidelines used to assess the model (Appendix E);
- Details of the NSW Cap development conditions and management rules (Appendix F);
- A copy of the user-survey filled in by representative BR Valley irrigators (Appendix G).

Some preliminary discussions of the Water Sharing Plan rules have been included in the report for completeness. However no modelling of these rules is detailed in this report.

Chapter 2: The Border Rivers Valley

2.1 Catchment Description

The Border Rivers catchment is located west of the Great Dividing Range. It has a total area of about 49,500 km^2 and lies, in approximately equal sections, in northern NSW and southern QLD. Principal streams of the region are the Macintyre and Severn Rivers in the south-east, the Dumaresq River in the east and Macintyre Brook and the Weir River in the north and north-west.

With the exemption of the Weir River all of these main rivers are regulated with a major dam located upstream of each catchment. The entire BRS consist of these three major regulated subsystems each of which is named after the headwater Dam: Coolmunda subsystem with the Dam located on Macintyre Brook, Glenlyon subsystem with the Dam located on Pike Creek, QLD, some 7 km upstream from its junction with the Dumaresq River and Pindari subsystem with the Dam located on the Severn River in NSW about 22 km upstream from Ashford.

The general characteristics of each of the sub-systems vary considerably and described individually below.

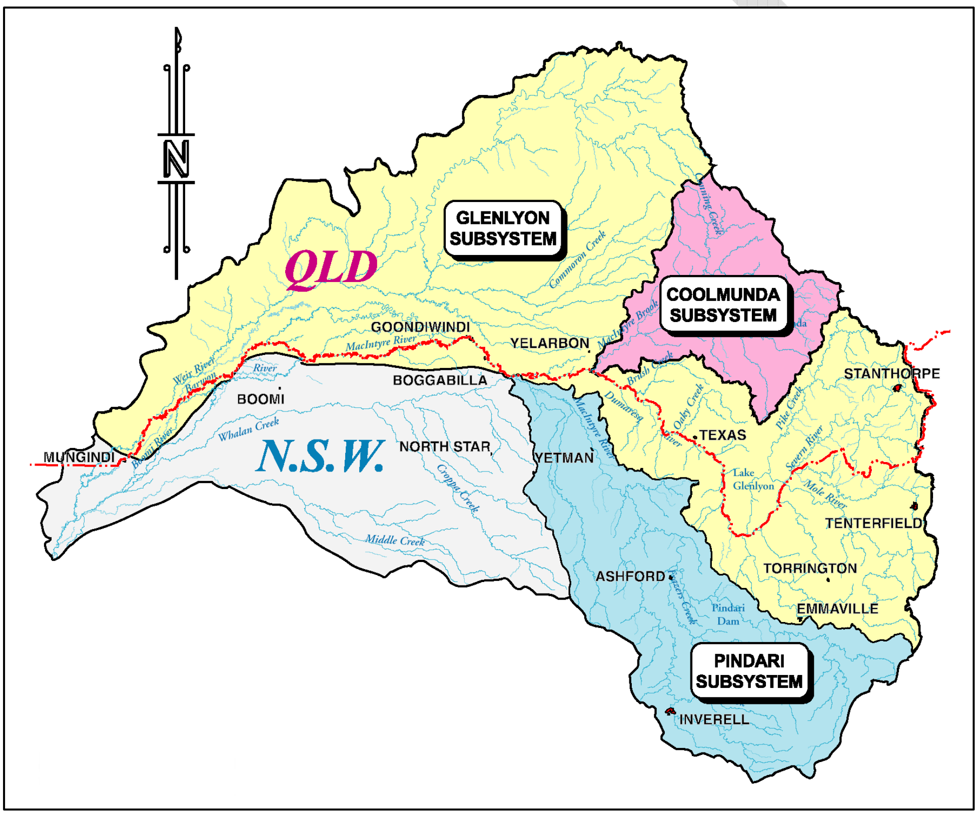


Figure 2.1. Border Rivers Catchment and Sub-Systems

2.1.1 Coolmunda Subsystem

The Coolmunda sub-system is wholly within the Macintyre Brook catchment (Figure 2.1 and Figure 2.3). This catchment encloses an area of 4,213 km^2, about 10% of the total BRS catchment, and is situated wholly within Queensland. Topography is steep on the eastern edge and reduces to undulating hills and flat flood plains to the west.

Soils are generally sandy throughout the catchment, as described more fully in the DWR summary water resources publication [DLWC, 1995c]. Rainfall is highest in the east, decreasing from median annual totals of 800 mm to 600 mm in the west. The rainfall patterns are strongly season, with most of the rain falling during summer. Evaporation variability is the reverse of rainfall, with mean annual values of 1200 mm in the east increasing to 1750 mm in the west.

Vegetation cover varies from medium density eucalypt forest in the upper (eastern) catchment, to flat grazing areas with scattered trees in the lower portion. The Macintyre Brook Irrigation Project is the main irrigation area, and is located on strips of land immediately adjacent to Macintyre Brook, from the d/s edge of Coolmunda Dam to its confluence with the Dumaresq River.).

Coolmunda Dam commenced operation in 1968, has a capacity of 75.2 GL at full supply level, and is used to service around 120 active licence holders. Most of the licence holders are irrigators, with the only exceptions being the town water supply for Inglewood, and industrial water for Johnstone's Quarry.

Figure 2.2 Coolmunda sub-system boundary.

Table 2.1. Coolmunda Sub-system storage capacity

Storage	Inactive Storage Volume (ML)	Full Storage Volume (ML)
Coolmunda Dam	482	69,060

2.1.2 The Pindari Subsystem

The Pindari sub-system is located within the Severn and Macintyre Rivers catchments (Figure 2.3) and encloses an area of 8,400 km^2, about 19% of the total BRS catchment area. The sub system is situated wholly within NSW.

The upper part of the catchment to the east is in the Great Dividing Range, and has steep topography and high relief. This grades into undulating hills around Ashford, and flattens downstream of Yetman. Soil types vary from volcanic soils and rocks in the upper catchment, to friable loamy soils with brown clay subsoils in mid-catchment and sandy soils near the river in the lower catchment. Vegetation cover varies from eucalypt forests in the upper catchment, to flat grazing areas with scattered trees towards the catchment outlet. There is a number of small lagoons d/s of Yetman, but only one low level offtake was noted, this being the Boonal anabranch that returns to the river 9 km d/s of the confluence of the Dumaresq and Macintyre Rivers.

Pindari Dam, a fixed-crest mass concrete storage, commenced operation in 1969 with a total capacity of 37.9 GL at full supply level. Capacity enlargement works began in 1993 and were completed by the end of 1995 to give a new capacity of 312 GL at full supply level. Most of the licence holders are irrigators, with town water licences for Ashford and Boggabilla; and a thermal power station demand at Ashford.

Median annual rainfall ranges from 800 mm at the eastern edge to 600 mm on the western edge, with most of the rain falling in summer. Evaporation variation is the reverse that of rainfall, ranging from an annual mean of 1200 mm in the east 1750 mm in the west.

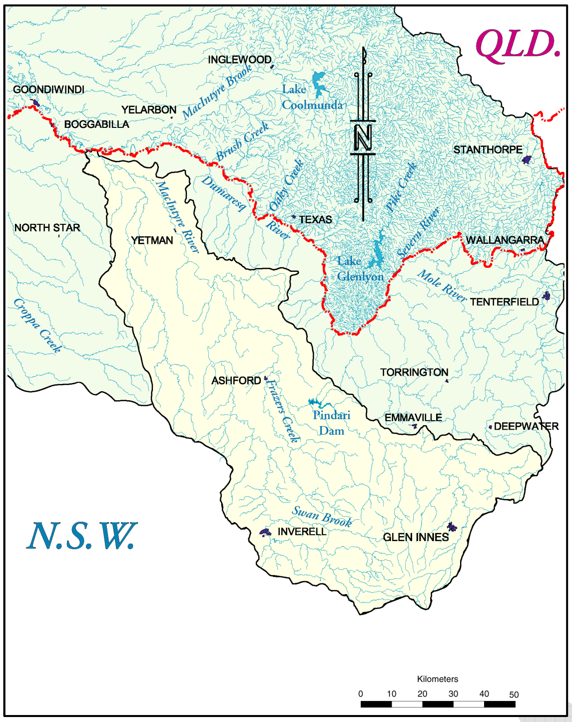


Figure 2.3 Pindari sub-system boundary

Table 2 2 Pindari sub-system Storage capacities

Storage	Inactive Storage Volume (ML)	Full Storage Volume (ML)
Original Pindari Dam	80	37,900
Enlarged Pindari Dam	80	312,900

2.1.3 The Glenlyon Subsystem

Glenlyon sub-system is the largest of the three modelled sub-systems, draining an area of 31,500 km^2, about 70% of the BRS (Figure 2.4). The catchment spans both states, and is split into upper and lower zones by the incursion of the Pindari and Coolmunda sub-systems.

The Great Dividing Range forms the eastern boundary of Glenlyon sub-system, with elevations up to 1,500 m and steep slopes. The elevation decreases to the west, grading into the western plains around Boggabilla.

The geology and soils can be divided into two distinct regions. The eastern region is the eroded remnants of a mountainous belt capped by basalt or granite rocks, and the western region is composed of alluvial and riverine plain deposits.

The rainfall is summer dominant, ranging from an annual median of 800 mm in the east to less than 500 mm at Mungindi in the west. Evaporation varies from 1,200 mm in the east to a maximum of 2,000 mm in the west.

Vegetation in the upper eastern catchment mostly consists of eucalypt forests, giving way to grazing land with isolated eucalypt patches to the west, and finally to River Red-gums and Coolibah along the water course of the western area of the river. There are a number of significant wetlands adjacent to the main river course from Goondiwindi to Mungindi in the form of lagoons and anabranches. These include: Whalan Creek, Telephone-Malgarai Lagoons, Rainbow Lagoon, Kildonan Lagoon, Maynes Lagoon, Morella Watercourse, Boobera Lagoon, Serpentine Lagoon, Brigalow Creek, Callandoon Creek, Dingo Creek, Boomi River, Boomangarra Creek, Little Barwon River, and Little Weir River.

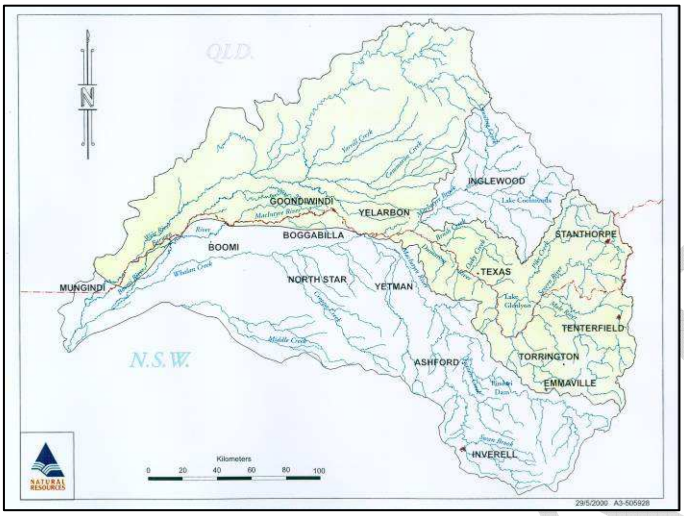


Figure 2.4 Glenlyon sub-system boundary

Table 2 3: Glenlyon sub-system Storage capacity

Storage	Inactive Storage Volume (ML)	Full Storage Volume (ML)
Glenlyon Dam	6,000	253,600
Boggabilla Weir	415	6,182

2.2 Climatic data

The data used to calibrate the model behaviour was obtained mostly from the BoM database.

2.2.1 Rainfall

Rainfall data is required by IQQM to (i) generating catchment inflows using rainfall-runoff models; (ii) drive the soil moisture accounting module; and (iii) compute the contributions to reservoirs and river reaches due to rainfall on the water surface.

An extensive network of daily read rainfall gauges covers the BRS and selection of appropriate gauges for each of the above mentioned purposes in the BRS IQQM is discussed in Section 3.3.4. A full listing of the gauges selected is provided in Table A.1, Table A.2, and Table A.3. These tables also show which nearby rainfall stations were used to fill in gaps in the records of rainfall stations used in IQQM. The location of key rainfall gauges is shown in Figure 2.5, Figure 2.6, and Figure 2.7 for Coolmunda, Pindari, and Glenlyon sub-systems respectively.

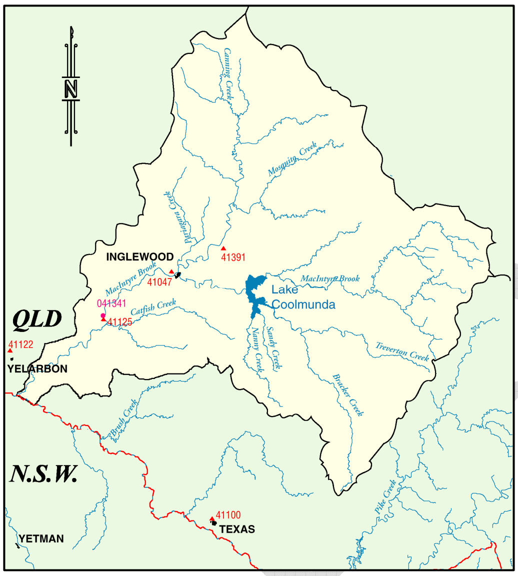
2.2.2 Evaporation

As with rainfall data, evaporation data is required by IQQM to (i) estimate evapotranspiration for generating catchment inflows using rainfall-runoff; (ii) estimate evapotranspiration from the crops; and (iii) to compute evaporation losses from reservoirs and river reaches.

Class A Pan Evaporation data was available at the following six BoM sites:

- Warwick ;
- Applethorpe;
- Inglewood;
- Pindari Dam;
- Wallangra; and
- Boggabilla.

The gap-filled rainfall records were used in conjunction with the nearest evaporation records to estimate daily evaporation for periods when evaporation was not measured. Selection of gauges for each of the above mentioned purposes is discussed in Section 3.3.4, with a full listing of the gauges selected provided in Table A.4 to Table A.7and show in is shown in Figure 2.5, Figure 2.6, and Figure 2.7 for Coolmunda, Pindari, and Glenlyon sub-systems respectively.



Principal rain gauges used:

041047: Inglewood PO

041125: Whetstone PO

041100: Texas PO

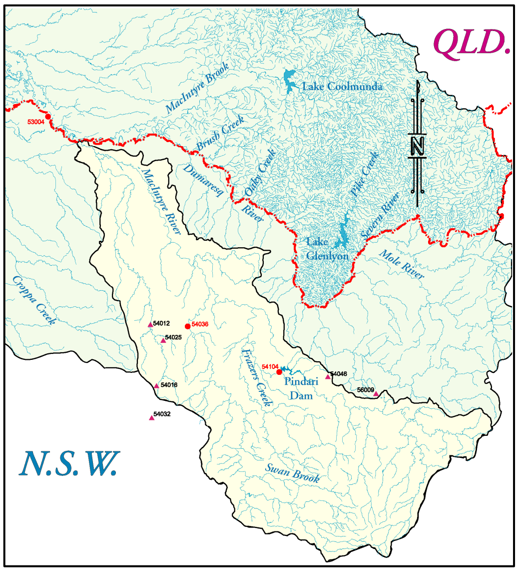
041391: Inglewood (Woodspring)

041341: Inglewood tobacco research station

Principal evaporation gauge used:

041341: Inglewood Tobacco Research Station

Figure 2.5 Coolmunda sub-system rain and evaporation gauge locations.



Principal rain gauges used:

53004: Boggabilla PO

54012: Coolatai

54016: Delunga

54025: Ottley

54032: Coolatai

54036: Wallangra Station

54046: Ashford

54104: Pindari Dam [also evaporation gauge]

56009: Emmaville PO

Figure 2.6 Pindari sub-system rain and evaporation gauge locations.

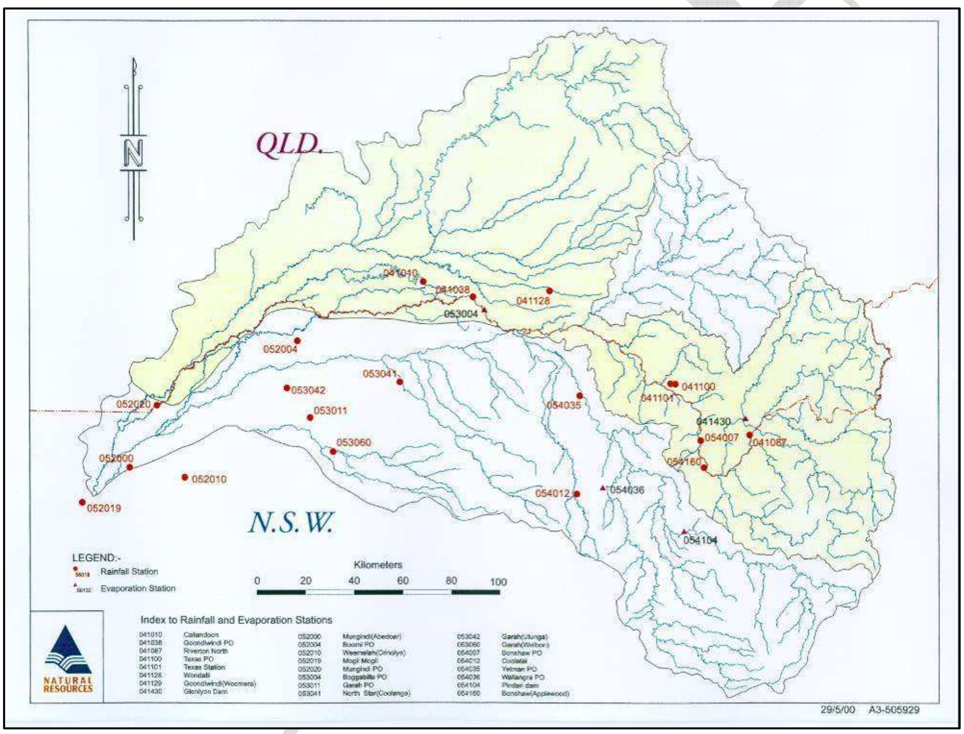


Figure 2.7 Glenlyon sub-system rain and evaporation gauge locations.

2.3 Flow Data

2.3.1 Stream-flows

Stream-flow data is used in IQQM for model calibration (Section 3.4) and for model simulations (Section 5.33.4).

IQQM requires estimates of tributary inflows along all reaches of the river system, and these aggregated tributary inflows combined with storage releases and recorded diversions are matched against observed back-calculated inflows into the headwater dams, and along the main-stream. The tributary inflows used in the models are in order of preference either: (i) directly gauged, (ii) estimated using a calibrated daily rainfall runoff model, or (iii) estimated using statistical and mass balance methods. These aggregated estimates are then calibrated to gauged stream-flow data along the main stream. Once calibrated, the inflow estimates are extended to the full modelling period using the calibrated rainfall-runoff models, and used to simulate scenarios.

The stream-flow stations in the Coolmunda sub-system are operated by the QDERM (Figure 2.8). A full list of gauges in the Coolmunda sub-system used in the BRS IQQM and how they were used is presented in Table A.8.

Principal flow gauges:

416410: Macintyre Brook at Barangarook

416409: Macintyre Brook at Coolmunda Dam

416402: Macintyre Brook at Inglewood

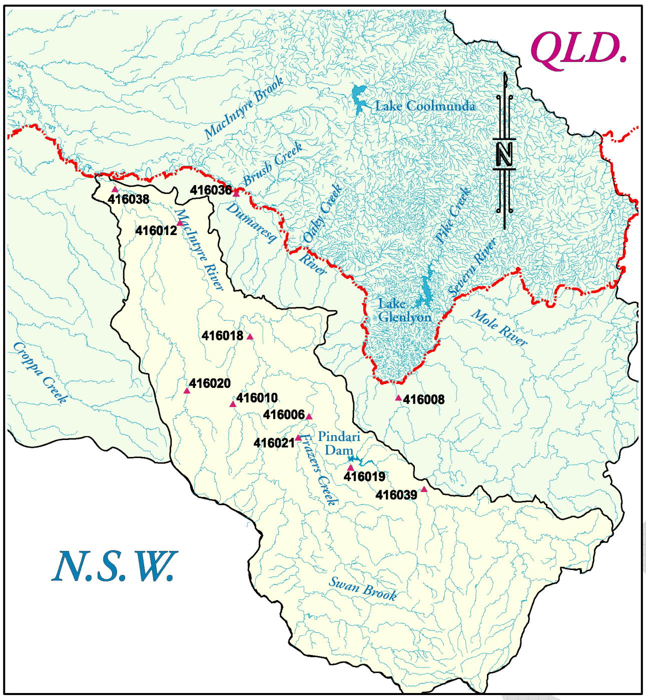
416415: Macintyre Brook at Booba Sands

416404: Bracker Creek at Terraine

416407: Canning Creek at Woodspring

Figure 2.8 Coolmunda sub-system stream gauge locations.

The stream-flow stations in the Pindari sub-system are operated by the NOW. Principal flow gauges used. A full list of stream-flow gauges in the Pindari sub-system and how they were used in the BR IQQM is presented in Table A.9 and shown in the Figure 2.9.



Principal flow gauges:

416039: Severn River at Strathbogie
416030: Pindari Dam level records
416019: Severn River at Pindari tailwater
416021: Frazers Creek at Ashford
416006: Severn River at Ashford
416010: Macintyre River at Wallangra
416018: Macintyre River at Old Dam Site
416012: Macintyre River at Holdfast
416038: Macintyre River at Boonal
416020: Ottleys Creek at Coolatai

Figure 2.9 Pindari sub-system stream gauge locations

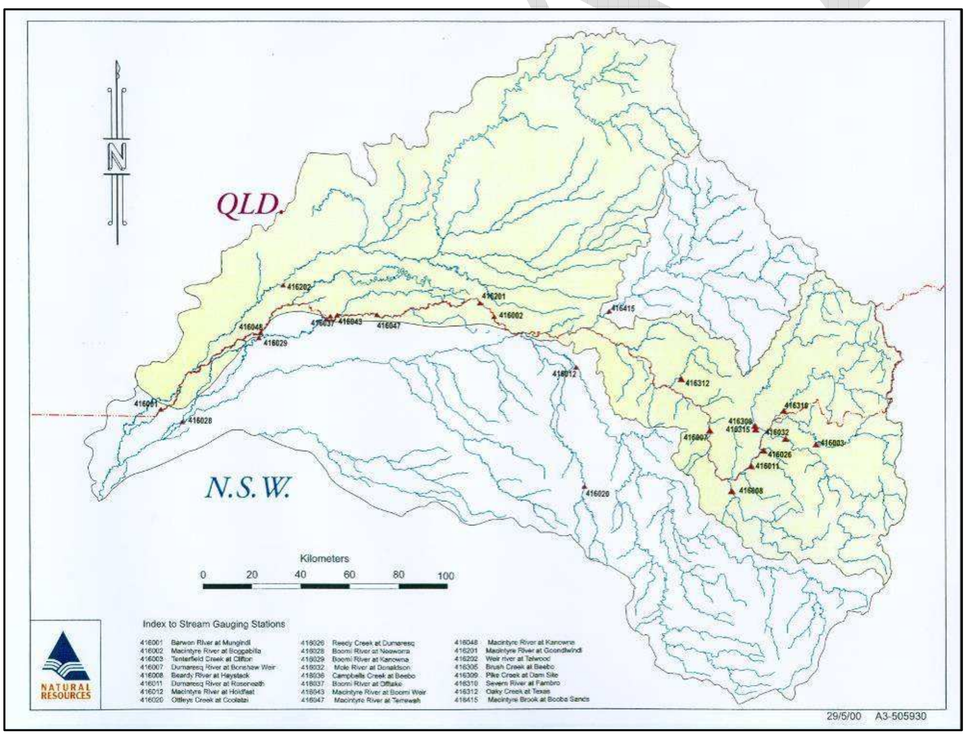


Figure 2.10 Glenlyon sub-system stream gauge locations

2.3.2 Inflow into Dams

All three headwater dams in the BRS have good sets of operational daily records on storage levels, volumes, rainfall and releases since each storage became operational [DWR, 1979-2001, QDNR 1985-1992 and QDNR, 1985-2001]). The data from these Officer-in-Charge (OIC) sheets were used to estimate dam inflow using a mass balance method, and these inflow estimates were used to calibrate tributary inflows using a rainfall runoff model (Section 3.5.4.1). Gauging stations upstream of Coolmunda Dam (416404 and 416410) and one upstream Pindari Dam (416039) were also used to generate long term inflows to Coolmunda Dam and Pindari Dam respectively (Section 5.3.2). There were not any gauging stations upstream of the Glenlyon Dam, and therefore its long term inflow sequence was generated using a rainfall runoff (Section 5.3.2).

2.3.3 Ungauged tributary configuration

In the BRS gauging stations on tributaries are typically located some distance upstream from the confluence with the main river, resulting in large catchment areas that are not directly gauged. About 13% of the catchment area in the Glenlyon sub-system is ungauged, with corresponding figures and this figure is much higher in the Coolmunda and Pindari sub-systems with about 29% and 36% respectively. The estimation of these inflows is described in Section 3.4.

2.3.4 Floodplain temporary storages

Three major floodplain storage areas were identified as significant: u/s of Whalan Creek, Callandoon Creek, and Kanowna. DLWC and QDNR regional staff from the Goondiwindi office provided estimates of the areal extent and inflow and outflow control hydraulics of these floodplains.

2.4 Irrigation Information

There are licences for surface water diversion throughout the BRS, both in the regulated sections below all three major dams, as well as in the unregulated parts above the dams and along the tributaries. Regulated licences in the BRS have operated under a volumetric allocation scheme (VAS) since 1981, and have an annual licensed volume. An administrative embargo on the issue of new licences introduced prior to the introduction of the VAS became a statutory embargo in 1982. Some licence purposes such as town water supplies, research farming, stock and domestic supplies are exempt from the embargo.

Licences to extract water from streams outside the influence of regulated flows from the dams are known as unregulated or area-based licences. These licences have been operating on the basis of a maximum authorised irrigable area, and a lower flow limit for pumping (usually a visible flow at the nearest flow gauging station). The operation of these licences has not been closely monitored, and there is generally been very little diversion or cropping data.

Irrigation licences to extract regulated water in both QLD and NSW are issued for a number of prescribed purposes, the most common of which is irrigating annual crops. For purposes such as permanent plantings, town water supplies, industrial, and stock and domestic use, a High Security (HS) entitlement with priority access to available water is necessary.

HS entitlements in the NSW Border Rivers total 3 GL, representing 1% of the total licensed volume. The lower General Security (GS) irrigation entitlements represent the other 99% of the total NSW system licensed volume. These GS entitlements have two components; A 60 ML ‘A’ component has priority in allocations compared with the remaining ‘B’ component of an entitlement. The system was introduced on 10/11/1986.

All regulated irrigation licences in both NSW and QLD are issued with conditions such as an authorised pump capacity relating to the maximum rate at which they can divert water from the rivers.

Meter readings for regulated licences were generally available on a quarterly basis. These totals were disaggregated to daily totals s using the daily dam release records as a guide.

2.4.1 The Coolmunda Subsystem

2.4.1.1 Irrigation Licences

The number of regulated licences in 1987 was about 150, which decreased to about 120 by 1996. The total licensed volume for the sub-system in 1987 was 18,900 ML, distributed approximately as follows: 3% u/s of the dam; 37% between the dam and Inglewood; 45% between Inglewood and Booba Sands, and 15% d/s of Booba Sands

2.4.1.2 Irrigator infrastructure

Installed pump capacities were available in meter inspectors’ records. Based on this data the total irrigator pump capacity was 820 ML/d for the sub-system. Advice received from the QDNR operations group identified that no significant water harvesting was occurring, and no significant OFS infrastructure existed.

2.4.1.3 Crop areas

Data estimating the annual areas planted and crop mix was obtained from QDNR (and their predecessor) annual financial reports, based on information supplied by irrigators to field staff. Estimates of annual irrigated crop areas and crop type were available for regulated licences. The total annual areas planted ranged from 1,000 ha to 2,500 ha, with lucerne being the largest single crop type (50%) followed by cereals (35%), and the remaining area to vegetables and others.

This is the only comprehensive crop area information available, so it is difficult to assess its accuracy. However, comparable surveyed data collected by the cotton industry for the BRS are generally within 10% of DLWC and QDNR estimates.

2.4.2 The Pindari Subsystem

The sixty-five regulated irrigation licence holders in the sub-system have annual licence entitlements of 22,900 ML. Analysis of the licence data showed that the licensed volumes were distributed approximately as follows: 4% between the dam and Ashford; 16% from Ashford to the confluence of the Severn and Macintyre Rivers; 20% between the confluence and Yetman u/s of Holdfast gauge, and the remaining 60% from Yetman to the confluence of the Macintyre and Dumaresq Rivers.

2.4.2.1 Irrigator diversions and storage infrastructure

Installed pump capacities were available from meter inspectors’ records. Analysis of this data the total system shows pumping capacity increased over the period 1986-1990 from 76 ML/d to 293 ML/d.

OFS infrastructure was not observed in this sub-system prior to 1989. Development of OFS occurred in response to anticipated reductions in reliability of supply, with the additional Pindari storage contributing to the overall Border Rivers resources. The subsequent estimated increase in development from 2,800 ML in 1989 to 6,000 ML by 1991/92 as reported by irrigators to operations staff (was all d/s of the Severn-Macintyre junction Where OFS exist and floodplain conditions are suitable flows across the floodplain can be harvested into storage without being metered. This can occur when flows are high enough to fill on-farm storages directly, or are pumped into storage from lagoons that are filled during floods to higher using unmetered secondary pumps. Anecdotal information regarding these activities indicates these floodplain harvesting activities were negligible for the calibration period.

The monthly volumes of Regulated and Supplementary Access water diverted by each licence holder were available based on pump meter readings. Monthly Supplementary Access volumes were disaggregated to daily volumes using records of Supplementary Access announcements, assuming a constant pump rate. Monthly Regulated diverted volumes were disaggregated to daily volumes based on the daily pattern of differences between u/s and d/s flow gauges

2.4.2.2 Crop areas

Data on planted areas and crop types reported by regulated irrigators was available for from information recorded by the DLWC River Operations Group in Goondiwindi. Total annual areas planted varied from 1,017 ha in 1985/86 to 1,456 ha in 1989/90.

Crop mix for the upper reaches of the subsystem was similar to the Coolmunda subsystem irrigators, with Lucerne being the dominant single crop type (50%) followed by cereals and pasture (about 12% each), with the remaining 25% being mixed horticultural crops. For lower parts of the subsystem, cotton was by far the dominant crop type, ranging from 50% to 100% of the total. The remaining portion was made up mainly of cereals and pasture, with smaller portions of vegetables and other. The accuracy of this information is as described previously in Section 2.4.1.2,

2.4.2.3 End of year diversions

Observed diversion data for the period 1986/87-1995/96 period indicated irrigators were diverting unused allocated water at the end of the irrigation season and storing it in their OFS for use it later as pre-watering. The likely reason for this practice was to avoid socialising their unused allocation at the end of the water year. This no longer happens as a result of the introduction in 2001 of continuous accounting in the BRS.

2.4.3 The Glenlyon Subsystem

2.4.3.1 Irrigation Licenses and Diversions

There were approximately 400 unregulated licence holders and 330 regulated licence holders in the Glenlyon sub-system prior to 1990. In the QLD BR, the number of unregulated licences grew significantly between 1988 and 1991, while the number of regulated licenses increased only marginally. The moratorium on new licences restricted growth in the number of regulated and unregulated licenses in the NSW BR The history of licensing in the Glenlyon sub-system between 1985 and 1996 is shown in Figure 2.11.

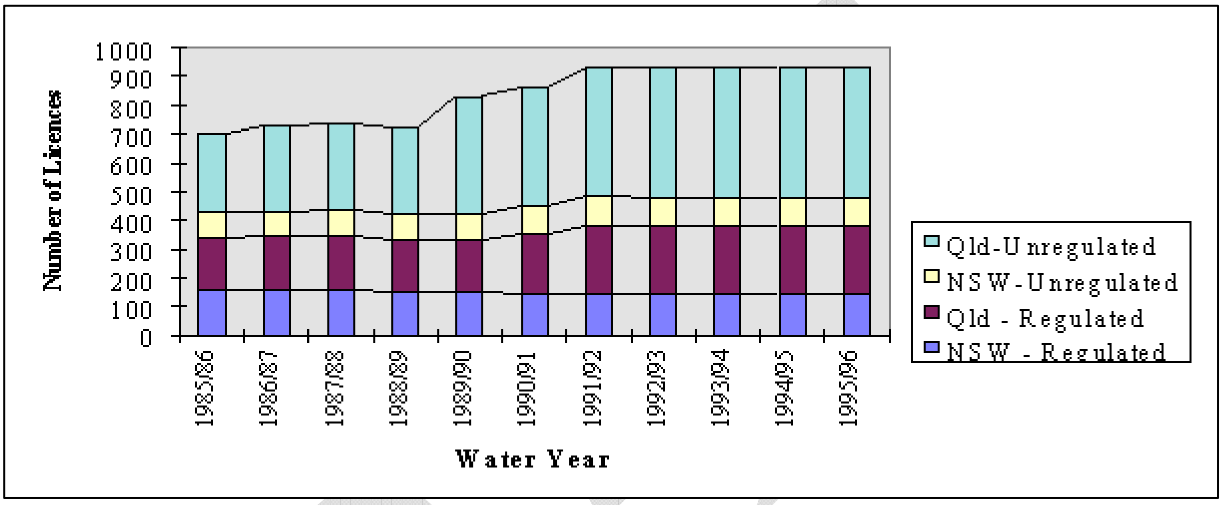


Figure 2.11 History of licence numbers in the Glenlyon sub-system.

Analysis of the regulated licence data shows that 16% of the entitlements were between the Glenlyon Dam and the Dumaresq-Macintyre confluence; 30% were between this confluence and Goondiwindi; 29% were between Goondiwindi and Boomi, and the remaining 25% were from Boomi to Mungindi.

The 330 regulated irrigation licence holders had annual licence volume entitlements of approximately 238,000 ML; much larger than the other two sub-systems. Together with around 83,000 ML of entitlement issued to Queensland irrigators, the total system entitlements are 1.3 times the capacity of Glenlyon storage. Consequently, for the 1985/86 – 1999/00 period, regulated diversions for NSW did not exceed 120,000 ML. However, the high proportion of unregulated valley inflows and high levels of OFS development resulted in Supplementary Access diversions similar in magnitude to regulated diversions. Historical records of metered irrigation diversions for the BR Valley are summarised in

Table 2.2.

2.4.3.2 Pump Capacity

Estimates of pump capacities were based on meter inspectors' records where available or alternatively from authorised capacities. The aggregate capacity in NSW BR increased from 4,500 ML/d to 7,000 ML/d (~56% increase) over the period 1985/86-2001/02, while in Queensland they increased from under 2,200 ML/d to over 15,000 ML/d. Historical figures taken from NOW and QDERM's licensing information and regional surveys are summarised in Table 2.3.

2.4.3.3 On Farm storage Capacity

Significant volumes of OFS have been built in the BRS. Early records of volumes are sparse, and the first detailed survey was undertaken in 1985/86 by operations staff from NOW and QDERM. The historical growth in OFS is summarised in Table 2.4. OFS development increased during the calibration period, particularly in the QLD BR. The aggregate OFS volume in 2001/02 was about 75% of the total full storage capacity of the Glenlyon Dam and the enlarged Pindari Dam, giving an indication of the increased reliance on both Supplementary Access and other alternative water harvesting sources by the BR farmers.

Where OFS exist and floodplain conditions are suitable, flows across the floodplain can be "harvested" into storage without being metered. This can occur when flows are high enough to fill on-farm storages either directly or to be pumped into storage by secondary pumps without meters (typically from lagoons that are filled during floods to higher, constructed storages). Prior to the 2003 Irrigators Survey there was only anecdotal information available regarding these practices. Floodplain harvesting activities were thought to be undertaken by a number of irrigators in the system.

Table 2.2 Total GS and SA irrigation diversions by water year (ML)

Year	New South Wales				Queensland			
	Pindari		Glenlyon		Glenlyon		Coolmunda	
	GS	SA	GS	SA	GS	SA	GS	SA
1984/85	n/a	n/a	64,071	52,178	3,668	6,523	9,600	n/a
1985/86	n/a	n/a	63,164	54,344	25,192	6,471	9,500	n/a
1986/87	1,229	9,323	35,126	104,540	33,626	9,148	8,200	n/a
1987/88	2,232	2,120	25,364	65,429	20,115	22,205	6,700	n/a
1988/89	6,117	2,084	101,465	33,500	38,708	5,254	6,700	n/a
1989/90	3,726	3,825	41,159	109,863	25,448	39,390	6,500	n/a
1990/91	5,435	2,351	103,670	41,775	60,195	24,749	10,100	n/a
1991/92	9,250	7,906	44,354	113,543	33,488	54,581	10,900	n/a
1992/93	9,834	5,374	78,969	38,702	50,431	26,273	14,400	n/a
1993/94	6,684	1,897	34,429	64,296	12,327	41,139	7,500	n/a
1994/95	3,975	1,471	6,244	45,814	1,940	35,689	2,800	n/a
1995/96	4,709	2,269	16,126	113,698	4,608	104,690	6,800	n/a
1996/97	2,414	1,515	102,061	63,822	42,941	48,799	4,500	n/a
1997/98	5,309	3,163	95,171	84,000	30,520	78,700	7,700	n/a
1998/99	5,231	1,004	92,978	65,118	22,971	57,551	6,133	n/a
1999/00	6,198	2,093	109,995	59,064	40,006	55,250	10,380	n/a
2000/01	3,181	6,259	111,481	111,497	50,884	145,878	14,915	n/a

Table 2.3 Border Rivers historical installed Pump capacity

Water Year	Installed pump capacity (ML/d)		
	NSW[1]	QLD[2]	Total BRS[3]
1984/85	4,481	1,362	5,301
1985/86	4,486	1,685	5,306
1986/87	4,886	1,735	5,706
1987/88	5,066	2,344	8,230
1988/89	5,066	2,327	8,213
1989/90	5,086	2,534	8,440
1990/91	5,217	3,422	9,459
1991/92	5,476	5,238	11,534
1992/93	5,783	5,520	11,841
1993/94	5,956	5,813	12,589
1994/95	5,945	5,923	12,688
1995/96	n/a	n/a	n/a
1996/97	6,723	n/a	n/a
1997/98	n/a	7,024	n/a
1998/99	6,863	16,803	23,758
1999/00	n/a	n/a	n/a
2000/01	6,996	14,264	22,080

(1) NOW licensing records

(2) QLD for Glenlyon only

(3) Includes constant 820 ML/d pump capacity for Coolmunda

Table 2.4 Border Rivers historical On-Farm Storage Capacity

Water Year	On-Farm Storage Capacity (ML		
	NSW	QLD	Total BRS
1985/86	25,000	10,755	35,755
1986/87	42,920	11,910	54,830
1987/88	51,250	14,585	65,835
1988/89	59,850	14,910	74,760
1989/90	67,355	33,060	100,415
1990/91	73,500	51,455	124,955
1991/92	100,590	83,980	184,570
1992/93	107,800	86,860	194,660
1993/94	129,200	101,335	230,535
1994/95	135,130	116,230	251,360
1995/96	137,280	116,730	254,010
1996/97	138,005	124,050	262,055
1997/98	140,430	145,200	285,630
1998/99	142,360	163,025	305,385
1999/00	146,210	228,342	374,552
2000/01	n/a	n/a	n/a
2001/02	153,260	281,467	434,727

2.4.3.4 Crop areas and crop mix

Data on planted irrigated crop areas and crop types was available for regulated licences from a various sources including crop return books maintained by water operations groups No area data has been collected since 2001/02.

The crop return books are the most comprehensive information and preferred source of data. Comparisons with ACF surveyed data for the whole BRS revealed inconsistencies. However, it is difficult to assess the level of accuracy of either data set, although regional data is within 10% of estimates reported by the ACF. The data indicates development continued on both sides of the BRS, although NSW irrigated areas appear to plateau after the Pindari Dam enlargement took full effect in 1996. Adopted total crop area data is summarised in Table 2.5.

Crop mix for irrigators u/s of the Dumaresq-Macintyre Rivers confluence is mainly lucerne, pasture and cereals, similar to that of the Coolmunda sub-system and the upper Pindari sub-system. Below the confluence cotton is by far the dominant crop. The crop composition remained fairly constant over the period of available data..

Table 2.5 BRS historical irrigated crop areas (ha)

Year	New South Wales			Queensland			TOTAL
	Cotton	Other	Total	Cotton	Other	Total	
1982/83	10,500	2,080	12,580	n/a	n/a	n/a	**n/a**
1983/84	8,200	1,250	9,450	n/a	n/a	n/a	**n/a**
1984/85	10,000	2,380	12,380	n/a	n/a	n/a	**n/a**
1985/86	13,000	3,780	16,780	n/a	n/a	8,840	**25,620**
1986/87	12,732	3,440	16,172	n/a	n/a	6,790	**22,960**
1987/88	21,032	1,750	22,782	n/a	n/a	8,570	**31,350**
1988/89	23,000	4,000	27,000	4,200	3,800	8,000	**35,000**
1989/90	25,000	5,000	30,000	6,800	3,700	10,500	**40,500**
1990/91	25,800	4,200	30,000	9,800	3,600	13,400	**43,400**
1991/92	23,200	2,800	26,000	11,900	3,100	15,000	**41,000**
1992/93	24,690	3,010	27,700	13,890	3,500	17,390	**45,090**
1993/94	19,000	2,500	21,500	8,600	2,600	11,200	**32,700**
1994/95	9,800	600	10,400	6,000	1,500	7,500	**17,900**
1995/96	19,600	5,400	25,000	10,900	3,500	14,400	**39,400**
1996/97	31,600	2,800	34,400	18,700	2,500	21,200	**55,600**
1997/98	34,247	3,400	37,647	18,555	2,645	21,200	**58,847**
1998/99	34,600	3,565	38,165	22,482	2,676	25,158	**63,323**
1999/00	36,172	3,755	39,927	25,573	3,109	28,682	**68,609**
2000/01	36,200	3,045	39,245	27,798	3,122	30,920	**70,165**
2001/02	36,800	3,200	40,000	n/a	n/a	n/a	**n/a**

Table 2.6 Historical QLD Border Rivers crop mix (% of total)

Water Year	Cotton	Lucerne	Pasture	Winter Cereal	Summer Cereal	Vegetables	Other
1985/86	51	6	14	12	16	0	0
1989/90	66	8	10	6	9	1	0
1990/91	73	0	0	0	0	0	27
1991/92	79	0	0	0	0	0	21
1992/93	79	5	8	4	2	2	0
1993/94	77	6	7	6	1	3	0
1994/95	80	5	5	6	2	2	0
1995/96	75	4	3	9	8	1	0
1996/97	88	0	0	0	0	0	12
1997/98	88	0	0	0	0	0	12
1998/99	89	2	1	2	6	0	0
1999/00	89	0	0	0	0	0	11
2000/01	90	0	0	0	0	0	10

Table 2.7 Historical NSW Border Rivers crop mix (% of total)

Water Year	Cotton	Lucerne	Pasture	Winter Cereal	Summer Cereal	Vegetables	Other
1982/83	79	5	3	7	0	0	6
1983/84	82	4	3	5	0	0	6
1984/85	77	6	3	8	0	0	5
1985/86	77	8	6	8	0	0	1
1986/87	79	3	1	17	0	0	0
1987/88	92	2	1	4	1	0	0
1988/89	93	2	1	3	1	0	0
1989/90	93	2	1	4	0	0	0
1990/91	91	2	2	6	0	0	0
1991/92	89	3	2	7	0	0	0
1992/93	86	2	3	9	0	0	0
1993/94	82	3	4	10	1	0	0
1994/95	83	4	7	5	0	0	0
1995/96	82	4	6	8	0	0	0
1996/97	91	2	3	2	2	0	0
1997/98	88	2	3	4	2	0	1
1998/99	90	2	3	3	1	0	1
1999/00	90	1	2	4	1	0	1
2000/01	92	1	2	2	1	0	1

2.5 Town Water Supplies

In total seven urban centres are supplied with regulated water in the BRS:

- Inglewood TWS (488 ML/y) entitlement is supplied by Coolmunda Dam;
- Ashford TWS (156 ML/y) entitlement is supplied by Pindari Dam;
- The QLD towns of Yelarbon (106 ML/y), Texas (276 ML/y) and Goondiwindi (1,801 ML/y) are supplied by Glenlyon Dam; while NSW towns of Boggabilla and Mungindi with a combined entitlement of 1,338 ML/y are supplied by both Glenlyon Dam and Pindari Dam.

Prior to NSW becoming a single allocation system all the NSW townships located downstream of Dumaresq-Macintyre Rivers junction were supplied by Glenlyon Dam. In addition, the obligation to supply the town of Boggabilla with water came into effect after construction of Boggabilla Weir in 1991.

Shire Councils provided records of total monthly diversions. The diversions from Inglewood TWS ranged from 0.7 ML/d in July to 1.6 ML/d in January. Diversions for the rest of town water supplies in system with the exception of Goondiwindi were very small relative to irrigation water use. Goondiwindi's diversions were larger than other towns' diversions combined.

2.6 Industrial and Mining Diversions

There are very little industrial and/or mining diversions in the BRS. Only Coolmunda subsystem had records for this water use purpose. Johnstone's Quarry located between Coolmunda Dam and Inglewood and has a small annual licensed volume of 10 ML. However, in some years, temporary transfer of irrigation licences increased total diversions to more than 250 ML..

2.7 Stock and Domestic Requirements

Licences with a total 1,205 ML HS entitlement have been provided in NSW for stock and domestic purposes in Glenlyon and Pindari sub-systems. These entitlements are generally distributed as small amounts of additional entitlement with the GS irrigation licences. Because of the low volumes involved relative to the GS usage, no information is available to distinguish this S&D usage from irrigation, and consequently,

2.8 Resource Assessment

The QLD and NSW Border Rivers are both managed under volumetric allocation schemes. The BRC assesses available resources the start of the water year, and at regular intervals or following significant inflow events. Resource assessment adopts a conservative approach, assuming drought conditions from the date of the assessment. The resource assessment process sums all water resources available at that time as, well as the minimum additional resources that can be expected to become available for the remainder of the water year. Allowance is then made for essential requirements, including high security entitlements, environmental and other reserves, as well as projected transmission, operational and evaporative losses. The remaining resources are then shared among GS entitlement holders, communicated as a percentage of the system licensed volume in an allocation announcement. The schematic of the process for water accounting in the two-state BRS is presented in Figure 2.12.

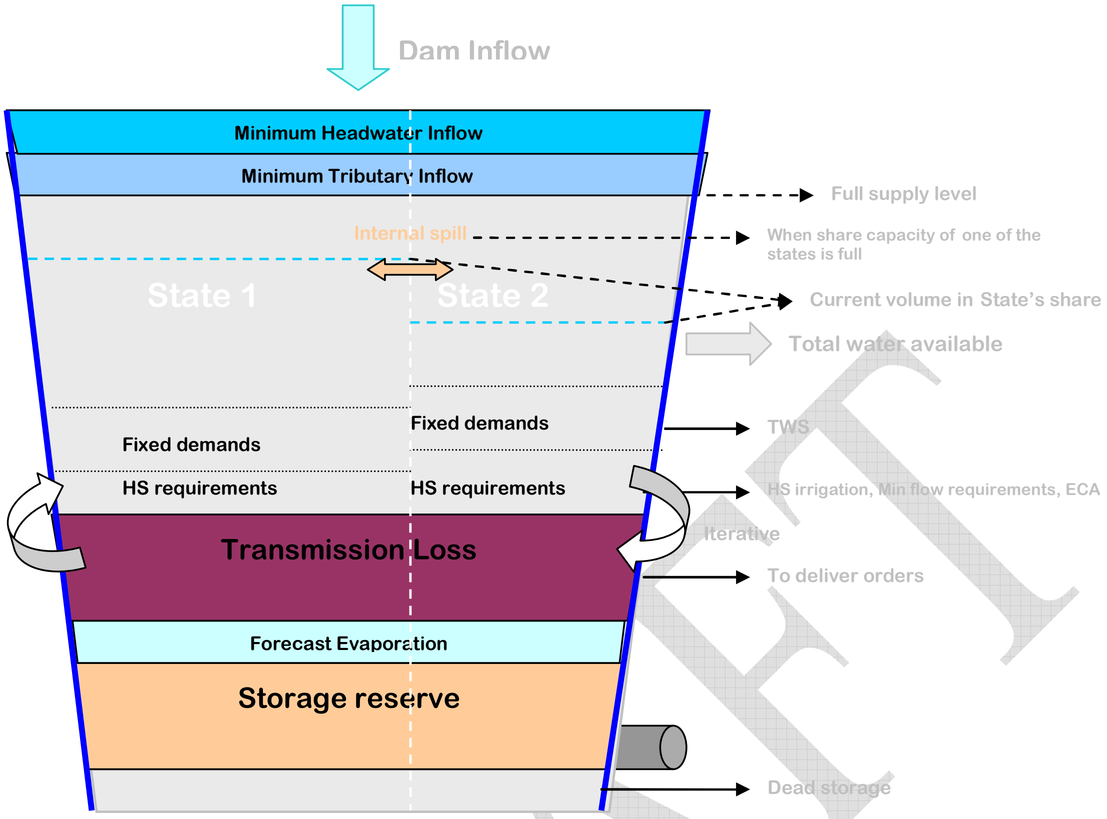


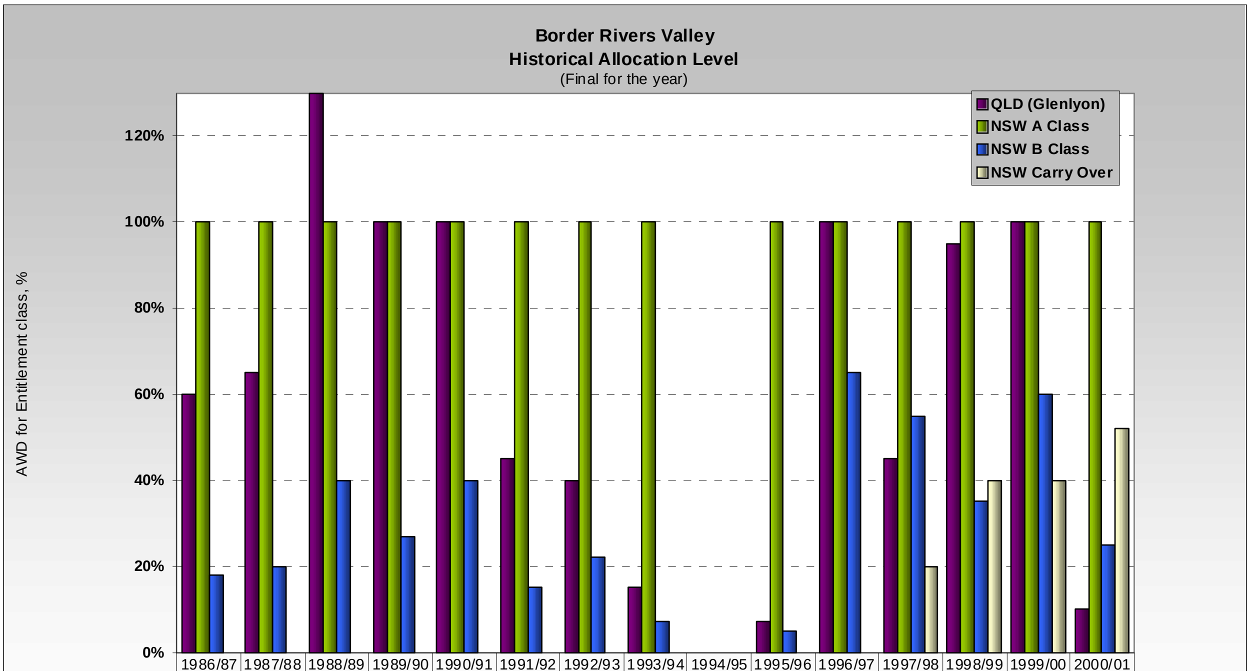
Figure 2.12 Water accounting process in the BR Glenlyon system.

The resource assessment arrangements changed over the period the model was calibrated. Prior to October 1991 the Coolmunda sub-system was managed as an independent sub-system of the overall BRS, servicing the MBIP scheme only. After October 1991 the Coolmunda subsystem was considered as an interdependent portion of the overall BRS, with 6.4 GL of licensed volume being sold to DRIP irrigators located downstream of the Coolmunda Dam. Similarly, prior to 1990 NSW Pindari and Glenlyon systems were operated as independent allocation systems. Only since 1990/91 irrigation season have these been operated as a single allocation system.

The single NSW allocation system is operated under a harmony rule, which aims to minimise physical spill volumes from either Dam. Prior to the enlargement of Pindari Dam in 1995, orders from NSW users with access to both Pindari and Glenlyon Dams were passed up from Boggabilla Weir, with a preference to empty Pindari Dam first given its then small volume. After Pindari Dam was enlarged, orders from NSW users located downstream of the Dumaresq-Macintyre Rivers junction are sent to either Pindari Dam or Glenlyon Dam in order to maximise the valley resources, i.e., minimise the spills and maximise the airspace to store further inflows.

The water year has also changed over the years. Prior to 1986/87 the water year commenced on 1st July. From 1987/88 to 2007/08 the water year commenced on 1st of October. Since 2008/09, the water year has again started on 1st July.

The announced allocations for the Glenlyon-Pindari subsystem from 1986/7 to 2000/01 are shown in Figure 2.13.



	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
QLD (Glenlyon)	60%	65%	130%	100%	100%	45%	40%	15%	0%	7%	100%	45%	95%	100%	10%
NSW A Class	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	100%
NSW B Class	18%	20%	40%	27%	40%	15%	22%	7%	0%	5%	65%	55%	35%	60%	25%
NSW Carry Over	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	40%	40%	52%

Water year

Figure 2.13: Allocation history in BRS Glenlyon and Pindari sub-systems. Note single system from 1990/91.

2.9 River and Storage Operation

The BRS is operated to ensure that maximum conservation of resource is achieved during regulated operation, and that EOS flows in excess of the target (Section 2.11.1) are kept to a minimum. EOS flows in excess of target usually occur during regulated operations because of either: high tributary inflows below the dams, irrigators not needing released water because of rainfall on crops, and, and errors in forecasting system requirements.

2.9.1 Tributary utilisation

The river operator forecasts what flow contributions they expect from downstream tributaries and adjusts the releases from the major storage to meet downstream orders. In practice a range of factors influence the river operator’s decision, including recent weather and the most recently observed inflows from the various downstream tributaries.

2.9.2 Operational Surpluses

Operational surpluses result from errors in forecasting demands for irrigation and transmission losses, both of which can be quite variable, as well as I over-ordering by irrigators. The variation in requirements results in higher releases from storage than orders based on crop requirements and average transmission losses would indicate.

The Glenlyon and Pindari sub systems operate under an order debiting system, where once water is ordered and the water released from a headwater storage, the irrigator’s account is debited whether or not the water is subsequently diverted. Prior to the late 1990s the water order debiting was informal, and the most common application of water order debiting was he denial of off-allocation access if ordered water is currently in transit for individual irrigators. In practice, irrigators would divert ordered water into their on-farm storages if they did not need to use the water immediately. IQQM representation and calibration of over-ordering is discussed further in Section 3.5.4.3

2.9.3 Storage releases for in-stream requirements

Minimum release requirements for Pindari Dam were introduced in the Environmental Impacts Statement (EIS) for its enlargement [DWR, 1991a]. A flow regime was identified to mitigate the impacts of the enlarged Pindari Dam on in-stream organisms. The release rules for Pindari Dam agreed to are based on dam inflows as follows:

- If the inflow is above 150 ML/d from July to March or 50 ML/d from April to June, then the release rate should be 150 ML/d or 50 ML/d respectively.
- If the inflow is below these thresholds, then the release rate should be equal to the inflow.
- If the inflow is below 10 ML/d at any time, then the release rate should be to 10 ML/d.

In addition to these release rules, there was also a requirement to initiate certain events for aquatic biota such as migration and spawning with a stimulus flow, where a flow of 400 ML/d will be released whenever 400 ML/d or greater releases have not occurred in the preceding three month period. This flow will be maintained for two days, with at least two days of both rising and falling stages.

There are no specific rules governing releases from either Coolmunda or Glenlyon storages.

2.10 Surplus Flow (Supplementary Access)

When flow is surplus to demands in either the Severn, Macintyre, or Dumaresq Rivers downstream of either Pindari Dam or Glenlyon Dam. Supplementary Access periods may be announced. Water diverted during these periods is not debited against allocated water. These surplus flows may include operational excess flows, tributary inflows and spills from Pindari Dam or Glenlyon Dam. Supplementary Diversion Periods are announced on a reach by reach basis, depending on the amount of surplus flow available and the access that each reach has previously received.

In 1992 NSW introduced the Northwest Flows Policy which reserves surplus flows in the Border Rivers, Namoi, Gwydir, Macquarie and Barwon-Darling systems to ensure flow targets for algal suppression and fish passage are met. This discussed further in Section 2.11.4.

2.11 River Flow Requirements

Historically the management rules governing these releases have been modified a number of times. For the purposes of the Border Rivers IQQM, we need to define these rules as they were for the scenarios to be simulated.

2.11.1 Minimum Flows

Although, there were no formal minimum or environmental flow requirements in the Pindari-Glenlyon sub-system, the system operators tried maintaining a minimum flow of 20 ML/d at Mungindi throughout 1980s and 1990s. A small thermal power station operated near the

Dumaresq-Macintyre Rivers junction until 1995. There was a requirement of minimum Pindari Dam releases of approximately 20 ML/d to meet demand for its cooling system.

A minimum *unregulated* flow requirement in the Barwon River at Mungindi of 100 ML/d should be maintained between the months of September and March inclusive.

2.11.2 Replenishments

The Boomi River is an effluent of the lower Macintyre River, flowing to the south and joining a regulated effluent of the Gwydir Valley before joining the Barwon River below Mungindi. Replenishment releases are made into the Boomi River annually to recognise the reduction in natural flows caused by river regulation. They are generally timed to coincide with stock and domestic requirements. Surplus flows, when available, are used to meet replenishment requirements. Flow is diverted into the Boomi River via a weir and an offtake regulator, which is capable of diverting up to approximately 170 ML/day during periods of regulated flows.

Prior to BR NSW becoming a single allocation system in 1990/91, replenishment flows were provided from Pindari Dam and these requirements constituted almost half of the total essential requirements of the Pindari subsystem. After Pindari Dam was enlarged a volume of 10 GL was set aside annually to provide replenishment flows should surplus flows not occur.

2.11.3 Environmental Releases

2.11.4 Other

NSW implemented the North-West Flows Policy [DWR, 1992] in 1992 to manage surplus flows in the Barwon-Darling river and its major tributaries. This policy is intended to ensure that sufficient surplus flow events are not diverted so as to meet identified fish passage and algal suppression flows at key points in the Barwon-Darling system. Irrigation access to surplus flows has been limited or denied around 3-4 times in the BRS since policy was implemented.

Chapter 3: Model Setup and Calibration

3.1 History

3.1.1 1998 BRS IQQM

The development of the BRS IQQM started in the late 1990s, and IQQMs were configured and calibrated for the three sub-systems which were then combined and validated into an integrated BRS IQQM.

The calibration period for each sub-system varied significantly, from just four years in the Pindari subsystem (1986 to 1990) to eight years in the Coolmunda subsystem (1987 to 1995). These periods were constrained by the availability of data, especially for diversions, crop areas and crop mixes.

This BRS IQQM was considered adequate at the time for some strategic purposes, including but not limited to policy development. However, a review identified a number of shortcomings in data and model capability to represent complex management processes DLWC, 1999b], and recommended several improvements including improving how certain irrigator groups and corresponding access infrastructure was represented; better represent unregulated irrigators, enable code to account for behaviour of A class entitlements in drought years, collect data on on-farm storages and floodplain harvesting, improve inflow and mainstream flow calibration

A voluntary survey was undertaken in 2003 in the NSW BRS to collect data on development since the late 1990s, and to better understand water harvesting practices. A copy of this survey is presented in Appendix G. The inclusion of this information along with the recommendations from the 1999 review meant that a comprehensive model recalibration was needed. The remainder of this chapter describes the recalibration process.

3.2 Model Configuration

The BRS was configured in IQQM based on the input data described in Section 2.1. The three independent sub-systems; Pindari, Glenlyon, and Coolmunda were independently configured sub-systems: and then combined to form the complete BRS IQQM. The number and types of nodes and links for each of the independent models were selected in accordance with the aims of the modelling detailed in Section 1.2 and are as follow:

- **Coolmunda subsystem** described in the Section 2.1.1. An IQQM containing 27 nodes and 7 links with hydrologic routing was configured. The node-link diagram representing this configuration is shown in Appendix C.
- **Pindari subsystem** described in the Section 2.1.2. An IQQM containing 38 nodes and 14 links with hydrologic routing was configured. The node-link representing this configuration is shown in Appendix C.
- **Glenlyon subsystem** described in the Section 2.1.3 An IQQM containing 163 nodes and 41 links with hydrologic routing was configured. The node-link diagram representing this configuration is shown in Appendix C.

The combined BRS IQQM contains 447 nodes and 89 links with hydrologic routing. Presentation of the combined BRS IQQM node-link diagram used in the BRS IQQM is shown in Appendix C.

3.3 Model calibration

3.3.1 Overview

Calibration of IQQM involves systematically adjusting parameters in the model until simulated results satisfactorily reproduce historical data over a selected period of time. An IQQM of a regulated river system is usually complex, with different processes simulated using different parameters that are compared to different types of data.

For this reason a calibration methodology was adopted to progressively eliminate unknowns. This involves six major steps, each of which holds a subset of input data at observed values, and calibrates a sub-set of parameters for that step (Table 3.1). At the end of the process, all calibrated parameters are brought together to assess how the overall model reproduces historical information. Where the integrated model shows unsatisfactory performance, one or more of the calibration steps may be revised.

Table 3.1. Steps in calibrating the BRS IQQM

Number and title	Fixed input data	Observed data for calibration	Parameters calibrated
1. Inflows	Rainfall and potential evapotranspiration	Gauged tributary flows	Sacramento model parameters.
2. Mainstream Flows	Gauged catchment inflows, storage releases, observed diversions.	Gauged mainstream flows.	Residual catchment inflows, routing parameters, transmission losses.
3. General Security Diversions	Observed flow, crop areas, crop mix, pump capacity, OFS capacity.	General Security diversions.	Irrigation efficiency, rainfall losses, soil moisture stores, OFS operation.
4. Supplementary Access Diversions		Supplementary access diversions and periods.	Supplementary access thresholds
5. Storage Behaviour		Storage levels	Tributary utilisation and over-order factors.
6. Planted Area		Observed crop areas	Planted area v available resources relationship

3.3.2 Calibration period

The period used to calibrate inflows and flow depends on available data, and varied by river reach over the period 1966-2000. The period to calibrate irrigation and storage operation was slightly more complex.

Analysis of the detailed data on irrigators' infrastructure available showed that IQQM could not be realistically calibrated before the 1985/86 irrigation season Changes in water year, system operation, 7-97, the enlargement of Pindari Dam, and changes in management rules meant that the model calibration period had to be divided further into six periods:

1. 1985/86;
2. 1986/87;

3. 1987/88 to 1989/90;
4. 1990/91 to 1994/95;
5. 1995/96 to 1996/97; and
6. 1997/98 to 1999/00.

As single year calibrations are impractical, the period from 1987/88 to 1999/00 was chosen for calibration. Diversions were calibrated from 1/10/1997 to 30/9/1997, storage behaviour from 1/10/1997-30/9/2000, and planted areas from 1/10/1997-30/9/2000.

3.3.3 Model configuration

Developed originally model of the entire BRS with addition of the Weir River IQQM developed by QDNR and modelling upgrades of the Callandoon Scheme has been used for purposes of the model calibration following 2003 NSW Irrigators Survey. To allow for significant development on yearly basis that was taking place over the entire calibration period Crop Time Series have been used. However, a number of changes in operation and management of the BR system including Pindari Enlargement, Maximum allowable allocation level, Irrigators Carry Over and a number of NSW allocation systems among others, forced us to perform model calibration in four different stages. The model has to be configured and run separately for each of the four individual from two to five years long calibration sub-periods.

Main differences in the model configuration for each calibration sub-periods are summarised in the Table 3.2. Fully developed NSW system is run under Annual Accounting with Order Debiting Scheme for all the calibration sub-periods and, therefore, not mentioned in this table.

Table 3.2 Model configuration summary

Calibration period	Number of allocation systems		Pindari size	QLD Maximum allocation (%)	Irrigators carryover	
	NSW	QLD			%	Reduction (exp
1987-1990	2	2	Small	130	0	n/a
1990-1995	1	2	Small	130	0	n/a
1995-1997	1	2	Large	100	20	Yes (Feb)
1997-2000	1	2	Large	100	100	No

3.3.4 Climatic data for model

3.3.4.1 Rainfall

Rainfall data is used in IQQM to drive the soil moisture accounting in the irrigation module, for computing the contribution of rain falling onto the surface of reservoirs and river reaches. Rainfall data is also used for generating and extending historical tributary inflows using Sacramento rainfall-runoff modelling.

Of the available rainfall stations in the valley, the following criteria were used to select an appropriate sub-set for use in the Border Rivers IQQM:

- adequate representation of spatial variability of the rainfall;
- availability of long term records to cover not just the intended calibration period, but also the intended long term simulation period;
- continuity and quality of data; and

Based on these criteria, twelve rainfall stations were used to represent the spatial rainfall distribution to drive the crop water requirements in different geographic zones in the BR IQQM:

- **<u>Coolmunda subsystem</u>** - one rainfall zone was used for all irrigation modelling;
- **<u>Pindari subsystem</u>** - data from nine sites with long term records were used to create **two** gap-filled time series of daily rainfalls representing two zones. The two zones represent Pindari Dam and the irrigation areas between the dam and the sub-system outlet.
- **<u>Glenlyon subsystem</u>** - data from sixty rainfall gauges with long term records were used to derive twenty-four gap-filled time series of daily rainfalls representing fifteen zones. Ten of these zones represented gauged tributary catchments requiring rainfall-runoff model calibration; four zones were for input to irrigation simulation in IQQM, from the Dam to Mungindi; and one zone was the Glenlyon storage. Daily evaporation data was generated for the fifteen climatic zones using the six evaporation sites available and the gap-filled rainfall records.

3.3.4.2 Evaporation

Evaporation data is used in IQQM to estimate crop evapotranspiration, for computing evaporation losses from storages, and for computing evaporation losses from river reaches. Evaporation data is also used for generating and extending historical tributary inflows using Sacramento rainfall-runoff modelling.

Of the available evaporation stations in the valley, the following criteria were used to select an appropriate sub-set for use in the BRS IQQM:

- adequate representation of spatial variability of the evaporation;
- availability of long term records to cover not just the intended calibration period, but also as much of the intended long term modelling period as possible.
- continuity and quality of data; and
- availability of long term rainfall data at a site nearby to generate long term evaporation data.

Based on these criteria, seven climate stations were used to represent the spatial evaporation distribution to drive the crop water requirements in the different geographic zones in the BRS IQQM.

Three additional evaporation sites were used to represent the evaporation from each of the three headwater storages. These sites are listed in Table A.4, Table A.5, and Table A.6. Additional sites were also selected for use in rainfall-runoff modelling.

3.4 Stream-flow

Mainstream flows are calibrated along a reach between two gauges by including all known water balance measurements, and then methodically accounting for components and processes with unknown values.

All known components that affect the reach water balance are forced to observed data. This includes inflows at the upstream end of reach and gauged tributary inflows, and diversions. The unknowns are then systematically estimated, including ungauged inflows, adjusting routing parameters, removing mass balance errors, and estimating transmission losses.

In response to the recommendations arising from the review of the original BRS IQQM, the Sacramento rainfall runoff models of 24 gauged tributary inflows were either recalibrated newly developed. Criteria used to select gauging stations to estimate tributary inflows include:

- Significance of the flow contribution from that catchment;
- Maximise total coverage of the gauged inflows from the catchment.
- Good quality records with a low percentage of missing data during the intended calibration period and long term simulation period.
- Availability of nearby rainfall and evaporation stations to set-up rainfall-runoff models for gap-filling and extending the data.

A complete list of the gauged tributaries with Sacramento models is presented in Appendix A Ungauged catchment contributions were estimated during flow calibration using in-house methodology [DLWC,1998[h]].

To better distinguish main stream transmission losses from tributary transmission losses, seven gauged tributary inflows previously modelled entering the main-stream directly were moved to a tributary with a loss node upstream of the junction with the main-stream. A loss rate of 0.2% per kilometre was adopted for these tributaries. This then required recalibrating ungauged inflows and losses on the main-stream. Location of these gauged inflow points and their approximate distance to the junction are presented in the Table 3.3.

Table 3.3 Gauged tributary locations

Tributary Inflow		Crossing Stream Junction	
Gauge	**Name**	**Name**	**Distance (km)**
416310	Severn River at Farnbro	Tenterfield Creek	7
416003	Tenterfield at Clifton	Severn River	45
n/a	Severn+Tanterfield Confluence	Dumaresq River	10
416032	Mole River at Donaldson	Dumaresq River	13
416021	Frazers Creek at Ashford	Severn River	12
416010	Macintyre River at Wallangra	Severn River	25
416020	Ottleys Creek at Coolatai	Macintyre River	115

The main-stream gauging stations are used to: determine flow routing parameters for each river reach; estimate ungauged catchment inflows while minimising mass balance errors; and derive transmission losses. Criteria used to select gauging stations to calibrate main-stream flows included:

- Limit excessive length of river reaches;
- Upstream and downstream of key features such as tributary inflows and effluent outflows;
- Good quality records with low percentage of missing data for the intended calibration period.

All known components that will affect the water balance along the reach are forced to observed data. This includes system inflows (flow at upstream end of reach as well as gauged tributary inflows) are used as inputs to the model. Other demands (including town water supplies) are diverted from river reaches using patterns. The remaining unknowns (river routing, ungauged catchment inflows and transmission losses) are systematically adjusted to achieve the best overall match to each main-stream gauge.

3.4.1.1 Coolmunda sub-system

The gauging stations used to calibrate inflows and main-stream flows in the Coolmunda sub-system are listed in Table A.8.

Inflows in the Coolmunda sub-system were represented using three gauged tributary inflows (two to the storage and one downstream tributary), along with three ungauged catchment inflows. Irrigators are represented as two groups; one u/s of Inglewood, and the other d/s of Inglewood, represented by a node just u/s of Booba Sands. The Inglewood TWS was represented separately. For individual sub-system modelling a grouping of irrigators at the end of the system, representing the licensed volume purchased by DRIP irrigators, was included.

After reviewing the available main-stream gauging stations against the criteria listed in Section 3.4, two main–stream calibration reaches were selected; Coolmunda Dam to Inglewood, and Inglewood to Booba Sands.

The flow records for the three gauged inflow tributaries; Bracker Creek @ Terraine; Canning Creek @ Woodspring; and Macintyre Brook @ Barangarook had periods of missing data. These were in-filled using a rainfall-runoff model, calibrated using local rainfall and evaporation for each tributary. For the Bracker Creek and Macintyre Brook tributaries this involved only a small number of days, but for Canning Creek it involved estimating flows from the time the Woodspring gauge had been removed in 1980.

The ungauged catchments from Coolmunda Dam to the sub-system outlet comprise 29% of the total catchment area. This area was separated into three major ungauged catchments: u/s of the Inglewood flow gauge; u/s of the Booba Sands flow gauge and u/s of the confluence of the Macintyre Brook with the Dumaresq River respectively. Time series of inflows were estimated for these areas by adopting the flow records from the nearest gauged tributary of similar size and geography, and multiplied by a factor to account for area and climatic differences.

3.4.1.2 Pindari sub-system

The gauging stations used to calibrate inflows and main-stream flows in the Pindari sub-system are listed in (Table A.9). Inflows were represented using the Pindari Dam inflow, three gauged tributary inflows as follows: Frazers Creek @ Ashford; Macintyre River @ Wallangra; and Ottleys Creek @Coolatai, and five ungauged catchment inflows. Based on the flow data suitability criteria described in Section 3.4, five flow calibration reaches were selected.

Periods of missing data in the flow records were filled using a rainfall-runoff model calibrated for each tributary using local rainfall and evaporation data. Frazers Creek required the most in-filling as it ceased operating in February 1989.

The ungauged catchments from Pindari Dam to the sub-system outlet comprised 36% of the total catchment area. This area was separated into five ungauged catchments u/s of the following gauges: Pindari Dam inflow, Ashford; Old Dam Site gauge; Holdfast, and Boonal. Time series of inflows were estimated for these areas by adopting the flow records from the nearest gauged tributary of similar size and geography, factored for climate and area. These were refined in conjunction with estimating transmission loss relationship for the reach.

3.4.1.3 Glenlyon sub-system

The gauging stations used to calibrated inflows and main-stream flows in the Glenlyon sub-system are listed in (Table A.10)

Inflows were represented gauged inflows from the Coolmunda and Pindari sub-systems (at Booba Sands and Holdfast respectively); Glenlyon Dam inflows, and ten gauged tributary inflows. In addition, inflows from twelve ungauged catchments were estimated as part of the main-stream flow calibration.

Periods of missing data from the gauges at the outlets of the Coolmunda and Pindari sub-systems were infilled using the respective sub-system IQQM results. Periods of missing data in ten tributary flow records were filled using a rainfall-runoff model calibrated for each tributary using local rainfall and evaporation data. Two gauges were used to represent effluent offtakes, at Callandoon effluent into QLD and on Boomi River into NSW;

Ten mainstream reaches were calibrated, and the result from each u/s reach was used to infill periods of missing data for the beginning of the d/s reach. Less reliance was placed on gauges with poor high flow rating tables (all gauges d/s of Goondiwindi), or with short or backwater affected records, such as Boggabilla, Terrewah, Boomi, and Kanowna.

The ungauged catchment area was separated into six ungauged catchment areas located u/s of mainstream gauges at Roseneath, Bonshaw, Mauro, Boggabilla, Kanowna, and Mungindi. To accommodate later plans to use the model for state sharing studies, several of these residual areas were split into their NSW and QLD components, with separate individual time series, those affected being u/s of Roseneath, Bonshaw, Mauro, and Boggabilla.

Time series of flows were estimated for these areas by adopting the flow records from the nearest gauged tributary of similar size and geography, factored to account for area and climate. These were refined in conjunction with estimating transmission loss relationship for the reach.

3.5 Irrigation

3.5.1 Overview

Changes introduced to the model following the 2003 Irrigators' Survey were related to farm management practices, and would directly affect the diversion calibration results achieved for original BRS IQQM calibration [DLWC, 1999a-c].

The objective of the diversion re-calibration was to firstly validate previously derived parameters using updated modelling of irrigator farm management aspects including OFS operation and harvesting water from alternative sources such as flood plain and rainfall-runoff.

Records of total regulated and supplementary access diversions, crop areas and crop mixes were generally available for individual irrigators throughout the calibration period. The information was aggregated at a reach level such that it represented a broad cross-section of geographic location and usage behaviour, thus producing 27 different irrigator groups that were used to represent the irrigators in the regulated part of the BRS, with NSW accounting for 13 of these groups. Three of the QLD groups including Yambocully irrigators (6b), Callandoon irrigators (6c) and Weir River irrigators with access to regulated flow (10) are modelled based on individual properties using six, seven and nine irrigation nodes respectively. In addition, eleven unregulated irrigator groups in the Weir River catchment are represented in the BR IQQM.

Adopted crop factors used in modelling crop demand were as per guidelines published by the United Nations Food and Agriculture Organisation [FAO, 1999]. Some changes were then made to these crop factors, within allowable limits (±10%), to improve the calibration. The crop factors used for different crops and irrigation efficiency factors are presented in Table B.3 and Table B.4 respectively.

Time series of entitlements, crop types and areas, OFSs, pump capacity were used, and modelled diversions compared with recorded Regulated and Supplementary Access diversions. Previously calibrated parameters were revised where appropriate.

The parameters related to on-farm management practices such as OFS airspace and reserves, 2nd lift capacity used in FPH modelling and FPH thresholds were set up as constant over time based on information provided through the irrigator survey, and then adjusted slightly for each irrigator group during the diversion re-calibration.

3.5.2 Limitations and exclusions

A number of processes were not modelled because they were either: (i) out of scope; (ii) there was insufficient data to model; or (iii) they were not significant in the context of the model purpose. Some processes were modelled in a simplified form, as outlined below:

- Unregulated water users diverting water from unregulated streams other than in the Weir River were not included as crop area or diversion data was not available. The effects of this usage are to some extent captured in observed inflows. However the lack of explicit data means that this cannot be adjusted.
- The transfer market cannot be modelled explicitly in IQQM. IQQM assumes water shares at an irrigation node are fully activated, with no transfer of water shares between nodes. A regular transfer of water between reaches would be modelled as a permanent transfer of licence volume in the model.
- Town water supplies were modelled using a monthly fixed pattern of demand based on the advice of the relevant Shire Councils.
- Licensed volumes for stock and domestic purposes, industrial use and high security irrigation (two HS irrigation licences totalling up around 350 ML) were included with the nearest GS irrigator entitlement.
- Groundwater use was not represented because of lack of data and the relatively small impact on river flows.
- The stimulus flow environmental release rule for Pindari storage (Section 2.9.3) is not currently represented in the model.
- Rainfall and evaporation onto the river surface were not modelled explicitly and have, therefore, been accounted for as in stream losses.

To allow for the continuity in the model simulation, volumes of water in storages and carry-over values at the end of the preceding simulation period were manually adjusted for the beginning of the subsequent simulation period.

3.5.3 Diversion Calibration

IQQM uses a soil moisture accounting model and generated crop evapotranspiration to generate irrigation demands. The model takes into account crop areas and different crop types, crop factors, rainfall, evaporation, irrigation efficiency and active licence factors. The objective of this step is to calibrate the crop demand module over the calibration period. The parameters calibrated during flow calibration (ungauged inflows, routing, and losses) are used, crop areas and types are forced to observed data and the crop demand module is calibrated to replicate the observed demands based on the observed areas. The IQQM uses empirically estimated crop factors [FAO, 1999], with unknowns including the effective size of the soil moisture store and rainfall interception loss for each irrigator group, and the crop watering efficiency for each crop type. Values for these parameters were adjusted until simulated crop water demands best matched the observed data [DLWC, 1998[d]].

The on-farm storage operation is also modelled at this step. This includes estimating on-farm storage reserves, and rainfall and floodplain harvesting configuration. Values for all of these parameters are adjusted until the simulated crop water demands best match the observed data (Appendix E.2). This is a complex process with all of the parameters interacting with each other and a number of iterations were required.

3.5.3.1 Regulated diversions calibration

The regulated river diversions are affected by on-farm water management. For example, increased rainfall and floodplain harvesting reduces the need for regulated diversions. The inclusion of irrigator water harvesting from floodplains and rainfall runoff meant that regulated diversions had to be re-calibrated iteratively with re-calibrating on-farm management processes and supplementary access diversions.

3.5.3.2 Supplementary access diversion calibration

Surplus flow announcements are usually made on an event basis. Discussion with the river operator revealed that supplementary water volume availability were declared based on demand from irrigators (faxes, phone calls etc), sharing opportunities between irrigators, channel delivery constraints, and replenishment or end of system flow requirements. In the NSW BRS the available surplus flow is shared based on the irrigator share or regulated entitlement, while in the QLD BRS irrigators' access to supplementary water is shared based on pump capacity. It should be noted that irrigators in the Coolmunda system have no SW access. Historically, there was a large degree of variation in the triggers used to declare access to surplus flows from event to event.

IQQM models surplus flow within reaches, with surplus flow thresholds above which Supplementary water is available for diversions. Table 3-4 shows supplementary diversions reaches used in BRS IQQM. Supplementary Access diversions are affected by on-farm water management. For example, increased floodplain and rainfall runoff harvesting affects the available capacity in the OFS. Therefore, the supplementary water diversions are calibrated iteratively with the regulated diversion calibration and on-farm management configuration. A set of thresholds were developed by calibrating to match as best as possible the recorded days of supplementary water volumes and the supplementary water volumes diverted ic for each calibration sub-period.

Table 3-4 Supplementary Diversions Reaches used in BR IQQM

Reach description	Irrigator Groups
Glenlyon Subsystem	
Glenlyon Dam *to* Bonshaw Weir	QL1, NS1
Bonshaw Weir *to* Mauro Gauge	NS2, QL2
Mauro Gauge *to* Dumaresq-Macintyre Brook Junction	NS3, QL3
Dumaresq-Macintyre Brook Junction *to* Dumaresq-Macintyre River Junction	QL5, NS4
Dumaresq-Macintyre River Junction *to* Boggabilla Weir	QL6a, NS7a
Boggabilla Weir *to* Callandoon Creek offtake	NS7b, QL6a,b,c
Callandoon Creek offtake *to* Terrawah Gauge	NS8, QL7
Terrawah Gauge *to* Boomi Weir	QL8, NS9
Boomi Weir *to* Kanowna Gauge	QL9, NS10
Kanowna Gauge *to* Weir River Junction	QL10, NS11
Weir River Junction *to* Mungindi Gauge	QL11, NS12
Pindari Subsystem	
Pindari Dam *to* Severn-Macintyre R. Junction	NS5
Severn-Macintyre R. Junction *to* Dumaresq-Macintyre R. Junction	NS6

Although, we have attempted to maintain supplementary water diversions thresholds consistent across all the calibration sub-periods, it has been proven to be a very difficult task as historical SD announcements also lack some consistency. However, to achieve good quality diversion calibration (Section 4.2) we managed to keep these variations in SF thresholds to a minimum. This also assisted us in selecting the appropriate single set of SF thresholds for use in long-term simulations. The supplementary water thresholds derived during the calibration and adopted for Cap development conditions are presented in Table F.5.

3.5.3.3 On-farm management calibration

The evidence from the Irrigators' Survey was that floodplain and rainfall-runoff harvesting in the BRS is significant, however the, calibration process was restricted by a lack of data on actual diversions The calibration was based on information provided by the irrigators and a water balance within each reach.

- OFS storage reserve –effectively reduces the available capacity in the OFS, thus impacting on supplementary water diversions and rainfall and floodplain harvesting volumes. Wherever possible we tried to represent the OFS reserves to match information from the irrigators' survey. These were adjusted iteratively with other on-farm management processes to best match historical regulated and supplementary access diversions.
- OFS airspace –was required in the model because it effectively reduces the amount of available capacity in the on-farm storage during supplementary water and floodplain

harvesting events, thus impacting on supplementary water extractions and floodplain harvesting volumes. Wherever possible we tried to represent the OFS airspace to match the information gained from the user-surveys. These were adjusted iteratively with the other on-farm management parameters to achieve an optimum match with the historical ONA and SW extractions.

- Floodplain harvesting (FPH) – This process is significant in the BRS and therefore we needed to represent it to achieve satisfactory regulated and supplementary diversion calibration. In IQQM, this process is driven by a flow trigger threshold and then a configuration of second lift pumps to pump the water into the OFS. No good quality data on floodplain harvesting volumes exists, but wherever possible we configured the floodplain harvesting parameters such that the simulated volumes matched the information gained from the user-surveys and from a mass balance of river flows. FPH configuration was unchanged over calibration period, and ultimately was adopted for the Cap scenario, was used in the model to achieve the best possible match with historical behaviour.
- Rainfall harvesting (RFH) –this process is affected by the daily rainfall volume, rainfall interception loss, rainfall harvesting area, rainfall infiltration rate and antecedent soil moisture. Some of these parameters are constant such as allowable soil moisture depletion, fallow upper soil moisture depth, and the infiltration rate from the upper to lower fallow store. Other parameters change dynamically as a function of development and behaviour, such as pump capacity, OFS capacity and rainfall harvesting areas. No good quality data on rainfall harvesting volumes exists, but wherever possible we configured the rainfall harvesting parameters such that the simulated volumes matched the information gained from the irrigators' survey and from a mass balance of river flows. However, this process was not configured in the BRS IQQM for reasons explained in Section 5.4.2.4.

3.5.4 Storage Behaviour Calibration

The objective of this stage is to calibrate the river operational parameters which govern how much water is released from storages to meet irrigation demands over the calibration period. Storage behaviour calibration provides the best numerical check of the model's overall performance because all components of the system contribute to head water storage behaviour. In addition, any differences have a cumulative impact on the storage volume. These differences will, therefore, be quite apparent when comparing modelled and historical storage behaviour.

In this stage of model calibration, the calibrated parameters from flow and demand calibration are used, with crop types and areas and supplementary water diversions, as well as Resource Assessment configuration are still forced to observed data. However, in the Border Rivers supplementary water diversions were calibrated at the same time with on-allocation diversions and are simulated using a single set of supplementary water diversions thresholds specific to each calibration sub-period. The following sections detail the different processes required for storage calibration.

3.5.4.1 Inflow to dams

To minimise potential sources of errors, the historical dam inflows are usually used as input to all three headwater dams of the BRS. These are derived using a back-calculation procedure [DLWC, 1998] based on information obtained from the dam's OIC sheets The back-calculation technique is based on a water balance of dam inputs and outputs (Equation 3.1).

$$\textbf{Inflow} = \Delta\textbf{Storage} + \textbf{Outflows} + \textbf{Net(Evap} - \textbf{Rainfall)} \quad \{Eq.3.1\}$$

After a review of the available rainfall and evaporation stations and consideration of the criteria outlined in Section 3.3.4 the rainfall and evaporation stations listed Appendix A were selected to provide climatic data not contained in the OIC sheets.

The back-calculated inflows were only used directly in the storage behaviour calibration for Coolmunda Dam. The back-calculated inflows were used to calibrate upstream tributary models for Pindari and Glenlyon Dams, and the simulated flows were used for storage behaviour calibration.

3.5.4.2 Tributary utilisation

Inflow from tributaries reduces the amount of water that needs to be released to meet demands. Forecast of flow from a tributary on a day is modelled as a fraction of the known flow on the current day. Tributary utilisation is quoted as the river operator's adopted tributary recession factor. The number of days in the future for which the prediction is required is equal to the travel time from the storage.

The tributary recession factors typically reduce progressively down the main river because of the increasing uncertainty with predicting further into the future. In reality the factors vary with recent climatic conditions.

The factors which produced the best recalibration of storage behaviour over the period from 1987 to 2000, and used for scenario modelling are presented in Table B.6. These factors are generally consistent with advice received from river operators

3.5.4.3 Operational surplus

Operational surpluses are modelled by applying a fixed over-order factor to the orders placed by each of the irrigation groups. These operational surpluses allows for attenuation and variable losses. The over-order factors that produce the best calibration of storage behaviour over the 1987 to 2000 recalibration period are presented in Table B.7. They are very different from those obtained during the original model calibration, varying from 0% for irrigator groups upstream Dumaresq-Macintyre River junction to just 4% towards the EOS. These factors are consistent with advice from the river operator regarding typical operational surpluses. They are also consistent with irrigator group distance from the headwater dams, irrespective of the irrigators' state

3.5.5 Planted Area calibration

The main objective of this stage of the model calibration is to satisfactorily replicate observed planted areas based on available resources. The basis of this planting decision is described in Appendix D.

The area planted usually changes as a result of a number of factors including climate, development in the valley and market conditions. Therefore matching the historical planted area is the most difficult process in the model calibration. The area calibration process included consultation with irrigator representatives to understand their decision making processes. The actual calibration to historical data allows for:

- antecedent conditions, which affect both the amount of planted area and the timing;
- changed behaviour due to different water management rules;
- changed attitudes to boom-bust vs. reliable water supply behaviour;
- growth in the maximum area over the calibration period;
- access to other water sources including rainfall and floodplain harvesting;

The effects of external factors such as commodity prices and financial status are not modelled explicitly in IQQM. These may be linked to climatic conditions so indirectly they would be taken into account to a certain degree.

The approach used to achieve Area calibration for BR IQQM involved nominating representative values for expected rainfall and deriving farmers' risk function for each of the Irrigator group using iterative model runs until the best fit to recorded area data is achieved. Figure D.1 and the description in Appendix D explains the process used to calibrate of BR IQQM for defining farmers risk functions, as being definition of dry (lower), average, and wet (upper) straight line functions relating announced allocation at the start of the water year, versus expected water availability (i.e. anticipated allocation level at the end of the coming season).

It should be noted, however, that the planting decision derived during the calibration process is not always appropriate for use in Cap or other specific scenario simulations. For the BR IQQM, the risk behaviour prior to 1995 is not representative of NSW irrigators' risk behaviour of the Pindari post-enlargement period. Consequently, further discussion of the planting decision process in BR IQQM Cap scenario is presented in Section 5.4.3.4.

The farmers' risk function is calibrated by comparing the modelled and historical planted areas. We used post Pindari enlargement period of the chosen re-calibration period, i.e., 1995/96 – 1999/00 with two sub-periods, i.e. 1995/96-1996/97 and 1997/98-1999/00 based on differences in operational and management rules with the intention of deriving a single set of risk functions that would achieve good match to the observed time series of area planted for the entire 5-year long period. That set is thought to be representative of irrigator risk behaviour in the post-Pindari enlargement environment.

Expected rainfall refers to the portion of the annual rainfall conservatively expected to fall onto the crops in the growing season, by the irrigators. It is assumed as a constant for all the years of simulation. It is specified at each irrigation node, and determined based on local rainfall statistics for the growing season.

Expected rainfall derived during the original area calibration was estimated based on nearby rainfall stations. The same expected rainfall was used, and is presented in Table F.3. However risk functions derived originally had to be revised.

The preliminary risk functions for each irrigator group were derived through analysis of all relevant historical data including area planted, irrigator entitlement and usage, available water determination, OFS capacity, and rainfall. Some assumptions were necessary where data was not available, for example estimates of available water in the OFS at the start of the water year.

By varying the initial estimated parameters, including intercept and slope of the risk function, and comparing each simulation result with recorded data until the best possible match between recorded and simulated sequences of area planted was achieved, final values for all the parameters involved were calibrated for all irrigator groups.

When deriving risk function for 1995 to 2000 period, we found that, generally, to achieve good calibration results originally estimated risk had to be revised down for dry and average antecedent climatic conditions, while the risk for wet conditions had to be increased. This finding supports the irrigators' reported behavioural changes in the 2003 Irrigators' Survey. There is some variation from irrigator group to irrigator group with risk increasing with the distance from the HW Dams. It was also noticed, that with an exemption of a few irrigator groups, QLD irrigators display a slightly higher risk taking behaviour than their NSW counterparts within the same river reaches.

Both the adopted expected rainfall and new set of the individual irrigation node risk functions that also is used in the BR Cap scenario are presented in Table F.3.

3.5.5.1 Background information

The following background information is relevant for the Border Rivers IQQM area re-calibration within a scope of 2003 model upgrade:

1. To derive appropriate parameters for the risk functions, we used data from 1984/85 to 2000/01;
2. Climatic variability is reasonably well represented over this period, with a number of wet and dry years, with varying resource availability. We would expect the historical planted areas to be reasonably indicative of the farmers' behaviour over a range of climatic situations;
3. There is a general trend of increasing planted areas up to the late1990s (Table 2.5), even when variations in climatic conditions are taken into consideration;
4. Before the early-1990s there appeared to be a typical boom-bust style of behaviour in irrigator decisions, characterised by high risk in planting decisions in wet years and low planted areas in dry years;
5. A severe drought from 1992-1995 tended to mask the maximum area that could be planted, and resulted in planted areas with very high levels of risk. Irrigation was abandoned mid-season for some significant areas of cotton during this period due to lack of water, and it is probable that the level of risk taken by some during this period was unsustainable in the longer term.
6. Post mid-1990s was marked by the enlargement of Pindari Dam, completed in mid 1994. Due to the ongoing drought conditions, additional resources did not become effective until the dam filled sufficiently to allow higher allocations than were previously possible until late 1995. The effects of the enlarged storage can be seen from the 1996/97 season onwards. Despite wet climatic conditions in 1995/96-2000/01 and area development limitations, the boom-bust behaviour tended to be replaced with more consistent planting behaviour, characterised by generally higher target application rates (5 ML/ha to 7 ML/ha, i.e. lower risk) when deciding on areas to be planted in wetter years and lower target application rates (i.e. higher risk) in drier years. This results in a smaller variation between the planted areas from year to year.
7. For these reasons, the risk function varies over time and, therefore, we needed to examine years that are representative of the scenario being configured. The risk taking behaviour derived during the original BR IQQM calibration was thought to be

representative of the period of Pindari Dam, pre-enlargement. To derive appropriate irrigator risk behaviour for the scenarios featuring the enlarged Pindari Dam, we chose to focus on the period 1995/96 to 1999/00. Following methodology described above, a volumetric risk equation was derived for each defined irrigator group within IQQM over the period from 1995/96 to 1999/00.

8. Crops are planted based on the water that is available at the planting date, which includes the account balance, irrigator carry-over, water stored in OFS, and expected water availability, which includes rainfall in growing season and additional entitlement after the planting date. Inherent in the adopted risk behaviour is allowance for not only increases in AWD, but also access to water from other sources, such as supplementary access, rainfall harvesting, and floodplain harvesting.
9. The planted area is then calculated based on crop water requirements for a specific crop mix and limited to both minimum historical area planted and maximum area developed for irrigation.
10. Water is allocated for both summer and winter crops with equal share required to plant total (summer and winter) crop area. It means, that the planting decision for both summer and winter crops is made on the same date in accordance with the crop mix specified;
11. There was very little information available to estimate a winter planting decision.

Consideration of these specific issues during the area re-calibration process resulted in appropriate risk functions for each irrigation node for the 1995/96 to 1999/00 calibration period and together with expected rainfall derived during the original BR IQQM calibration these functions were adopted for the Cap scenario for the Border Rivers as discussed further in Chapter 5:

3.5.6 Resource Assessment Configuration

Resource assessment involves assessing how to distribute the available water resources to all water users. Current and future needs of high security users are provided for initially and then remaining resources are allocated to general security users. The operation of the system and any environmental needs are taken into consideration during this process. Up until the 2000/01 water year the BRS was operated on an annual accounting system. From 2001/02 onwards the resource assessment of the BRS has been undertaken on a continuous accounting basis. The water year also changed from 1/10 to 30/9, 1/730/6 in 2008/09. 2007/08 was a transitional water year of 15 months.

The following factors are generally taken into consideration in IQQM resource assessment:

- current volume available in the dam; and any downstream weirs;
- minimum expected inflow to the dam;
- recession on current inflows to the dam;
- minimum expected useful tributary inflow downstream of the dam;
- expected evaporation and transmission losses over the remainder of the irrigation season;
- all of the essential requirements placed on the dam.

It should be noted, that in Border Rivers being a two-state system the transmission and operational losses as well as inflows are split according to each state share (57:43, NSW being a larger share holder) along the common streams, i.e., Glenlyon system.

In consultation with the regional operators, the above information was analysed to identify what operating rules and decision processes had been used in the past. Rules were configured in IQQM that were relevant to the calibration period and/or proposed scenario runs as described in Section 3.3.

Chapter 4: Calibration Results

4.1 Flow calibration

Flow calibration results are presented at seven gauging station sites along the main-stream, from downstream of the major headwater storages, to the end of system at Mungindi. These stations are summarised in Table 4.1.

Table 4.1 Key gauging stations for reporting calibration results

Gauging station	Comments
Dumaresq R. @ Roseneath (416011)	the point of maximum flow and a good quality continuous long term record d/s Glenlyon Dam
Macintyre Bk. @ Booba Sands (418002)	representative inflow from Coolmunda subsystem
Macintyre R. @ Holdfast (416012)	the point of maximum flow and a good quality continuous long term record d/s Pindari Dam
Macintyre R. @ Goondiwindi (416201A)	representative gauge d/s main tributaries
Macintyre R. @ Kanowna (416048)	representative gauge d/s Boomi River offtake
Weir R. @ Talwood (416202A)	representative inflow from Weir River subsystem
Barwon R @ Mungindi (416001)	EOS and good quality continuous long term record gauge

The BRS IQQM for each calibration period was configured with the prevailing operation and management rules, and with time series of annual data forcing a range of observed data and farm management behaviour including area planted, crop mix and variable OFS reserves and Airspace. Resource Assessment was also forced to the observed AWD over the 1987/88 to 1996/97 period. Flow re-calibration results over the 1997/98 to 1999/00 period presented here were obtained using fully simulated resource assessment over the period. More details on model configuration these results were based upon are given in Section 3.3.

It should be noted that the results presented are the overall flow re-calibration results, performed after the diversions re-calibration stage. Time series of simulated flow for all calibration sub-periods were joined to better represent the overall modelled replication of the gauged data.

Revised flow calibration results are presented graphically as daily time series and flow duration curves in Figure 4.1 to Figure 4.9. Objective measures of the quality of model fit achieved are presented in Table 4-2 to Figure 4.5, with reference to Quality Assessment (QA) guidelines described in Appendix E.

Table 4-2 Flow calibration assessment Dumaresq R. @ Roseneath (1987-2000)

Parameter	Flow match by range (exceedance percentile)				Time Series Match	
	All (0-100)	Low (80-100)	Medium (20-80)	High (0-20)	Daily ($1-r^2$)	CMAAD
Flow range (ML/d)	0-44,517	0-50	51-1,122	1,122 44,517		
Total observed flow (GL)	4,200	1,746	1,044	3,140		
Bias in simulated (%)	+5.5	-10.7	-1.8	+8.1	5.0	-
Quality rating	High	Moderate	V. High	High	V.High	-

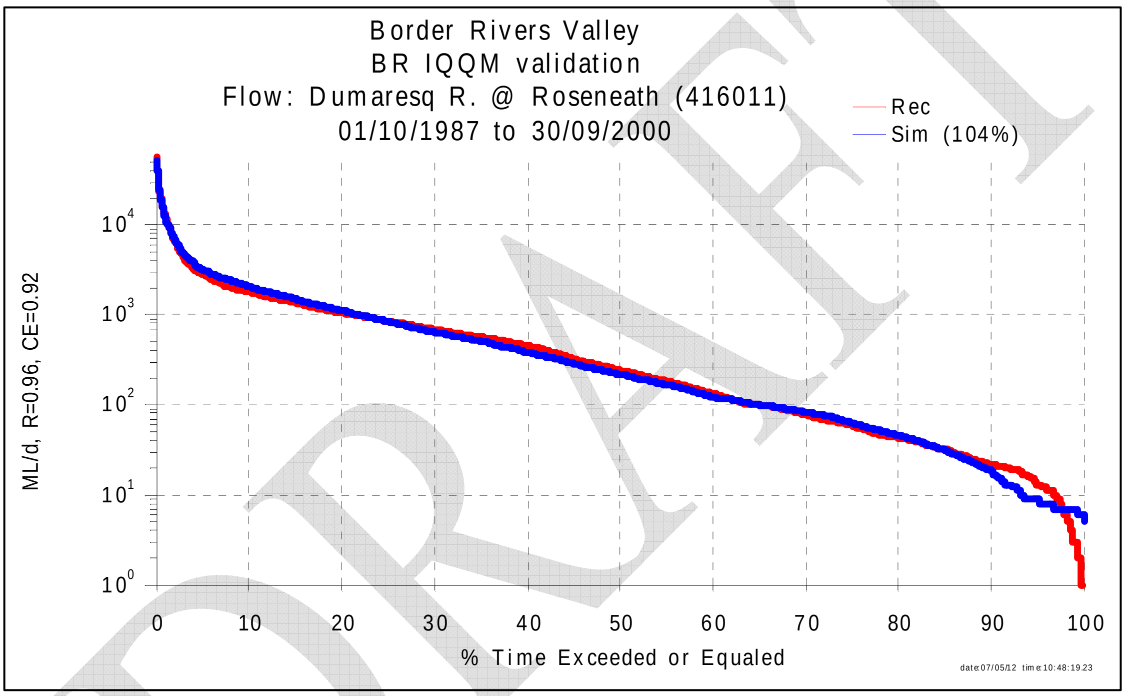


Figure 4.1 Flow calibration results for Dumaresq River @ Roseneath - FDC.

Table 4-3 Flow calibration assessment for Macintyre Brook @ Booba Sands (1987-2000)

Parameter	Flow match by range (exceedance percentile)				Time Series Match	
	All (0-100)	Low (80-100)	Medium (20-80)	High (0-20)	Daily ($1-r^2$)	CMAAD
Flow range (ML/d)	0-69,516	0-10	11-127	128-69,516		
Total observed flow (GL)	1,830	5,896	93.0	1,728		
Bias in simulated (%)	-17.5	-29.2	-17.4	-17.4	14.8	-17.7
Quality rating	Low	Low	Low	Moderate	High	Moderate

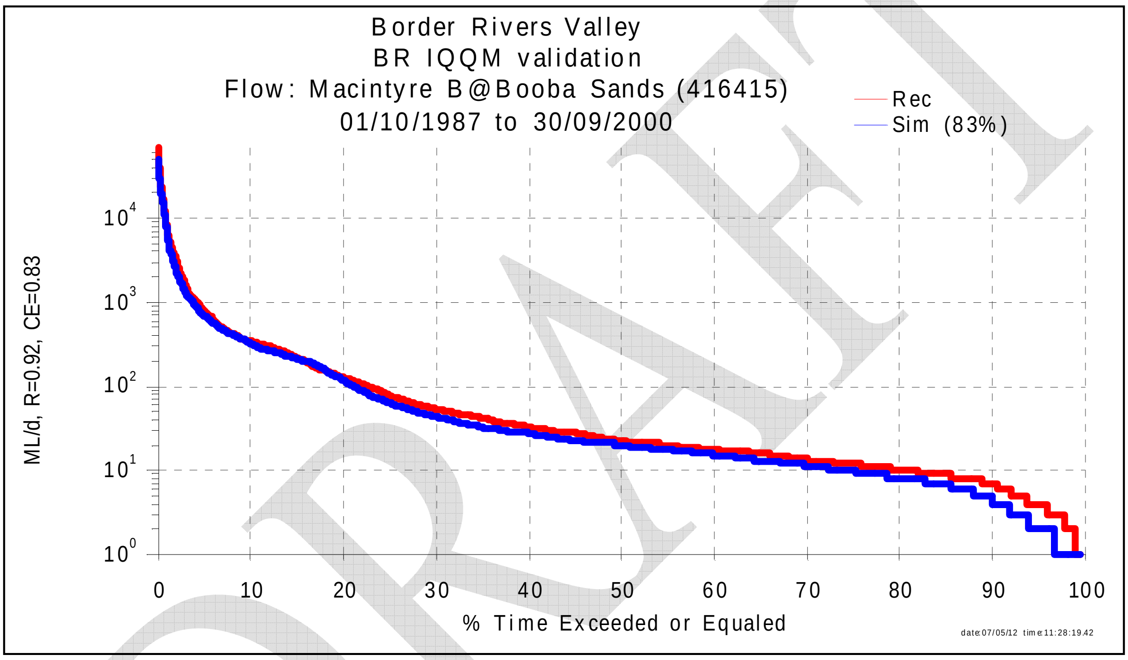


Figure 4.2 Flow calibration results for Macintyre Brook @ Booba Sands - FDC.

Table 4-4 Flow calibration assessment for Macintyre R. @ Holdfast (1987-2000)

Parameter	Flow match by range (exceedance percentile)				Time Series Match	
	All (0-100)	Low (80-100)	Medium (20-80)	High (0-20)	Daily ($1-r^2$)	CMAAD
Flow range (ML/d)	4-123,786	4-70	71-755	756-123,786		
Total observed flow (GL)	3,654	28.6	600	2,896		
Bias in simulated (%)	-3.4	-34.7	+0.5	-3.5	23.4	
Quality rating	V. High	V. Low	V. High	V. High	Moderate	

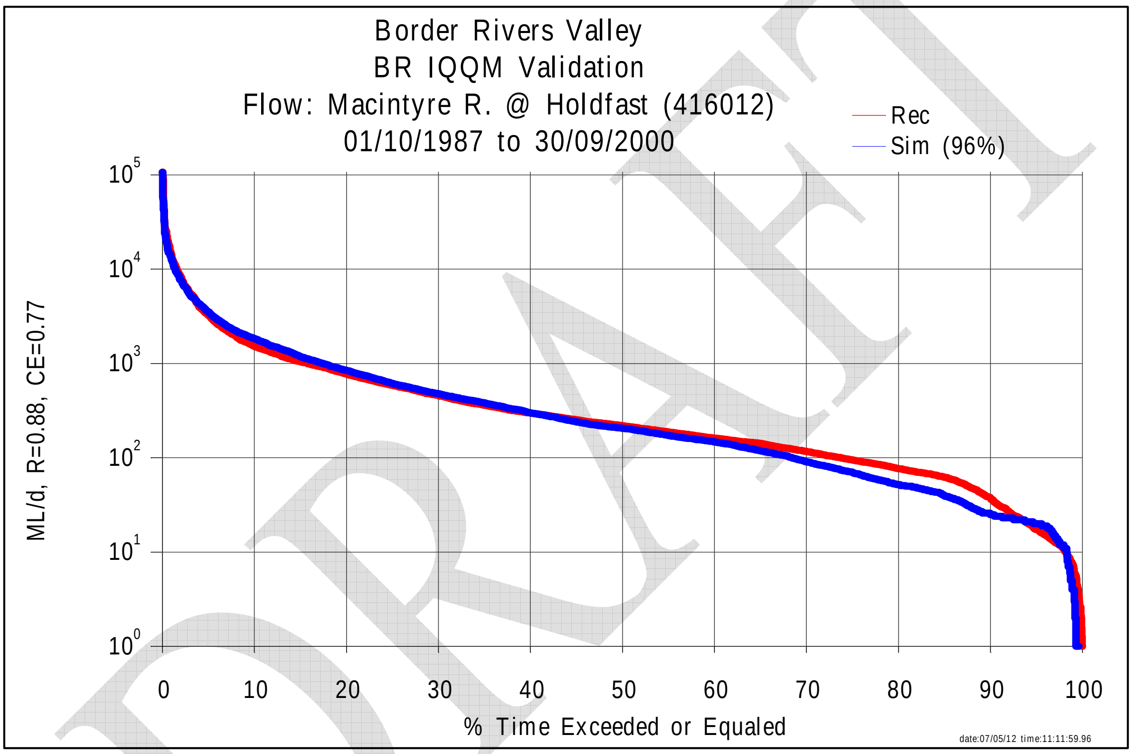


Figure 4.3 Flow calibration results for Macintyre R. @ Holdfast - FDC.

Table 4-5 **Flow calibration assessment for Macintyre R. @ Goondiwindi (1987-2000)**

Parameter	Flow match by range (exceedance percentile)				Time Series Match	
	All (0-100)	Low (80-100)	Medium (20-80)	High (0-20)	Daily ($1-r^2$)	CMAAD
Flow range (ML/d)	0-150,612	0-128	129-1,832	1,833-150,612		
Total observed flow (GL)	11,470	47	1,852	9,423		
Bias in simulated (%)	-4.7	+8.7	+6.3	-7.1	7.7	-5.0
Quality rating	High	High	High	V. High	High	V. High

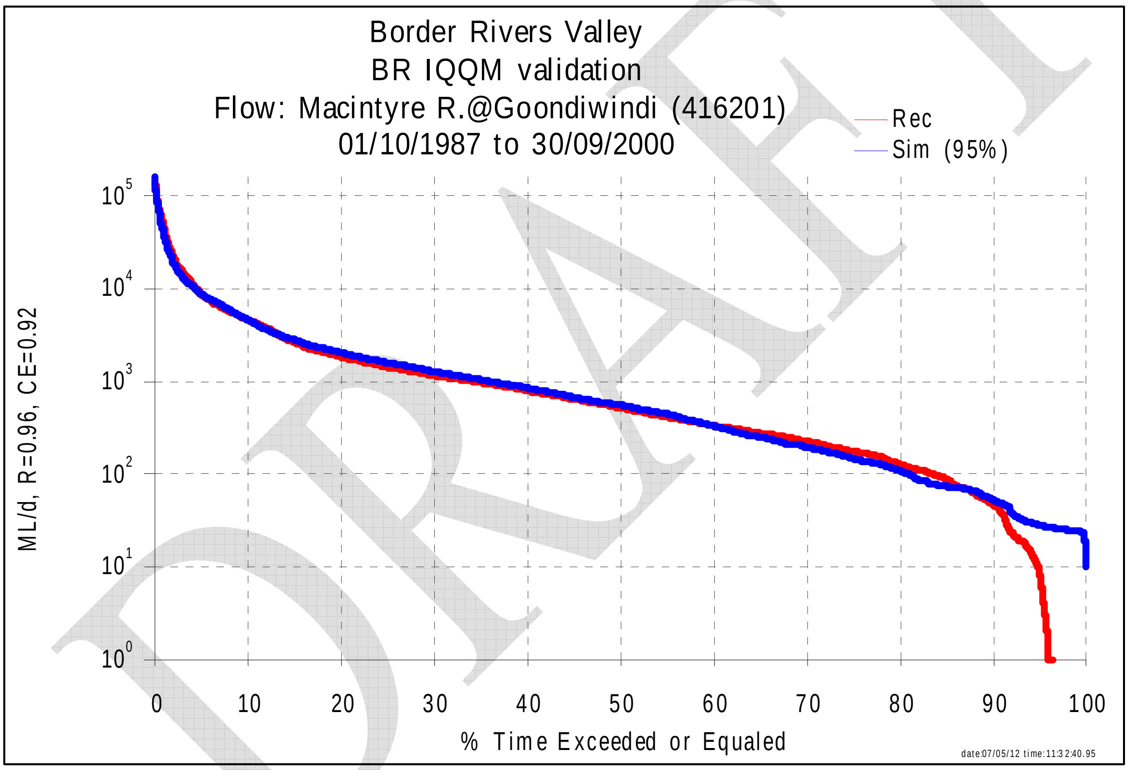


Figure 4.4 **Flow calibration results for Macintyre R. @ Goondiwindi - FDC.**

Table 4-6 Flow calibration assessment for Weir R. @ Talwood (1987-2000)

Parameter	Flow match by range (exceedance percentile)				Time Series Match	
	All (0-100)	Low (80-100)	Medium (20-80)	High (0-20)	Daily (1-r²)	CMAAD
Flow range (ML/d)	0-30,352	0-0	0-86	87-30,352		
Total observed flow (GL)	2,554	0	34	2,520		
Bias in simulated (%)	+12.5	0	+534	+6.8	+31.3	+13.4
Quality rating	Moderate	V. High	V. Low	V. High	Moderate	High

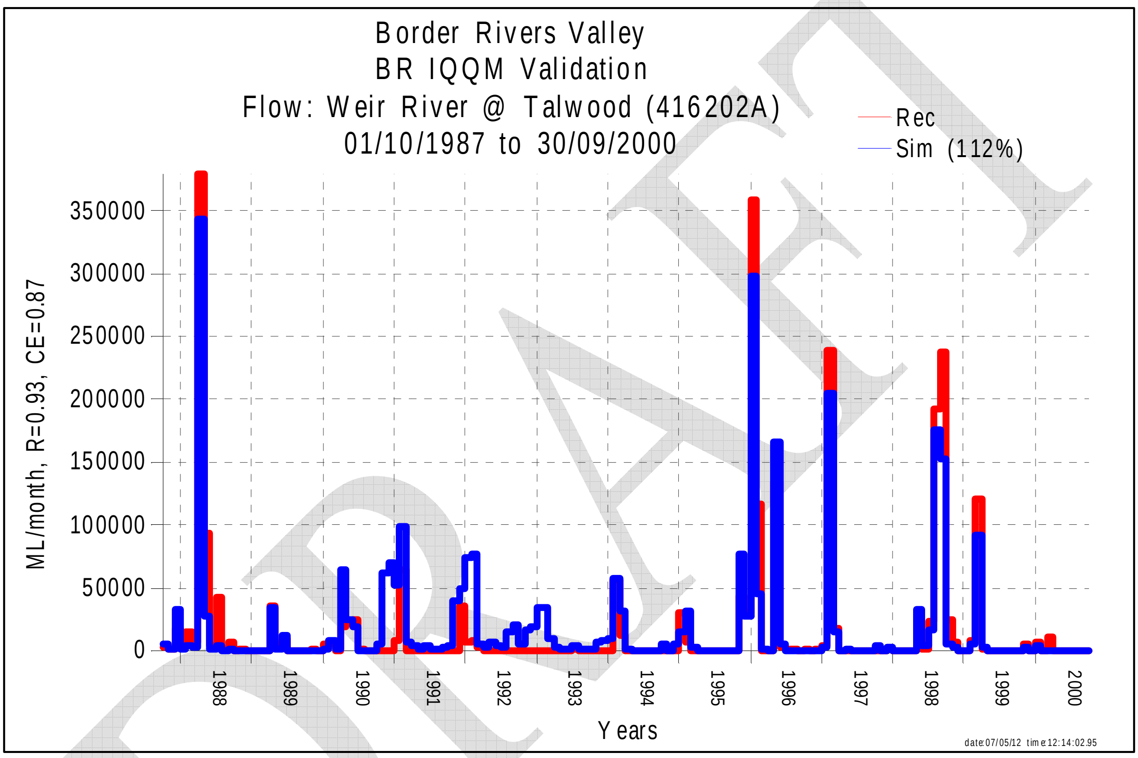


Figure 4.5 Flow calibration results for Weir R. @ Talwood –monthly time series.

Table 4-7 Flow calibration assessment for Barwon R. @ Mungindi (1987-2000)

Parameter	Flow match by range (exceedance percentile)				Time Series Match	
	All (0-100)	Low (80-100)	Medium (20-80)	High (0-20)	Daily ($1-r^2$)	CMAAD
Flow range (ML/d)	0-58,297	0-7	8-1,227	1,228-58,279		
Total observed flow (GL)	5,265	0.8	665	4,598		
Bias in simulated (%)	-11.6	+536	+6.9	-14.4	+11.5	
Quality rating	Moderate	V. Low	High	High	High	

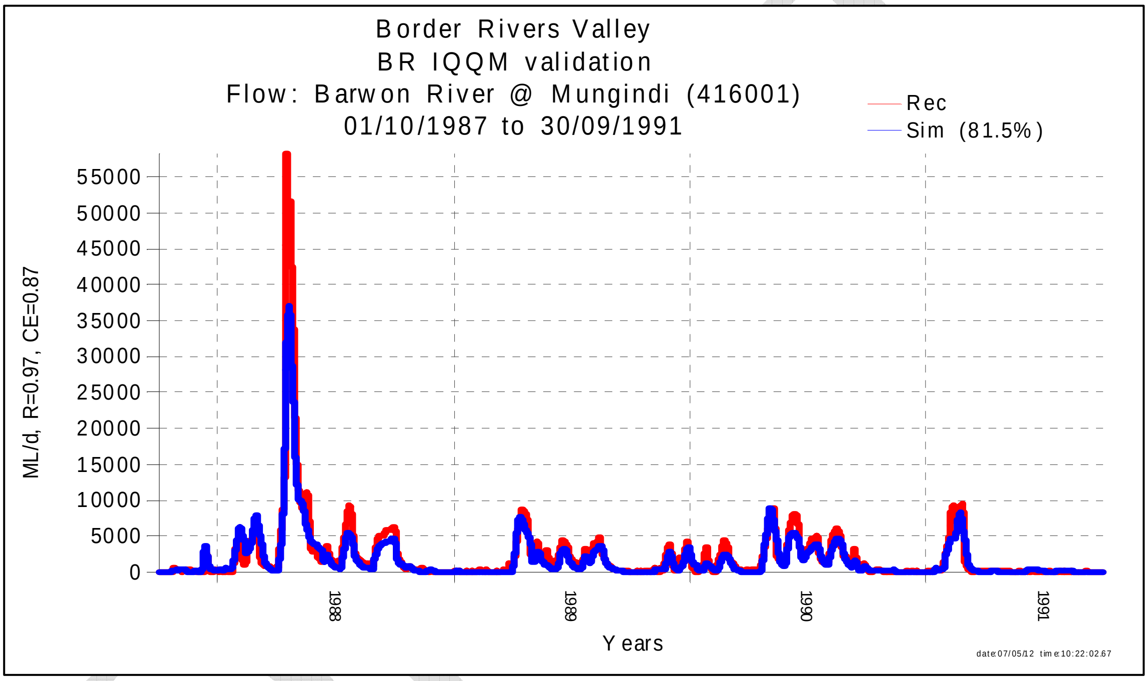


Figure 4.6 Flow calibration results for Barwon R. @ Mungindi – Daily time series 1987-1991

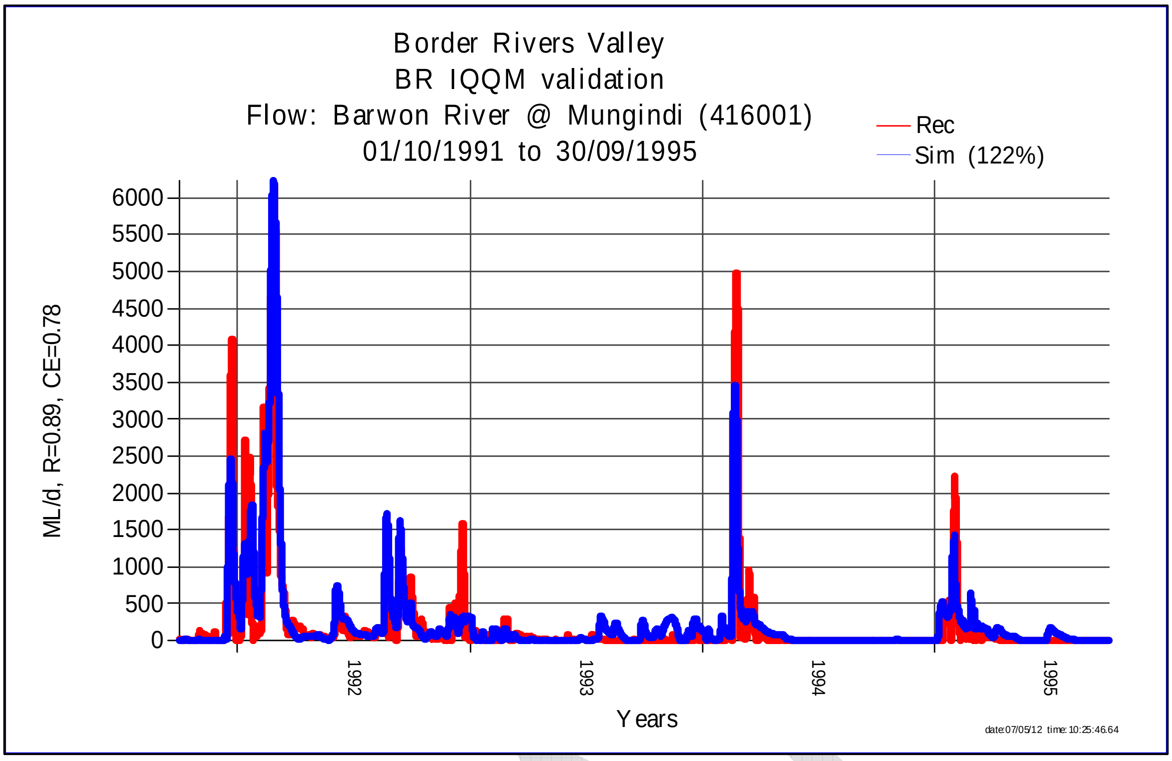


Figure 4.7 **Flow calibration results for Barwon R. @ Mungindi – Daily time series 1991-1995**

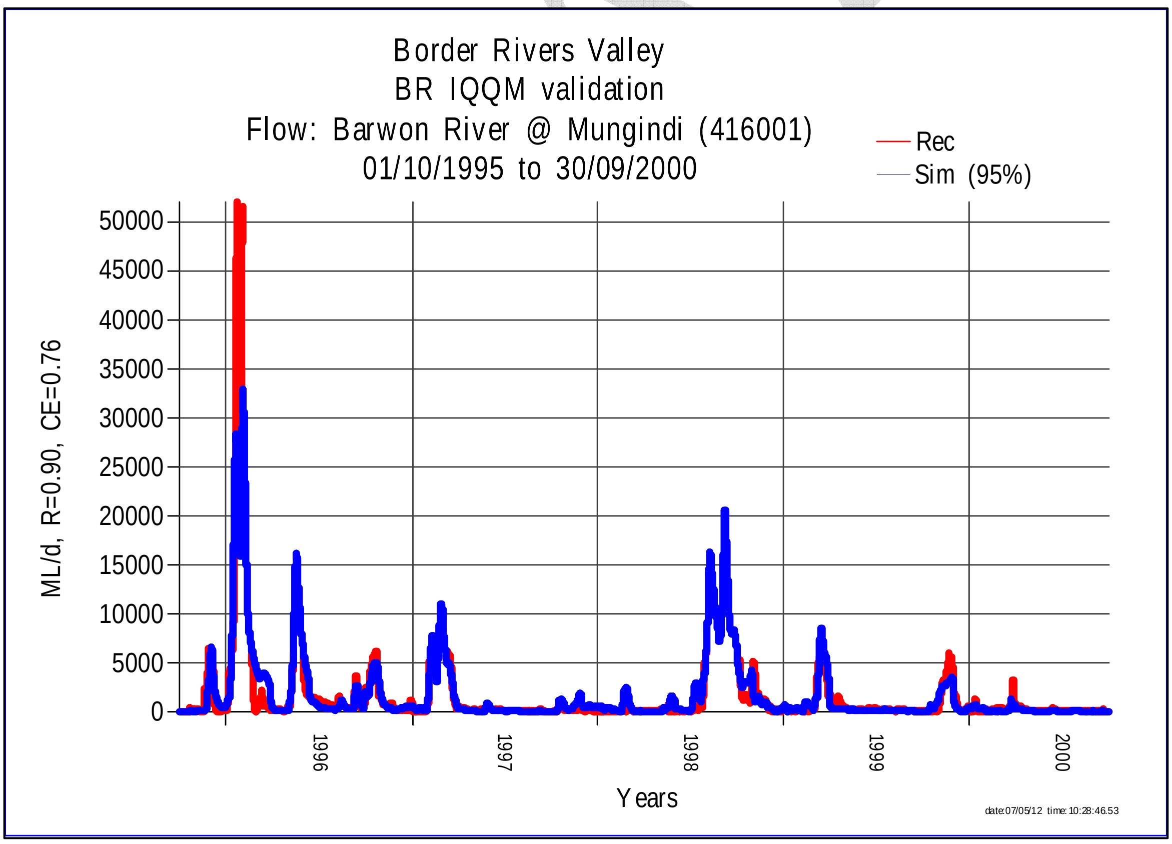


Figure 4.8 **Flow calibration results for Barwon R. @ Mungindi – Daily time series 1995-2000**

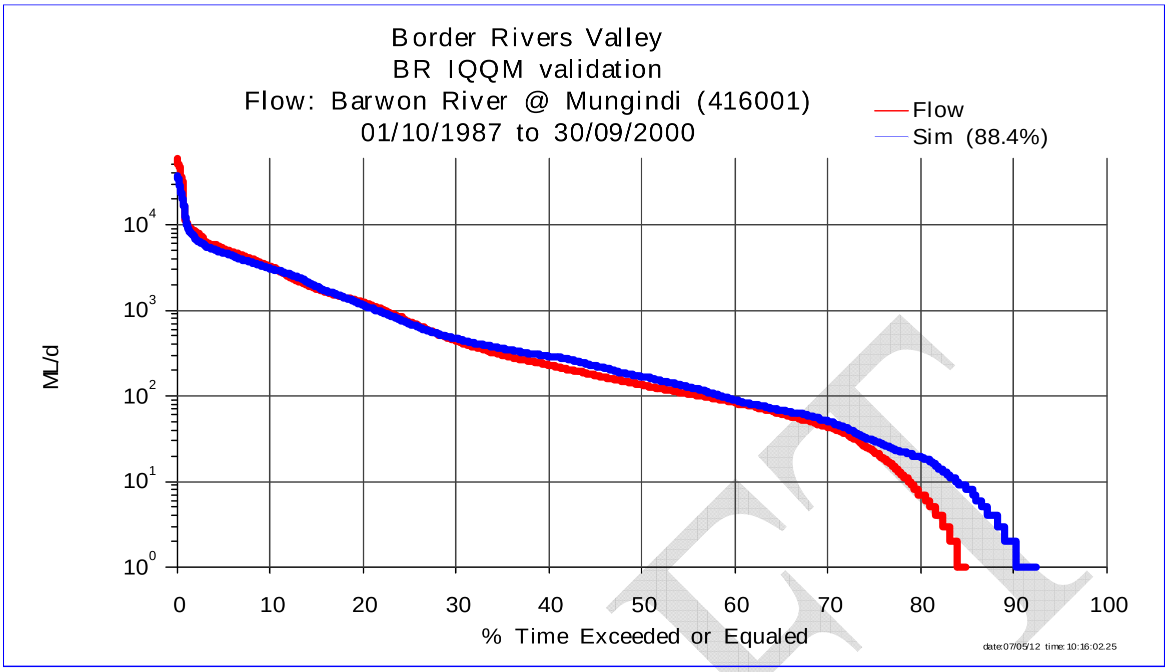


Figure 4.9 **Flow calibration results for Barwon R. @ Mungindi - FDC.**

4.2 Diversions

Objective measures of the quality of model fit achieved are presented in Table 4-8 to Table 4-14 based on the QA guidelines described in Appendix E. Diversions re-calibration results obtained are presented graphically in Figure 4.10 to Figure 4.17. The calibrated annual diversions have been presented as a single, continuous graph after combining results for the sub-periods.

The QA results show that 'High' and 'V.High' diversion calibration quality was achieved for all except for Severn-Macintyre rivers sub-system, which had an overall rating of just 'Moderate'. However, even for that sub-system a good match of simulated figures to actual data is achieved for ONA and ONA+ OFA diversions with some underestimation by the model, particularly, for calibration period prior to 1995. OFA diversions are also significantly underestimated by the model prior to 1995 in the Pindari system, while the situation is reversed for both ONA and OFA diversions match in the post-1995 calibration period.

Table 4-8 Diversion calibration quality assessment (1987-2000) for NSW Glenlyon subsystem

Parameter	Diversion Volume Comparison			Time Series Match		
	GS	SA	Total	GS	SA	Total
Total Observed (GL)	852	899	1,751			
Bias in simulated (%)	1.0	-0.6	0.1	11.2	6.3	5.5
Rating	V. High	V.High	V.High	High	V.High	V.High

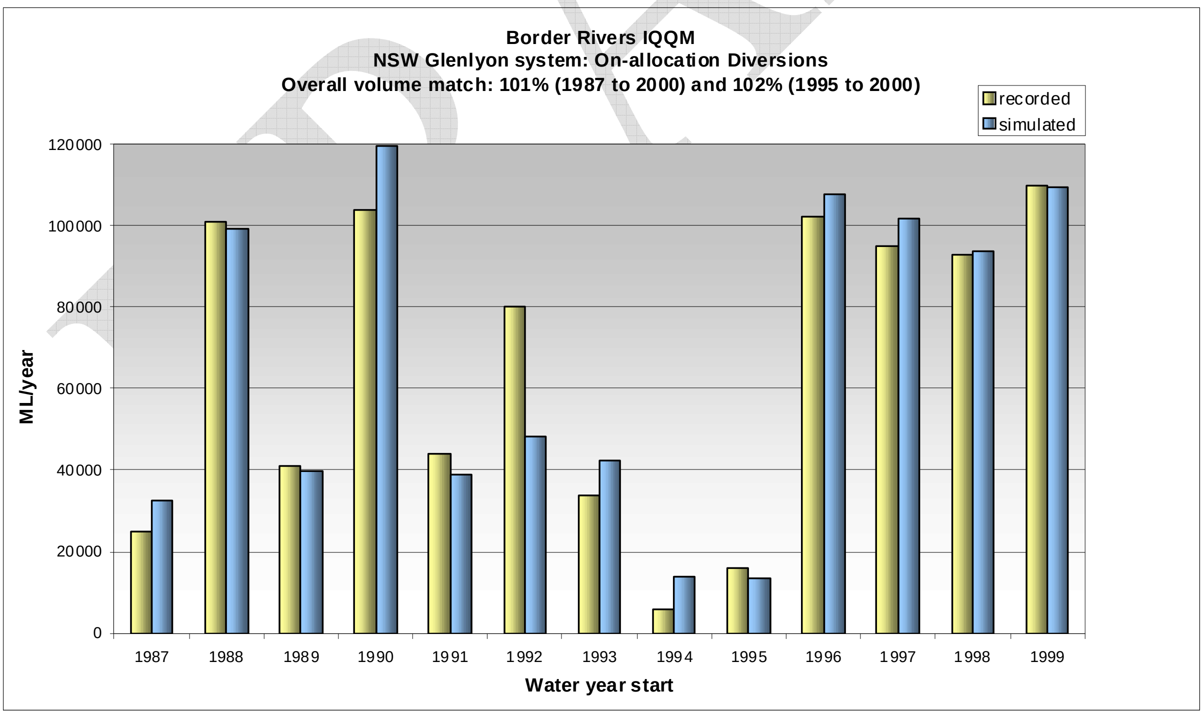


Figure 4.10 On-allocation diversion calibration results for NSW Glenlyon subsystem.

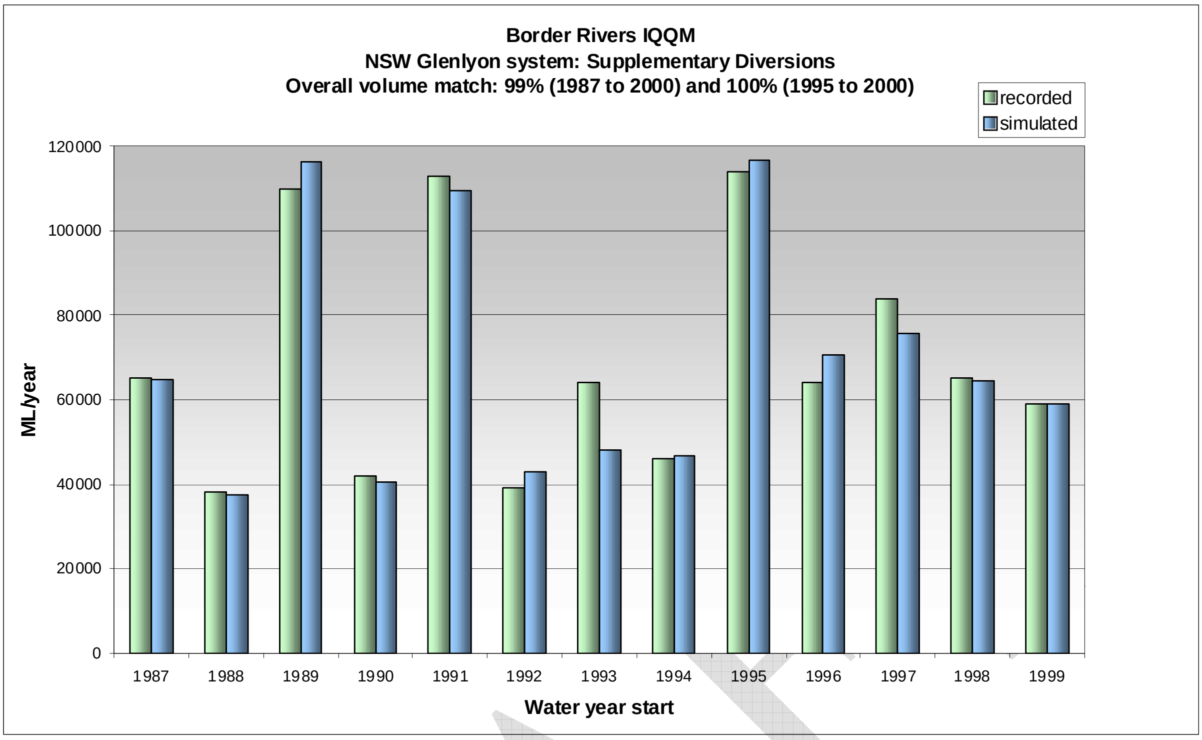


Figure 4.11 Supplementary diversion calibration results for NSW Glenlyon subsystem

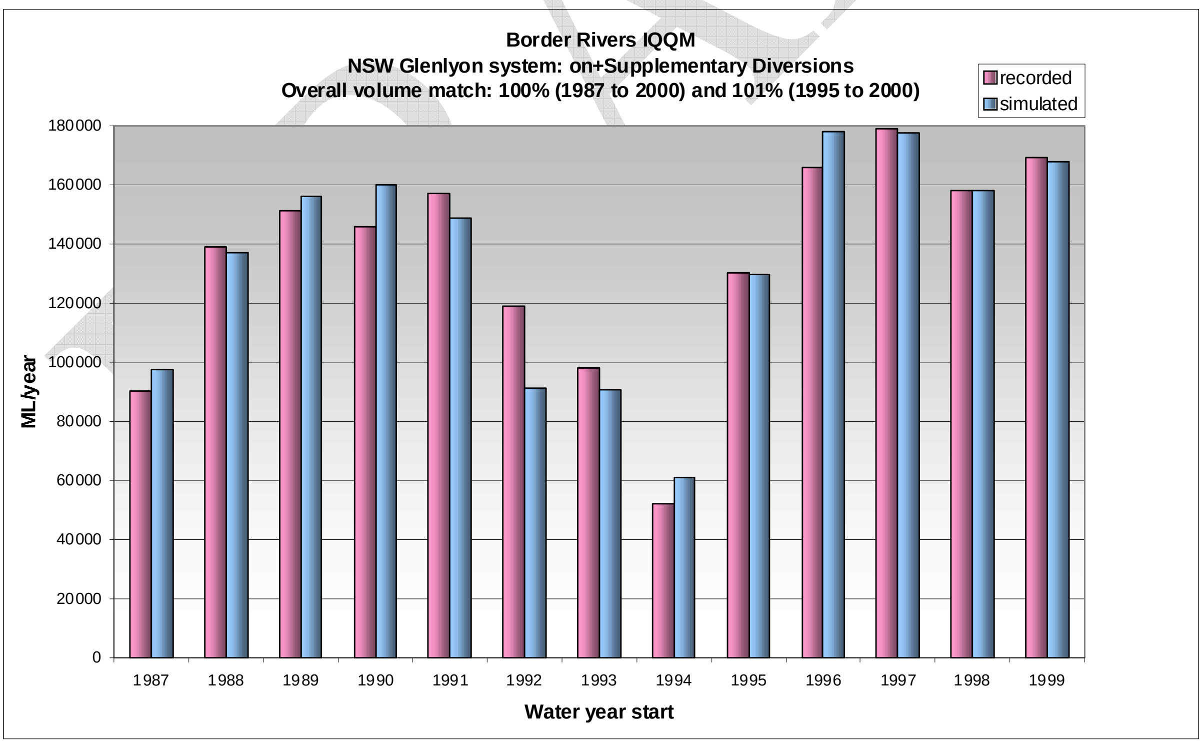


Figure 4.12 Total diversion calibration results for NSW Glenlyon subsystem.

Table 4-9 Diversion calibration quality assessment (1987-2000) for QLD Glenlyon subsystem

Parameter	Diversion Volume Comparison			Time Series Match		
	GS	SA	Total	GS	SA	Total
Total Observed (GL)	384	594	978			
Bias in simulated (%)	-9.0	+2.9	-1.8	14.3	6.6	7.5
Rating	High	High	V. High	High	V. High	V. High

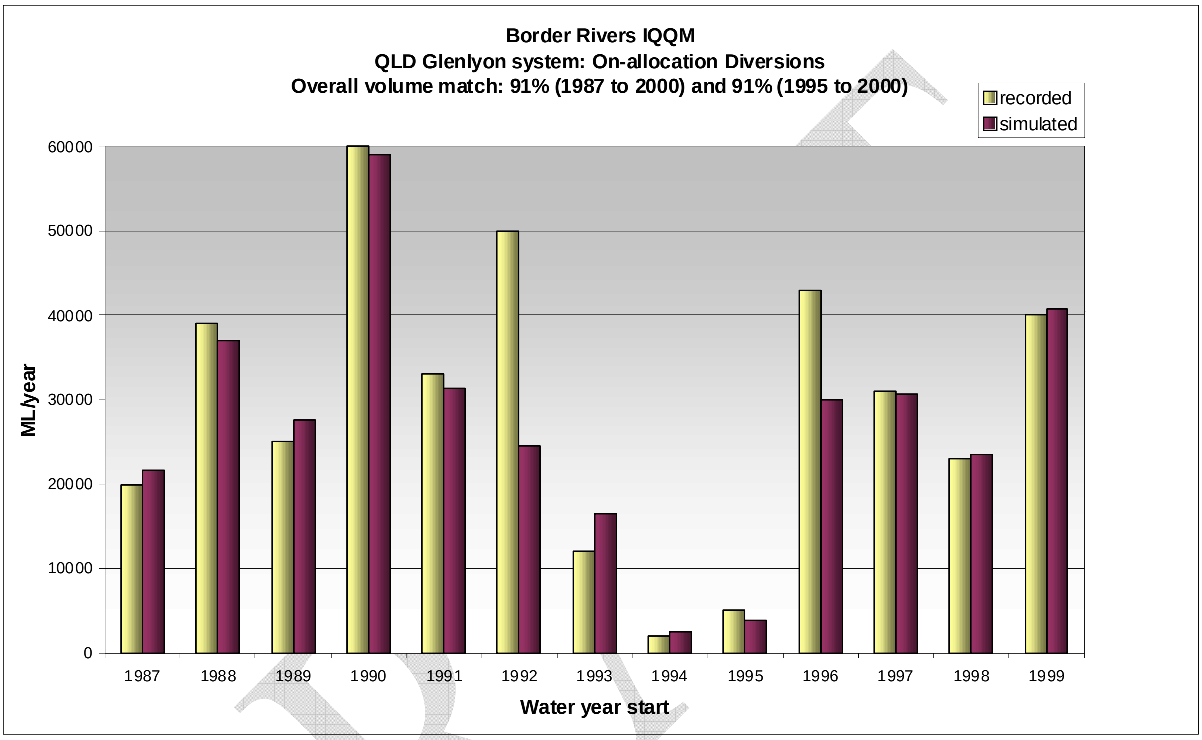


Figure 4.13 On-allocation diversions calibration results for QLD Glenlyon subsystem.

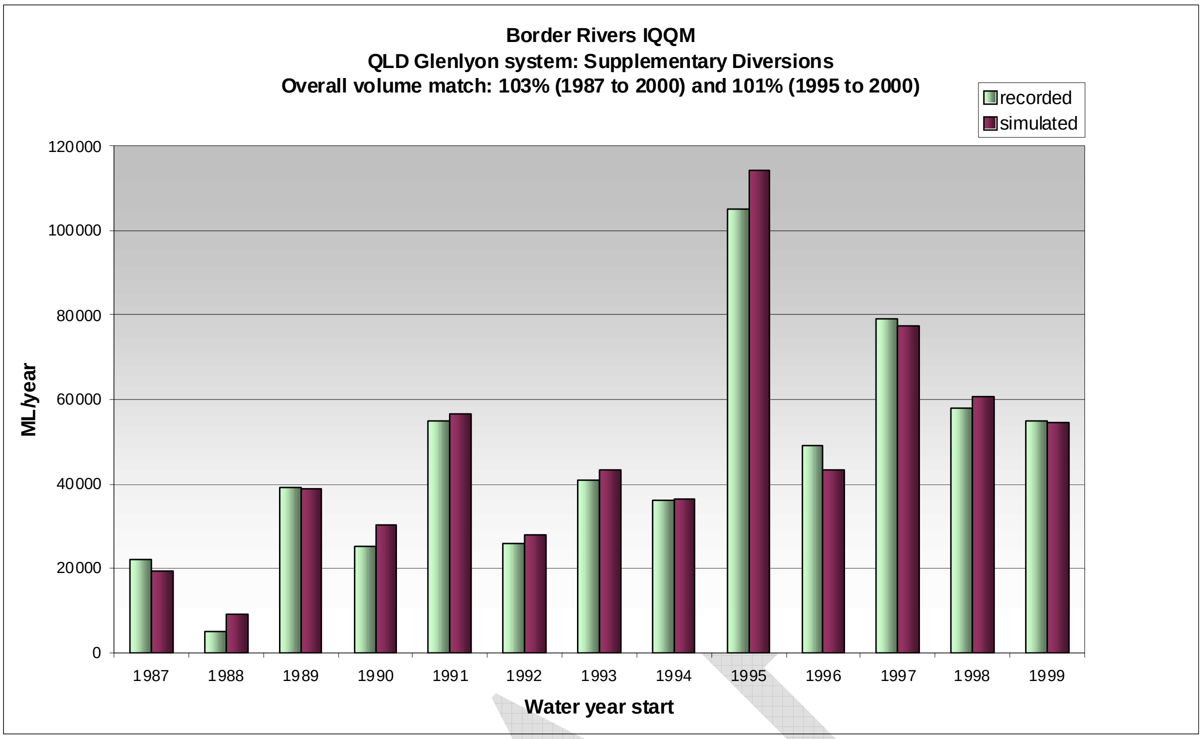


Figure 4.14 Supplementary diversions calibration results for QLD Glenlyon subsystem.

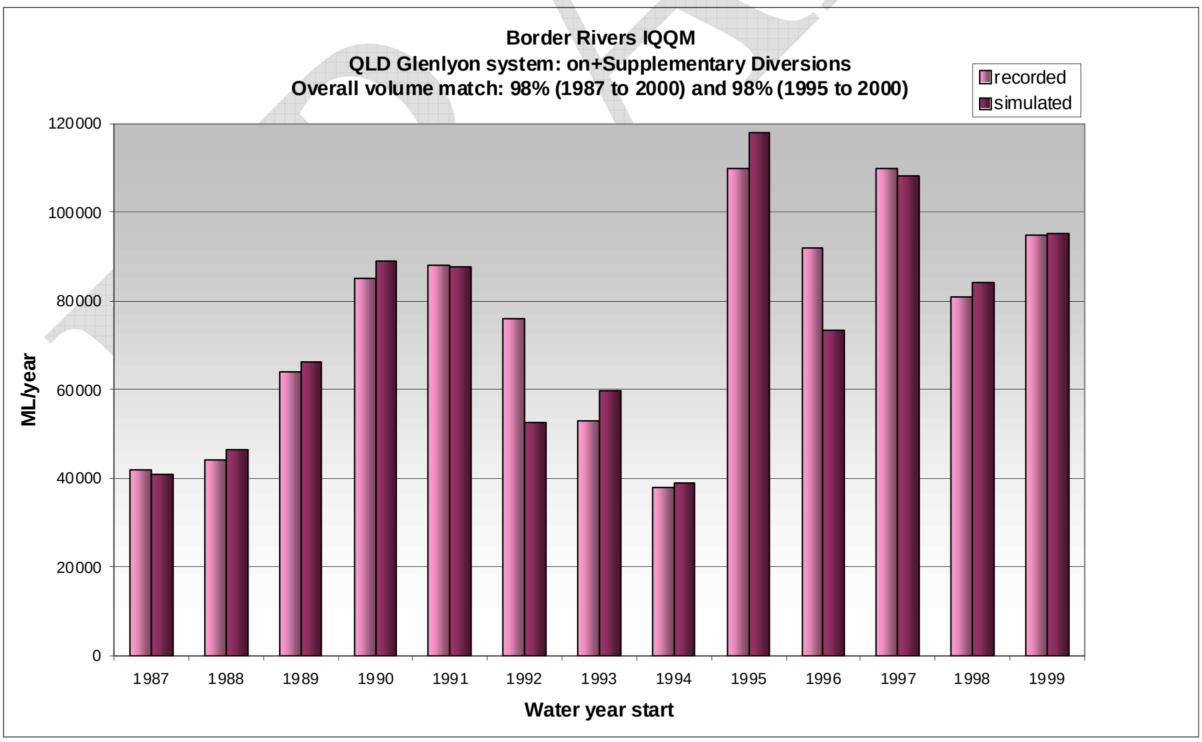


Figure 4.15 Total diversions calibration results for QLD Glenlyon subsystem.

Table 4-10 Diversion calibration quality assessment (1987-2000) for NSW Pindari subsystem

Parameter	Diversion Volume Comparison			Time Series Match		
	GS	SA	Total	GS	SA	Total
Total Observed (GL)	71.1	37.1	108			
Bias in simulated (%)	-8.9	-24.9	-14.4	27.1	32.9	25.6
Rating	High	Moderate	High	Moderate	Moderate	Moderate

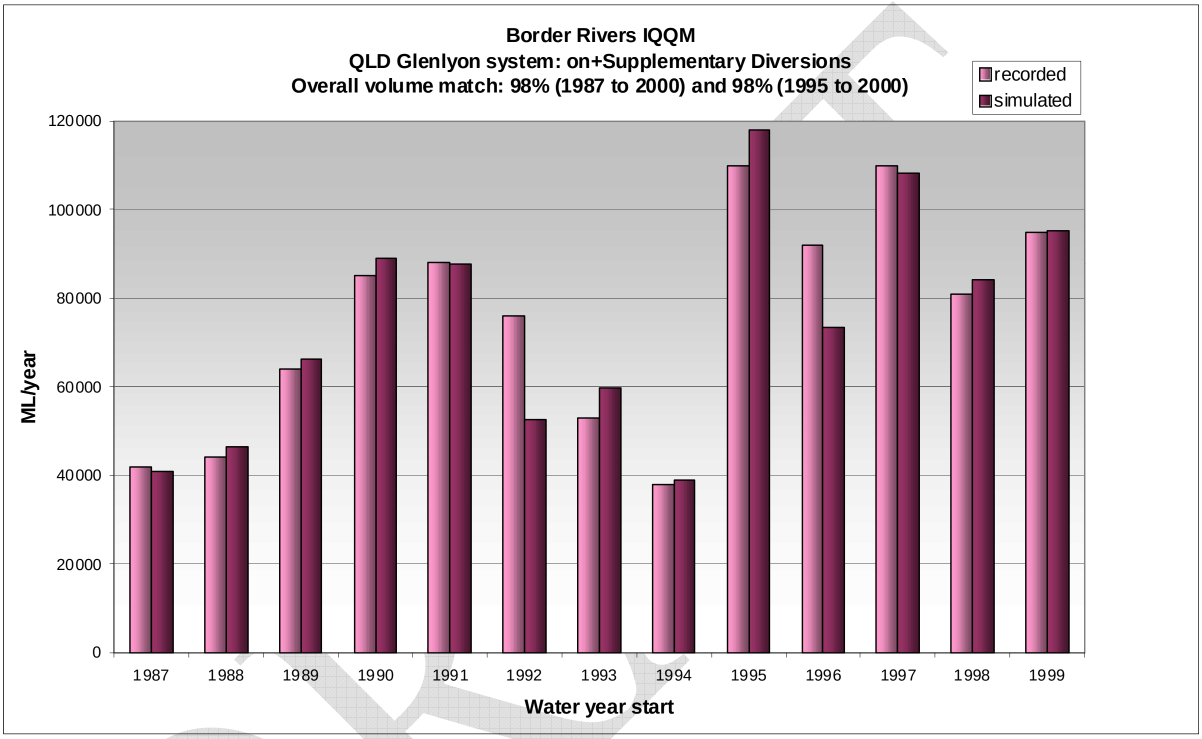


Figure 4.16 Total diversions calibration results for QLD Glenlyon subsystem.

Table 4-11 Diversion calibration quality assessment (1987-2000) for QLD Coolmunda subsystem

Parameter	Diversion Volume Comparison			Time Series Match		
	GS	SA	Total	GS	SA	Total
Total Observed (GL)	101	-	-			
Bias in simulated (%)	1.5	-	-	3.8	-	-
Rating	V.High	-	-	V.High	-	-

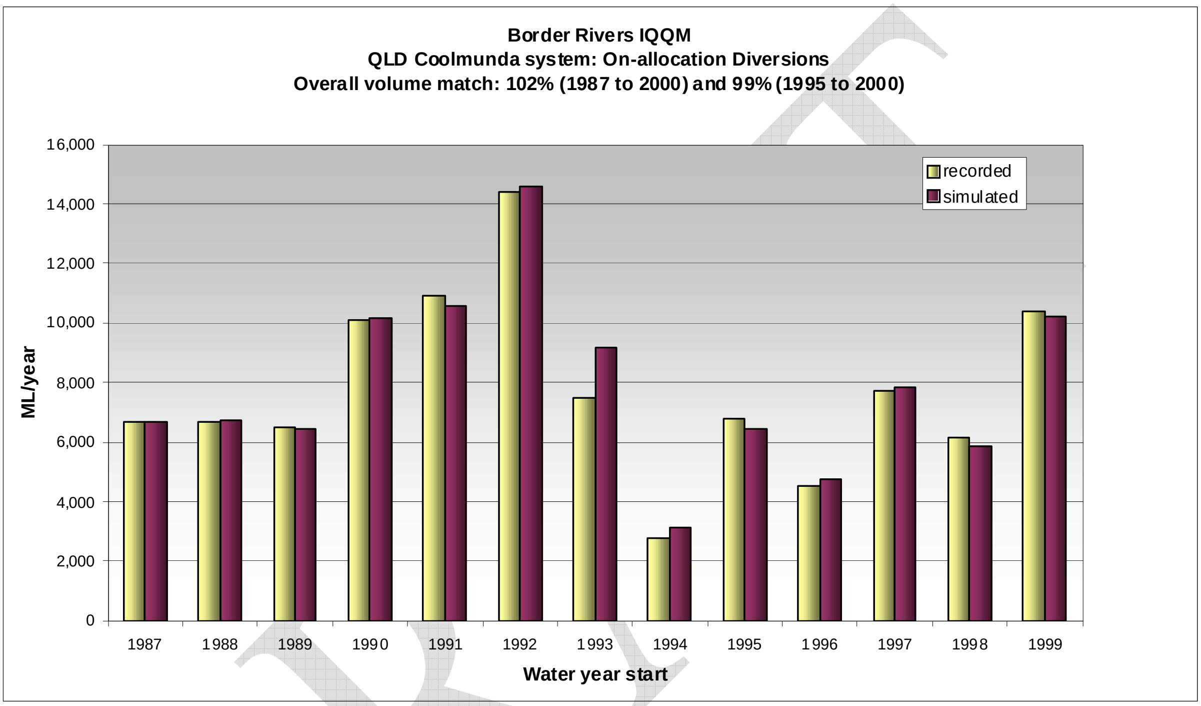


Figure 4.17 On-allocation diversion calibration results for QLD Coolmunda subsystem.

Table 4-12 Diversion calibration quality assessment (1987-2000) for NSW Total

Parameter	Diversion Volume Comparison			Time Series Match		
	GS	SA	Total	GS	SA	Total
Total Observed (GL)	923	936	1,859			
Bias in simulated (%)	+0.2	-1.6	-0.7	10.8	6.0	6.0
Rating	V. High	V. High	V. High	V. High	V. High	V. High

Table 4-13 Diversion calibration quality assessment (1987-2000) for QLD Total

Parameter	Diversion Volume Comparison			Time Series Match		
	GS	SA	Total	GS	SA	Total
Total Observed (GL)	485	594	1,079			
Bias in simulated (%)	-6.8	+2.9	-1.5	11.6	6.6	6.9
Rating	High	V. High	V. High	High	V. High	V. High

Table 4-14 Diversion calibration quality assessment (1987-2000) for BRS Total

Parameter	Diversion Volume Comparison			Time Series Match		
	GS	SA	Total	GS	SA	Total
Total Observed (GL)	1,408	1,530	2,938			
Bias in simulated (%)	-2.2	+0.2	-1.0	10.0	4.7	4.7
Rating	V. High	V. High	V. High	V. High	V. High	V. High

4.3 Storage Behaviour

The storage calibration achieved for Coolmunda, Glenlyon and Pindari Dams, and combined storages are summarised in Table 4-15 based on QA guidelines presented in Appendix E. The time series of the storage volume results for all calibration sub-periods are presented in Figure 4.18 to Figure 4.20 respectively, and for combined Glenlyon and Pindari in Figure 4.21.

Table 4-15 Storage calibration quality achieved (1987 – 2000)

Parameter	Time series end-of-month match (CMASDD)	
	Assessment (%)	Rating
Coolmunda Dam	2.2	V.High
Glenlyon Dam	1.7	V.High
Pindari Dam	1.2	V.High
Total Pindari and Glenlyon	1.3	V.High

A V. High rating was achieved for the results of all the headwater storage behaviour calibration. The results actually represent a validation over the period 1987-2000 for Coolmunda Dam, as it uses previously calibrated parameters representing irrigator behaviour, simulated inflows, and simulated AWD. For Pindari and Glenlyon sub-systems, the results are from models with parameters previously calibrated in the flow and diversion calibration phases. With the exemption of the 1997-2000 period, each allocation system is forced to the observed levels at this stage.

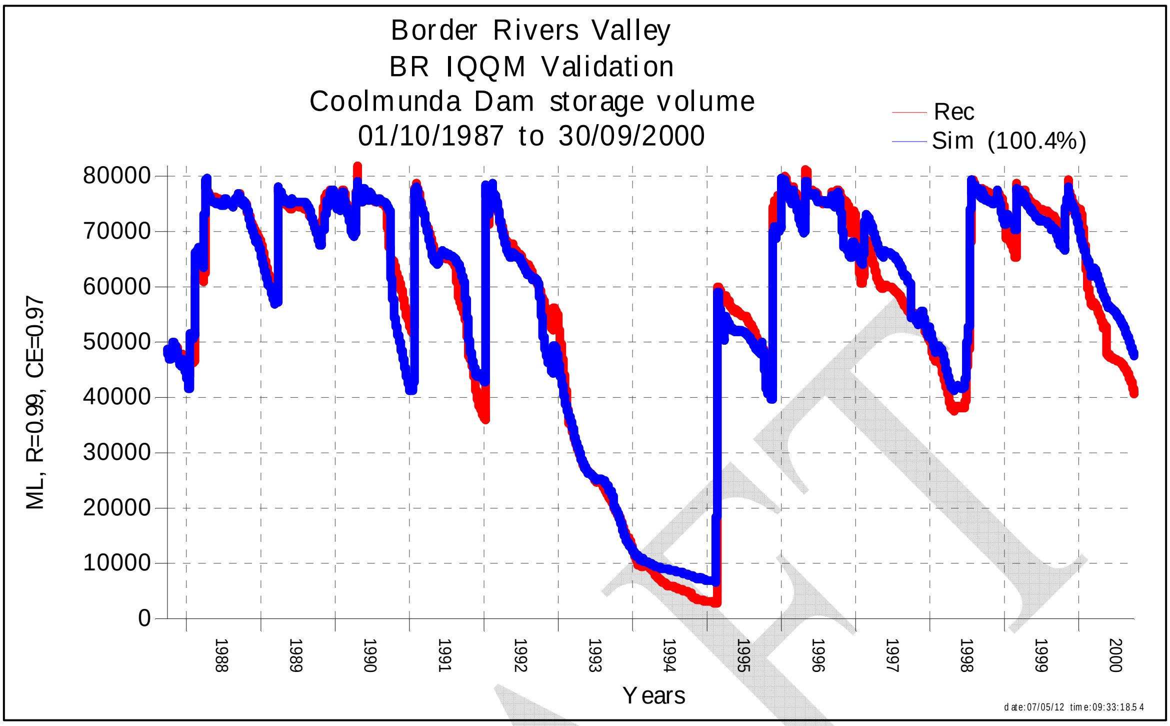


Figure 4.18 Comparison of observed and simulated Coolmunda Dam behaviour.

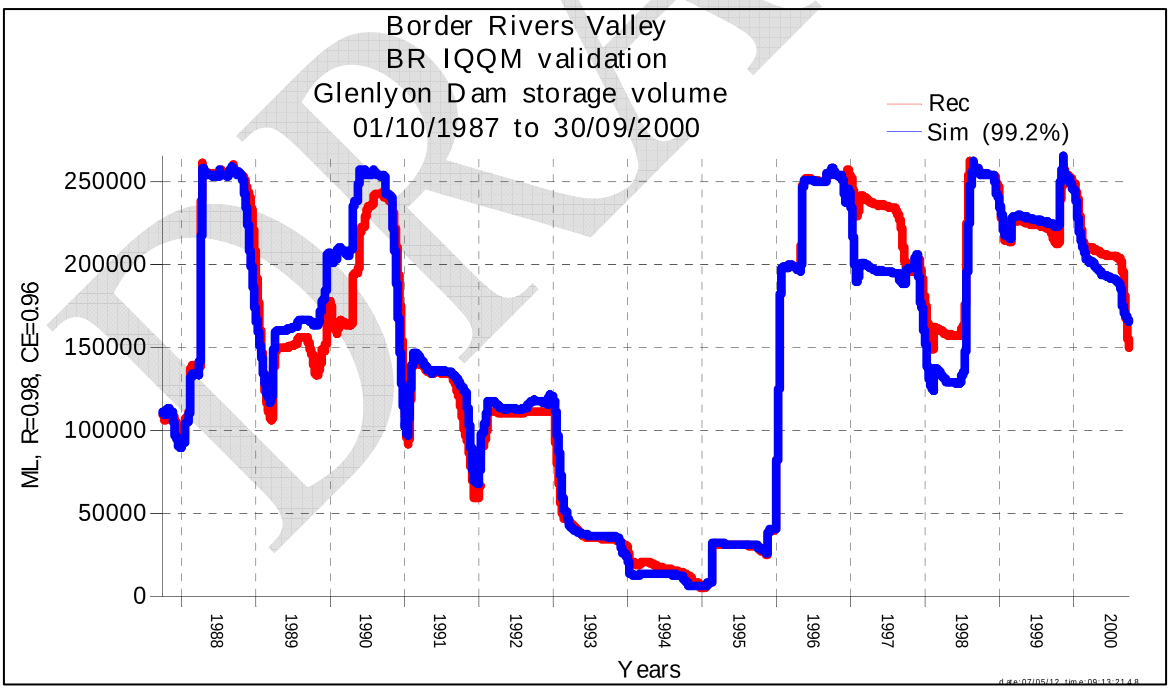


Figure 4.19 Comparison of observed and simulated Glenlyon Dam behaviour.

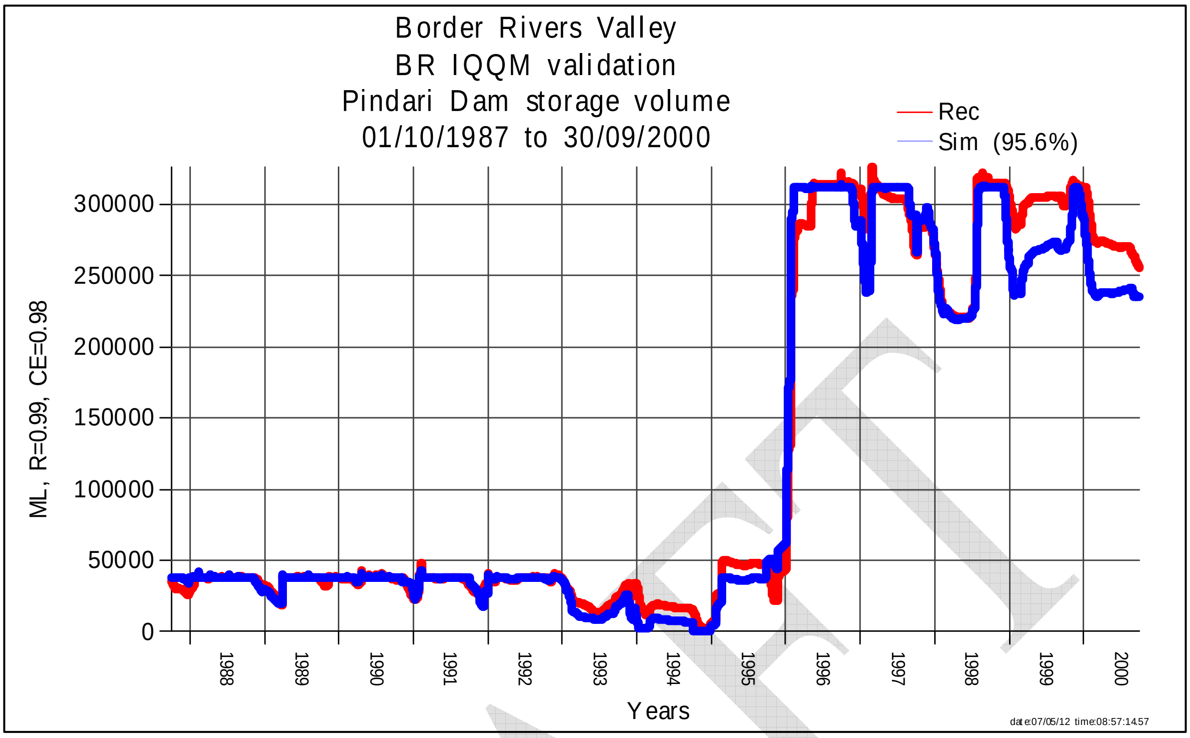


Figure 4.20 Comparison of observed and simulated Pindari Dam behaviour 1987-2000.

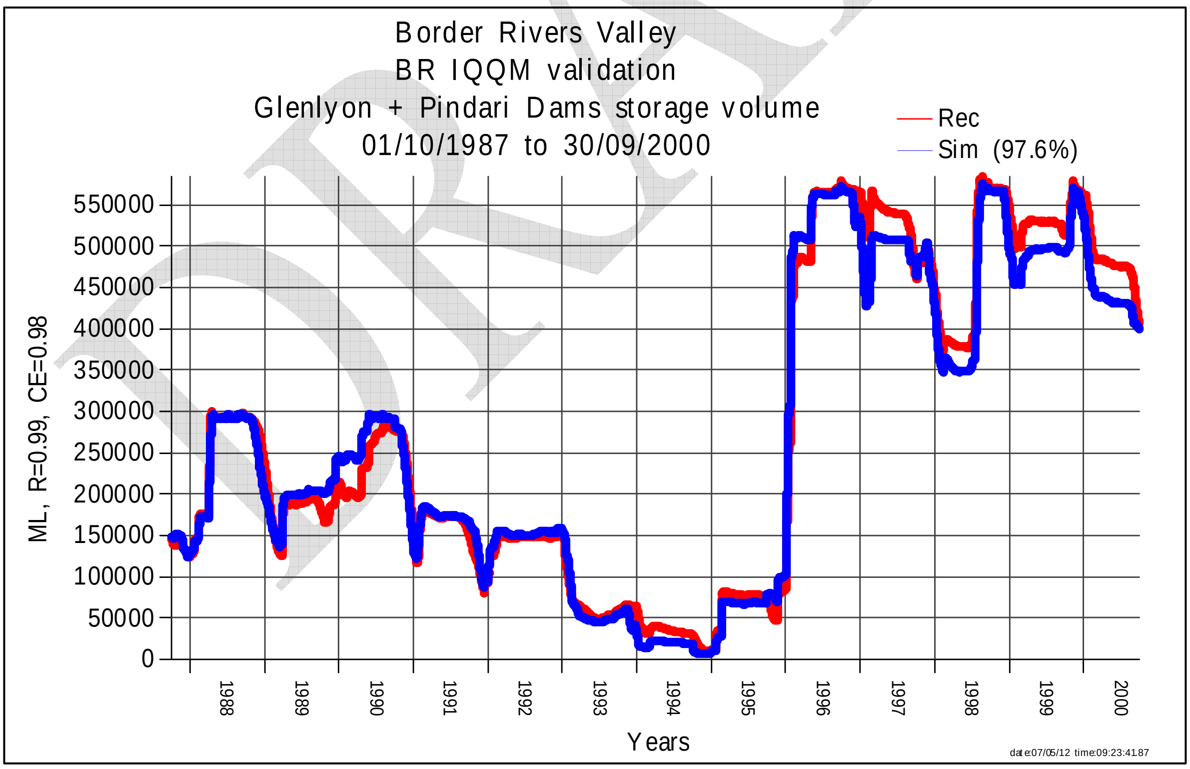


Figure 4.21 Comparison of observed and simulated storage volume (Glenlyon + Pindari)

4.4 Planted Area

Area calibration results achieved are presented in Figure 4.22 and Figure 4.23 while Table 4-16 summarises the quality of results using the guidelines in Appendix D. Area calibration quality assessment for Queensland is presented for the total area only due to lack of detailed data in three out of five years used for area calibration. We have presented the area calibration results for the two states separately for the 1995/96-1999/00. We also show the comparison for two sets of area data, from different sources (Section 2.4.3.4).

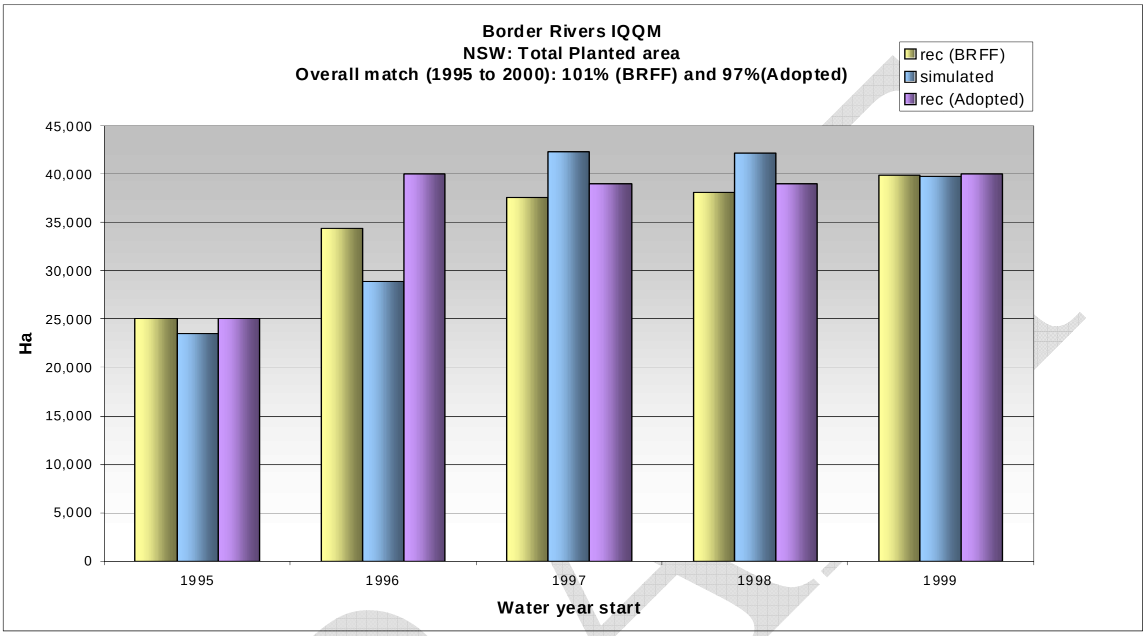


Figure 4.22 Comparison of observed and simulated planted areas for NSW

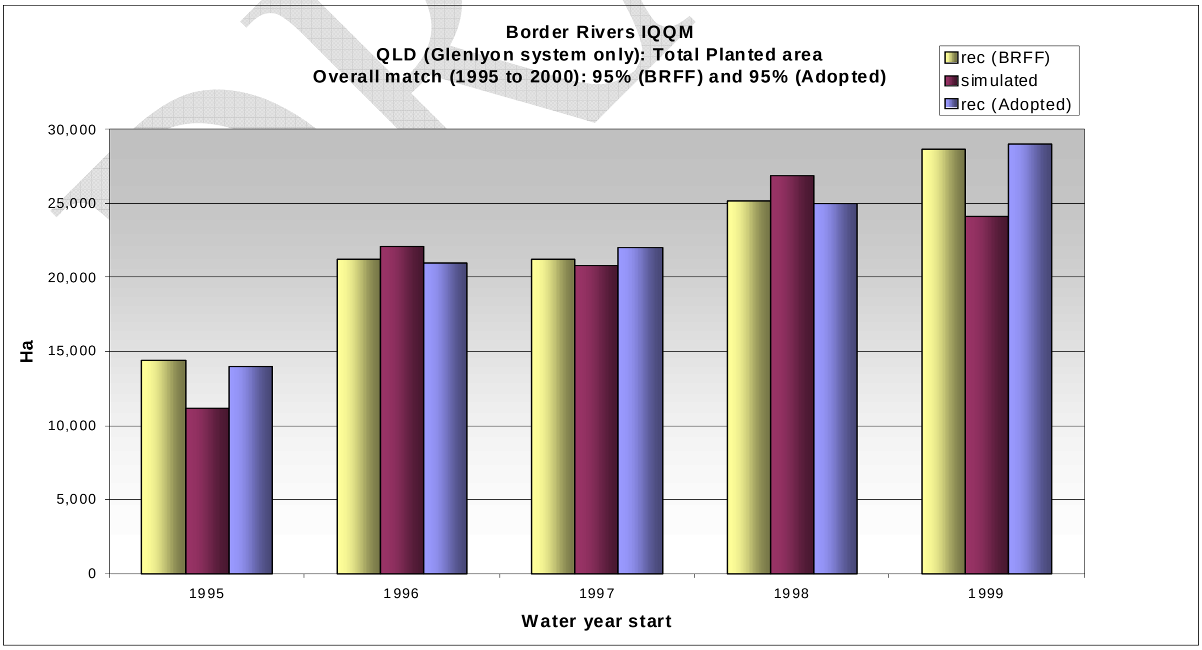


Figure 4.23 Comparison of observed and simulated planted areas for QLD (Glenlyon only)

Table 4-16 Planted Area calibration quality achieved 1995 -2000

Parameter	Diversion Volume Comparison			Time Series Match (CMAAD)		
	Summer	Winter[1]	Total	Summer	Winter	Total
NSW (Glenlyon and Pindari Subsystems)						
Total Observed (ha)	166,230[3]	16,770[2]	183,000			
Bias in simulated (%)	-8.2	60.0	-2.0			2.8
Rating	High	V.Low				V.High
QLD (Glenlyon and Coolmunda Subsystems)						
Total Observed (ha)	n/a	n/a	121,000			
Total simulated (ha)	95,671	26,994	122,655			
Bias in simulated (%)	-	-	1.4			1.7
Rating	-	-	V.High			V.High

Note: (1) – Perennial crops including Lucerne and Pasture and other minor crops classified as 'Others' in IQQM are included in winter Area in this assessment.

(2) – Based on DLWC Field Staff Surveys data (Section 2.4.3.5).

(3) – Estimated as adopted for calibration total area minus winter area.

4.5 Overall quality of the model calibration

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 4-17.

Table 4-17. Evaluation of overall quality of model calibration

Calibration Stage	Period	Location	Individual Ratings			
			Overall Ratio (%)		Pattern Match (%)	
			Achieved	Standard	Achieved	Standard
Flow	1987-2000	Mungindi	-11.6	-11.6	11.5	9.8
Demand	1987-2000	Whole valley	-1.0	-0.7	4.7	1.6
Storage	1987-2000	Pindari	-4.4	-3.0	1.2	1.5
		Glenlyon	-0.8	-1.0	1.7	2.1
		Pindari+Glenlyon	-2.4	-3.0	1.3	1.6
		Coolmunda	0.4	0.5	2.2	2.8
Area	1995-2000	NSW	-2.0	-2.0	2.8	1.2
	1996-2000	QLD	1.4	1.4	1.7	0.7
Sub-Total			2.9		2.7	
Average			2.8			
OQI	11		1.8		V.High	

There were four separate periods used to calibrate some of the components of the BRS IQQM. However, total results over the entire combined period are reported in Table 4-17. The adopted calibration period length for climatic representativeness purposes (Appendix E) is eleven years. We decided that this the effective climatic period that the model was fully tested over, since we did not include the 1985/86 and 1986/87 water years in the calibration.

According to the guidelines in Appendix D, the BRS IQQM calibration achieved a V. High Overall Quality Indicator. Based on this rating, the model is appropriate for the following uses as listed in Table E.6:

- 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

Chapter 5: Cap Development Conditions Scenario

The Border River Valley is a designated river valley under Schedule E of the Murray-Darling Basin Agreement, which required is to be managed to ensure that diversions do not exceed those that would have occurred under 1993/94 levels of irrigation infrastructure and management rules. NOW will use the BRS IQQM to estimate this diversion limit, and to assess the valley's compliance with the MDBMC Cap.

The previous chapters of this report have outlined how IQQM has been configured and calibrated for the BRS. This chapter outlines how IQQM has been further developed to perform a long term simulation of the valley at the Cap levels of development and management rules, using historical climatic data as input. This scenario will be referred as "*the Cap Scenario*". This chapter also outlines how the Cap scenario has been used for Cap auditing, i.e. the Cap scenario simulated from 1997/98 onwards. This scenario will be referred to as "*the Cap Audit Scenario*".

Both the Cap scenario and the Cap Audit scenario only relate to the regulated system and any recent catchment changes on unregulated tributaries are effectively incorporated into the historical stream-flow information used as model input.

5.1 Cap in Brief

The BRS IQQM was used to simulate the Cap scenario over period 1890-2011 to determine long term average annual diversions. The BRS IQQM was also used to simulate the Cap Audit scenario, as required under Schedule F, for the period 1997/98-2010/11 water years. The following assumptions were used to configure the Cap scenario:

- Level of entitlements including extent of their utilisation, interstate sharing arrangements and water accounting systems as at June 1994.
- Pindari storage post-enlargement works.
- New management and operating rules applicable to Pindari post-enlargement period, excluding system operating efficiency.
- Maximum and minimum planted areas as well as planting risk behaviour associated with the enlarged Pindari Dam. These are based on historical data and information collected through the Border Rivers Irrigators Survey.
- Pump Capacity applicable to Pindari Dam post-enlargement period to service additional area developed in response to Pindari Dam enlargement (based on the conditions that existed at 1999/00).
- On-farm storage capacity and operation as existed in 1993/94.
- The mix of crop types as observed during the 1990 – 1998 period.
- Irrigation efficiencies as observed up to 1995/96 irrigation season
- Appendix F contains details of specific model configuration parameters for the Cap scenario.

5.2 Climate Data

5.2.1 Rainfall

For the long term Cap scenario and the Cap Audit scenario, rainfall stations selected during calibration were extended with SILO patched point data for the intended simulation period.

5.2.2 Evaporation

For the long term Cap Scenario and the Cap Audit Scenario, the evaporation data for all stations except Glenlyon and Pindari Dams was extracted from the SILO data base, which provides long-term, gap-filled data.

For both Glenlyon Dam and Pindari Dam, we used the all the available record in excess of 30 years of daily evaporations and the long-term rainfall records from HYDSYS to generate long-term evaporation. This method is based on a relationship between historical monthly evaporation totals and number of rain days in the month using the rainfall station listed in Table A.7.

5.3 Flow data

5.3.1 Stream-flows

For model scenario runs, the main-stream flows are no longer required because the flows within the system are simulated based on the dam releases, gauged and ungauged tributary inflows, and the calibrated routing and losses.

The rainfall and evaporation stations selected for Sacramento rainfall-runoff modelling (Appendix A) were extended to cover the intended simulation period.

The tributary gauges selected for use in the model (Appendix A) do not have a long enough period of record to cover the full period of intended model simulation (from the 1890s to date). However, the climate data input was used with the Sacramento rainfall-runoff models to extend the tributary flow estimates over the intended simulation period. Long term ungauged catchment inflows were then derived based on applying the methodology outlined in Section 3.3.3.

5.3.2 Headwater Dams Inflows

To derive the required long-term inflow sequence to both Glenlyon and Pindari Dams, the OIC sheet mass balance approach was no longer sufficient alone as these records only began after these storage were built in 1976 and 1969 respectively.

5.3.2.1 Inflow to Pindari Dam

The long-term inflows to Pindari Dam were produced by assembling a model of the upstream sub-catchments. This model consists of a single calibration reach (Table B.1) with one gauged inflow location (Table A.9) and one ungauged inflow locations (Table B.2).

The upstream Pindari Dam flow calibration reach begins at gauge 41039 (Severn River @ Strathbogie). The recorded flow at that gauge is routed to the Dam and calibrated to the back-calculated Pindari Dam inflow derived as described in Section 3.3.5.1. The minimum concurrent period 1974-2003 of recorded data at gauge 416039 and back calculated Pindari Dam inflow, was used for calibration. A comparison of the simulated versus back-calculated inflows for the period of data available to the date presented in Figure 5.1 and Figure 5.2.

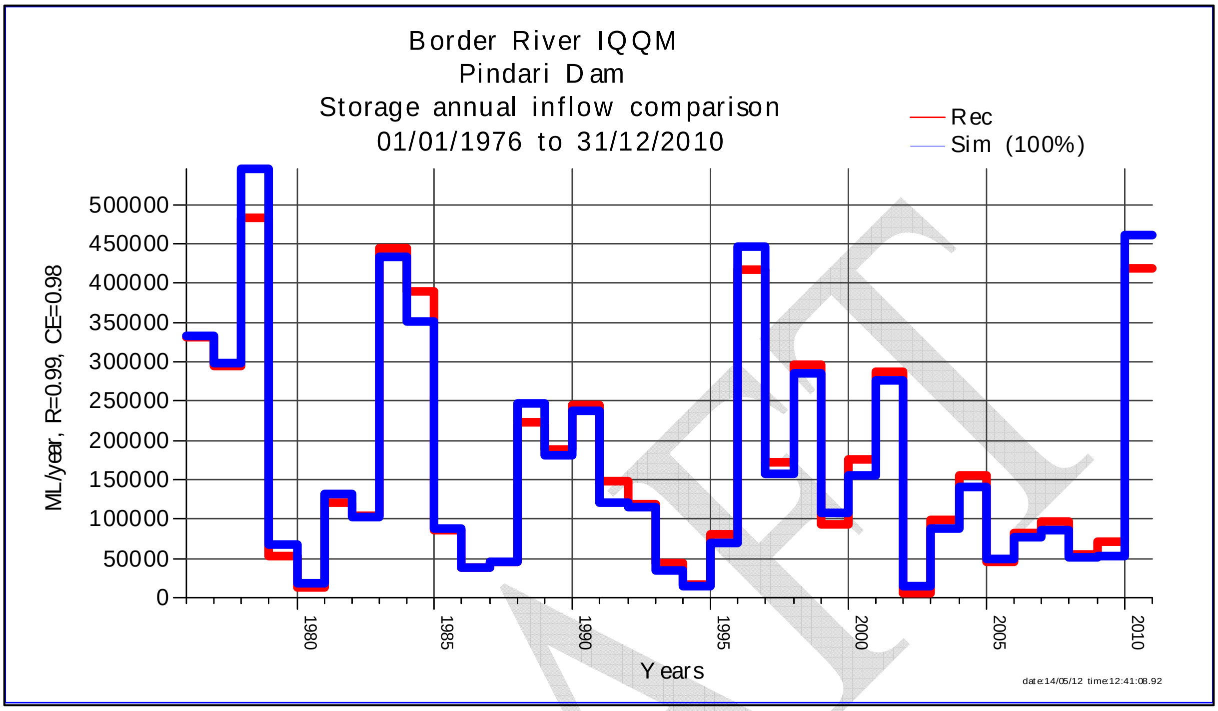


Figure 5.1: Comparison of OIC and simulated Pindari Dam inflows for 1980 to 2004

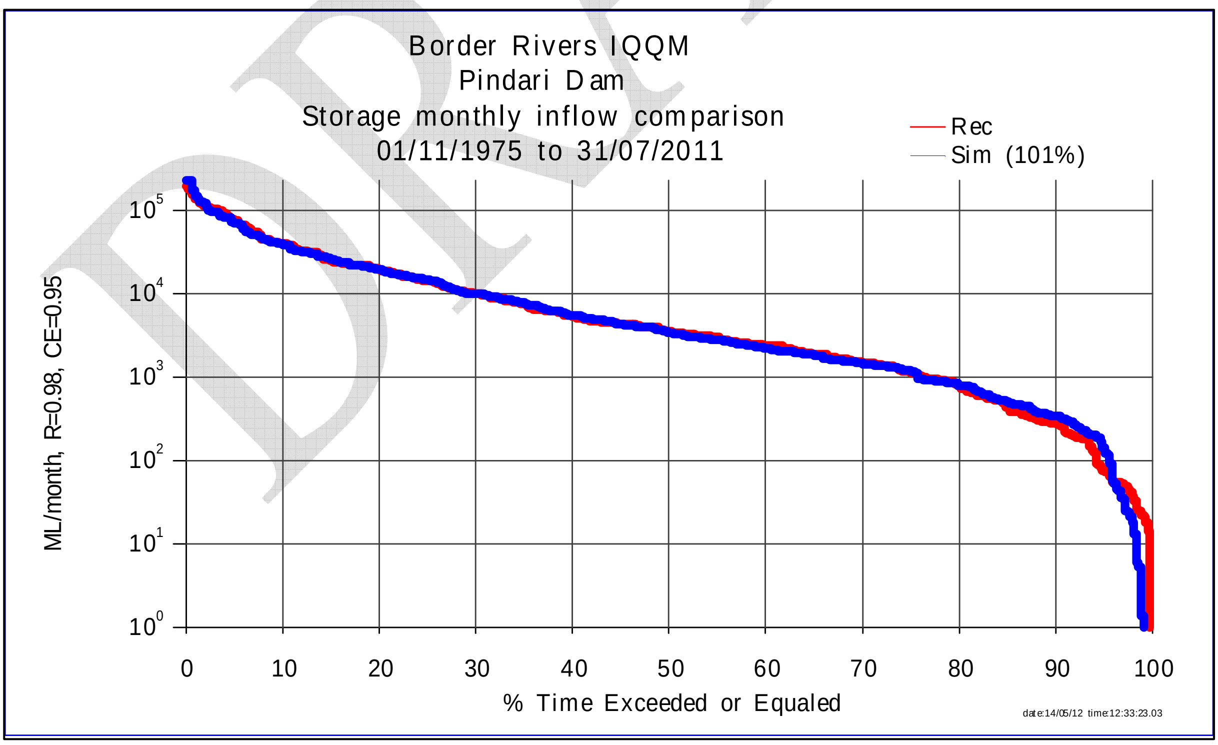


Figure 5.2 Comparison of OIC and simulated Pindari Dam inflows for 1980 to 2004.

Once the upstream model was calibrated, a Sacramento model for the gauged sub-catchment upstream of the dam was calibrated to the available observed data. Long term SILO rainfall and evaporation data was extracted for the climate stations used in the Sacramento model to generate long term runoff and gap-fill and extend the observed data for the simulation period. The combined long term flow at the Strathbogie sub-catchment of recorded and Sacramento generated flow, was then used as input to the upstream Pindari Dam model to generate a long term inflow sequence to Pindari Dam.

5.3.2.2 Inflow to Glenlyon Dam

The long-term inflows to Glenlyon Dam were estimated by back calculation and extended with Sacramento rainfall-runoff modelling. Daily operational records of valve release rates and estimates of dam spills were used to create a time series of total dam releases. These dam releases were used along with records of storage levels, rainfall and evaporation to back-calculate the time series of dam inflows by mass balance from 1976.

To extend these back calculated inflow data with flows at the Dam site prior to 1976 for long-term model simulations, a Sacramento model to generate Glenlyon Dam inflow was developed. Recorded rainfall and evaporation data at the dam site was used an input to the Sacramento model, and calibrated against the back-calculated inflows. Long term Sacramento runoff was then generated and used to extend the back-calculated data to cover the simulation period starting in 1890.

5.3.2.3 Inflow to Coolmunda Dam

Although, Coolmunda sub-system is an integral part of the BRS, Macintyre Brook IQQM has been configured independently and currently run for each specific scenario as stand alone model. Outflow from the Macintyre Brook IQQM is used as inflow into the BRS IQQM.

The long-term inflows to Coolmunda Dam were produced by assembling a model of the sub-catchments upstream of Coolmunda Dam. This model consists of a single calibration reach (Table B.1) with two gauged inflow locations (Table A.8) and two ungauged inflow locations (Table B.2).

The upstream Coolmunda Dam flow calibration reach is between gauges 416410 (Macintyre Brook @ Barongarook) and 416404 (Bracker Creek @ Terraine), and Coolmunda Dam. The recorded flow at both gauges was routed to the Dam and calibrated to the back-calculated Coolmunda Dam inflow derived as described in Section 3.5.4.1. All of the available observed data at both of these gauging stations over the minimum concurrent period with back-calculated data of inflow to Coolmunda Dam was used for calibration

Once the upstream model was calibrated, Sacramento models for the gauged sub-catchments upstream of the dam were calibrated to the available observed data. Long term SILO rainfall and evaporation data at each climate station was used in the Sacramento model to generate long term runoff for gap-filling and extending the observed data at both gauging stations upstream Coolmunda Dam to cover the simulation period. The long term flow from the Barongarook and Terraine sub-catchments was then used as input to the upstream Coolmunda Dam model to generate a long term inflows to Coolmunda Dam.

5.4 Irrigation Information

Wherever possible, observed data was used to configure the model for physical infrastructure including pump capacities and on-farm storages. Irrigation parameters such as crop irrigation efficiency were determined during model calibration. A full listing of the parameters describing the BRS IQQM Cap scenario is presented in Appendix F

5.4.1 Irrigation licences

The irrigation water share volume in 1993/94 was used for the Cap scenario (Appendix F).

5.4.2 On-Farm Storage Infrastructure and Usage

The OFS parameters are derived based on a combination of available data, calibration and consultation with irrigation representatives

5.4.2.1 Capacity

The on-farm storage capacity for the 1993/94 irrigation season, and pump capacities based on the conditions that existed in BR Queensland in 1993/94 and in BR NSW at the start of 1999/00 were used for the Cap scenario. These are detailed in Appendix F.

5.4.2.2 Reserves

The best calibration and validation results for the period 1990-95 was achieved with the monthly OFS reserves varying from 0.0-0.4 ML/ha in winter, and from 0.8-2.7 ML/ha for the rest of the year, with the highest values during the main irrigation season from October to February. OFS reserves were similar for irrigator groups from both sides of the river, and tended to increase with the distance from the headwater storages.

The adopted single set of monthly OFS reserves for each irrigation node in the Cap scenario is presented in Table F.7. Adopting these values effectively includes all relevant data and considers the irrigators' behaviour representative of that time as ascertained by the user-surveys [Border Rivers Irrigators Survey and Pers. communications, 2003-2004].

5.4.2.3 Airspace

The best calibration and validation results for 1987-95 period was achieved with the OFS airspace set to zero. Severe drought conditions between 1993 and 1995 did not help to calibrate OFS airspaces with any more precision as on-farm storages remained empty most of the time over that period. Even for a wet period that followed, i.e. 1997 to 2000, model with OFS airspace set to zero across all the irrigator groups achieved good calibration Section 3.3.4.6. Therefore, zero OFS airspace for each irrigation node was accepted in the Cap scenario (Table F.8).

This may indicate that recorded OFS capacity prior to 1993/94 is underestimated by about 5% to10%, the values which are suggested as common by irrigators when managing their farms [Border Rivers Irrigators Survey and Pers. communications, 2003-2004. Another possible reason is that rainfall harvesting was not modelled during the calibration for reasons explained in Section 3.5.3.3, meaning that irrigation tail-water and farm runoff was not accounted to supplement diversions. Consequently, to achieve a satisfactory demand calibration result, additional water was required from the river to compensate, and to accommodate that water extra space in the OFS was needed. Given, that volumes of the recorded ONA and SW diversions matches recorded volumes well (Section 4.2) the additional water diverted to satisfy crop requirements has to be FPH.

5.4.2.4 Rainfall Harvesting

Information collected in the 2003 Survey indicated a wide spread irrigator practice to harvest runoff from their developed area using a mixture of pumped and gravity fed runoff harvesting. For the recalibration, the model was configured for rainfall harvesting using this information. However, due to undocumented software features, the rainfall harvesting function remained disabled during the model re-calibration, and this was not discovered till after the model was re-calibrated. Best calibration results were achieved without representing rainfall harvesting in the model. Therefore, rainfall harvesting is not represented for the Cap scenario.

We have anticipated, however, that since we have achieved a good water balance in the model by matching simulated ONA and SW diversions to the recorded diversions, the effects of rainfall harvesting are compensated by other calibrated parameters such as OFS airspace and FPH diversions.

5.4.2.5 Floodplain Harvesting

The floodplain harvesting configuration adopted for the Cap scenario was based on the configuration required to calibrate for the period 1987/88-1999/00 period. Adopting this configuration effectively includes all relevant data and considers the irrigators' behaviour at that time as ascertained by the user-surveys [Border Rivers Irrigators Survey and Pers. communications, DLWC 2003-2004]. The adopted FPH parameters for each irrigation node in the Cap scenario are presented in Table F.6.

5.4.3 Cropping Information

There are a number of important cropping information parameters that require configuration in an IQQM simulation. Some of these parameters are derived during calibration, including an indication of the relevant farmers' risk and planting decisions at the time. Other parameters are based on historical data, such as crop mix.

5.4.3.1 Crop 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 on each side of the 1993/94 before determining the best crop mix to adopt for the Cap scenario.

Different sources of data analysed agree that historically Cotton has historically been the dominant crop in the Border Rivers Valley. Over the period 1988/89-2000/01, cotton was on average 88% of the area of total irrigated crops in NSW, and 79% in QLD. The proportion of total area remained practically unchanged after Pindari enlargement in NSW, whereas it increased from 72% to 87% in QLD for the same period.

Table 2.7 shows that the NSW crop mix from 1987/88 to 2000/01 was very consistent. Despite very low AWDs for the period 1991/92-1995/96 (Figure 2.13), the crop mix did not show any significant change, although there is an apparent increase in winter crop in these years. A weighted average of the crop mix from areas over the period 1990/91-1997/98 was considered representative of the behaviour under 1993/94 conditions and adopted for the Cap scenario (Figure 5.3). This results in an overall NSW BR valley crop mix of approximately 90% Cotton, 4% winter crop, 1% summer cereals and about 5% of perennial crops including Lucerne and other pastures. The crop mix adopted at each irrigation node remains constant for the entire simulation period and it as presented in Table F.4.

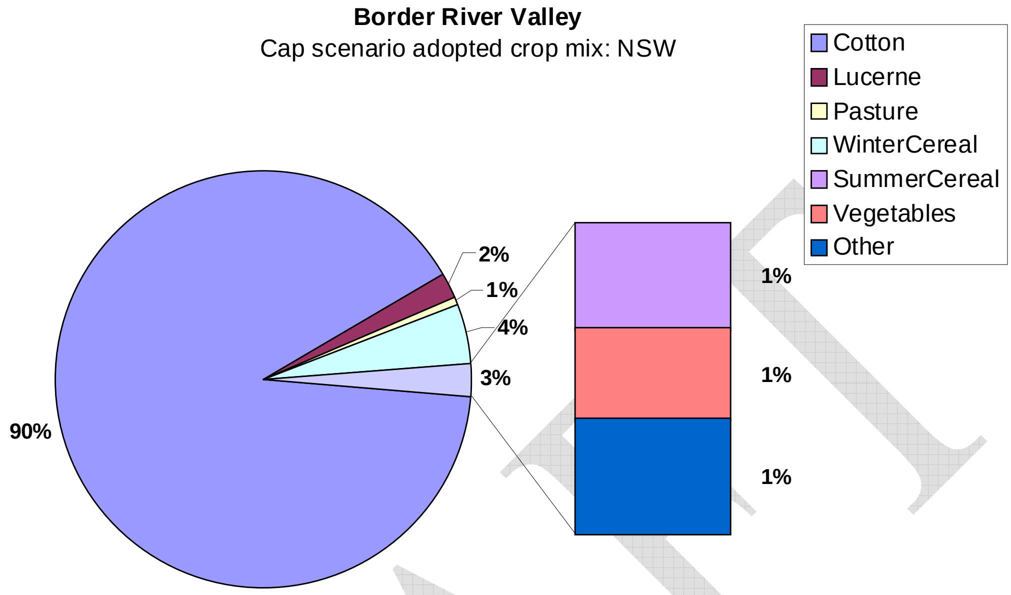


Figure 5.3 **NSW crop mix adopted for the Cap scenario.**

The history of QLD crop mix (Table 2.6) shows a steady increase in the proportion of cotton over the period 1985/86-2000/01, steadying between 75-80% over the period 1990-1995/96. There is very little variation in crops grown in QLD BR around 1993/94 irrespective of AWD. A weighted average of the crop mix from areas over the period 1992/93-1995/96 was considered representative of the behaviour under 1993/94 conditions and adopted for the Cap scenario (Figure 5.4).

This results in an overall QLD BR valley crop mix of approximately 78% Cotton, 6% winter crop, 4% summer cereals, about 12% of perennial crops including Lucerne (6%) and other pastures (4%) and 2% of vegetables. The crop mix adopted at each irrigation node remains constant for the entire simulation period and it as presented in Table F.4.

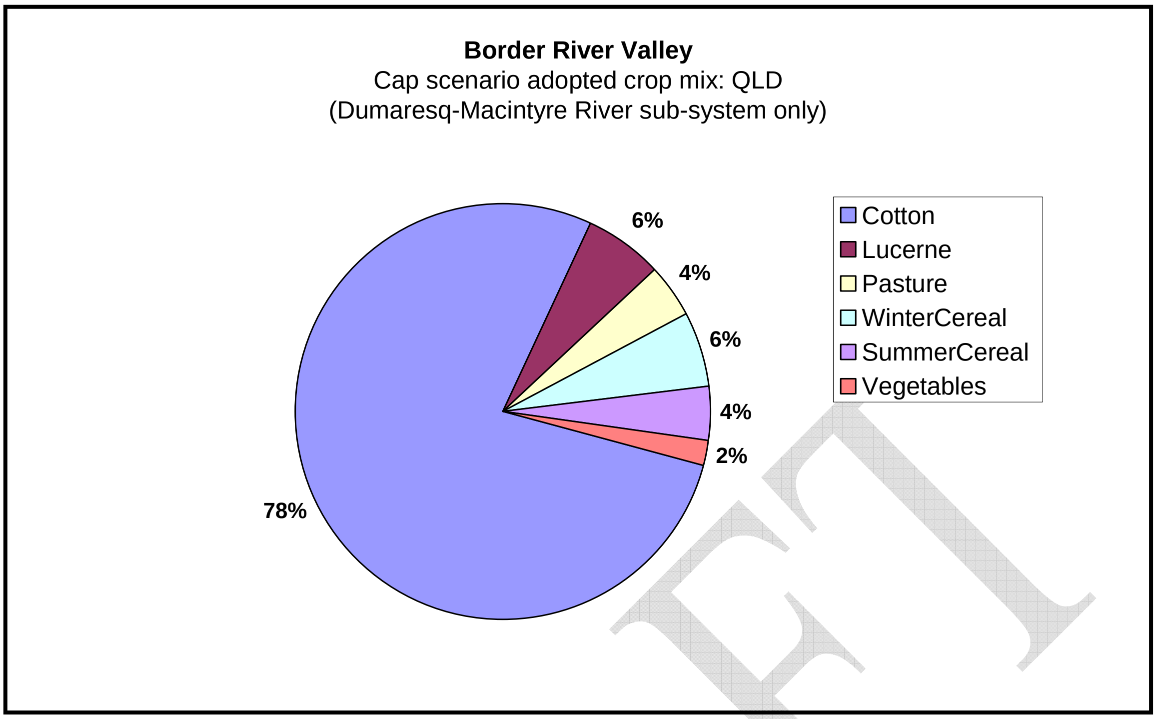


Figure 5.4 QLD crop mix adopted for the Cap scenario.

5.4.3.2 Maximum area

The maximum planted area is specified in IQQM to represent the most that irrigators would plant given sufficient resources available. In reality this is not always the case and there will be some variation from year to year, even if economic conditions remain largely unaltered. This is thought to be due to the need to rotate land on the farms, and variations in local climate affecting soil moisture at the planting decision dates.

Determination of an appropriate maximum area to adopt for the Cap scenario in IQQM is not a simple process, and needs to consider:

- climatic variability;
- historical increases in development;
- variation in irrigators' behaviour both for each individual from year to year and from individual reach to individual reach, due to any number of reasons including economic factors;
- variations in figures obtained from different data sources.

Inclusion of the enlarged Pindari Dam in the Cap complicates the process even further as it is difficult to determine what time frame should be allowed for the enlargement of the Pindari Dam to take its full effect in terms of developing new areas for irrigation. An examination of cropped area trends in Figure 5.5 shows that the maximum areas that have been planted in the NSW Border Rivers increased significantly since the enlargement of Pindari Dam. It is also evident that the available resources in the period following the Pindari enlargement are sufficient to plant a larger area. Both Pindari and Glenlyon storages spilled several times in the late 1990s, and Pindari storage was above 70% until end of 2001. However, the observed data indicates that the total area planted for the years after post Pindari Dam enlargement increased to new levels, and has since been relatively stable.

The observed data was analysed for all years up to and including the 2000/01 irrigation season and the maximum area for each node was estimated based on the maximum observed area in any one of these years, which for the majority of irrigator groups in NSW, was in the 1999/00 season, by which time the full effect of the Pindari storage enlargement had been realised.

To determine an appropriate maximum area for QLD Glenlyon system to use in the BRS IQQM Cap scenario, we concentrated on the period 1991/92-1997/98. Considering the period 1993/94-1995/96 was severely affected by the resource availability, the full effect of development taking place in early 1990s can be seen only in last two years of that period. Practically identical areas reported in those two years (Figure 5.6) suggest this area would be very good indication of maximum area developed in mid 1990s.

There was little information available on planted winter areas. As discussed in Section 3.5.5.1, we did not estimate farmers risk for winter crops. In BR IQQM the planting decision for both summer and winter crops is made on the same date in accordance with the crop mix specified, and total maximum area adopted includes maximum winter crop area.

Consideration of these issues resulted in an appropriate maximum total valley planted area for the Cap scenario in the BRS IQQM of about 61,200 ha, with NSW and QLD accounting for 40,000 ha and 21,200 ha respectively. This figure includes both summer and winter crops irrigated from regulated water supplies. Each state's total maximum planted area is disaggregated for each irrigation node independently (Table F.2) and remains constant for the entire simulation period.

5.4.3.3 Minimum area

The concept of a minimum planted area is based on the notion that, during severely resource constrained seasons, irrigators will still not continue to reduce their planted areas. This is assumed to be the result of a number of factors which include the need to keep perennial crops such as Lucerne alive, the costs associated with replacing them, and an attempt to maintain a minimal amount of production from opportunistic resource availability to provide cash flow. We also recognise that if there is no resource available at all, then there would be no planted area. This behaviour is consistent with that reported during the irrigators' surveys (Table 3.2).

Determination of an appropriate minimum area to adopt for the Cap scenario in IQQM is not a simple process and needs to consider:

- climatic variability;
- historical increases in development;
- variation in irrigators' behaviour both for each individual from year to year and from individual to individual, due to any number of reasons including economic factors;
- variations in figures obtained from different data sources.

Specifically in the BR IQQM, we considered the following issues:

1. With the exemption of 1994/95 season in NSW BR there was not one year of 0% AWD. This was largely because of the introduction of "60ML A/B Priority Scheme" in 1986. Only in 1994/95 did the 20,880ML of A Class GS entitlement (i.e. 8% of total GS entitlement) not receive their full allocation for the first time in recorded entire history.

2. The AWD for B Class entitlement did not exceed 40% till 1996/97, i.e. the first season when the effect of enlarged Pindari was noticed. With such low AWD and little or no opportunity to store or harvest water from other sources in and around 1994/95, we would expect the historical minimum planted area planted then to be reasonably indicative of the true minimum area up to that date;
3. The minimum total valley planted areas in the years from the mid-1980s up to 1994/95 yields a figure of 10,400 ha and 7,500 ha for NSW and QLD respectively in 1994/95 based on BRFF’s data (Table 2.5).
4. The minimum individual irrigator planted areas in the years from the mid-1980s up to 1994/95 indicates that the 1994/95 season was also a reasonably good indication of the minimum individual planted areas.
5. There was little information available on planted winter areas. Discussion with irrigation representatives indicated that an appropriate minimum winter area is 0 ha;

Consideration of these specific issues resulted in an appropriate minimum total valley planted area for the Cap scenario in the BR IQQM of 17,900 ha, with 10,400 ha in NSW and 7,500 ha in QLD.

5.4.3.4 Farmers’ risk function

The concept of a farmers’ risk function is that a certain ML/ha will be needed to meet the crop water requirements. This application rate plus current water in any on-farm storage plus any groundwater resources, together with expected rainfall and surplus water during the growing season, will in total, meet the crop water needs. In reality, the farmer determines an appropriate ML/ha at the start of each irrigation season to decide how much area to plant based on the amount of resources available.

Determination of an appropriate farmers’ risk function to adopt for the Cap scenario in the BR IQQM is not a simple process and needs to consider:

- the full range of climatic variability and resource availability;
- historical increases in development;
- variation in irrigators’ behaviour both from individual to individual and from year to year, due to any number of reasons including economic factors;
- variations in figures obtained from different data sources.

This process is a combination of calibration (Section 3.5.5) and consideration of the fact that the irrigators’ planting risk can vary over time. We need to examine years that are representative of the scenario being configured. For the BR Cap scenario, we chose to focus on the period 1995/96 to 1999/00 to derive an appropriate risk function for each of the irrigator node as calibration has confirmed consistent irrigator behaviour throughout this period, which also was in line with the Pindari storage enlargement. Therefore, we used the parameters derived during area calibration over this period for each individual irrigation node (Section 3.3.6.4).

There was little information available on planted winter areas. Discussion with irrigation representatives and a review of the cropping data indicated that the winter planting decision is governed by other factors than just available resource, such as likely water availability for the next summer crop, and the commodity prices.

The irrigators' planting risk can vary over time and, therefore, we need to examine years that are representative of the scenario being configured. For the BR Cap Scenario, we chose to focus on the period 1995/96 to 1999/00 to derive an appropriate risk function for each of the irrigator node as calibration has confirmed consistent irrigator behaviour throughout this period, which also was in line with the Pindari storage enlargement. Therefore, we used the parameters derived during area calibration over this period for each individual irrigation node.

There was little information available on planted winter areas. Discussion with irrigation representatives and a review of the cropping data indicated that the winter planting decision is governed by other factors than just available resource, such as likely water availability for the next summer crop, and the commodity prices.

As discussed in Section 3.5.5.1, we did not estimate farmers risk for winter crops. In BR IQQM the planting decision for both summer and winter crops is made on the same date in accordance with the crop mix specified. Consequently, an appropriate application rate in deciding how much winter crop to plant was determined such that the average winter planted area of about 1,300 ha on each side of the Border Rivers was achieved in the long term simulation (it should be noted that these figures do not include perennial crops).

The weighted average total BR NSW risk function and BR QLD for the Cap scenario are presented in Figure 5.5 and Figure 5.6 respectively. The risk functions derived for each irrigation node are presented in Table F.3.

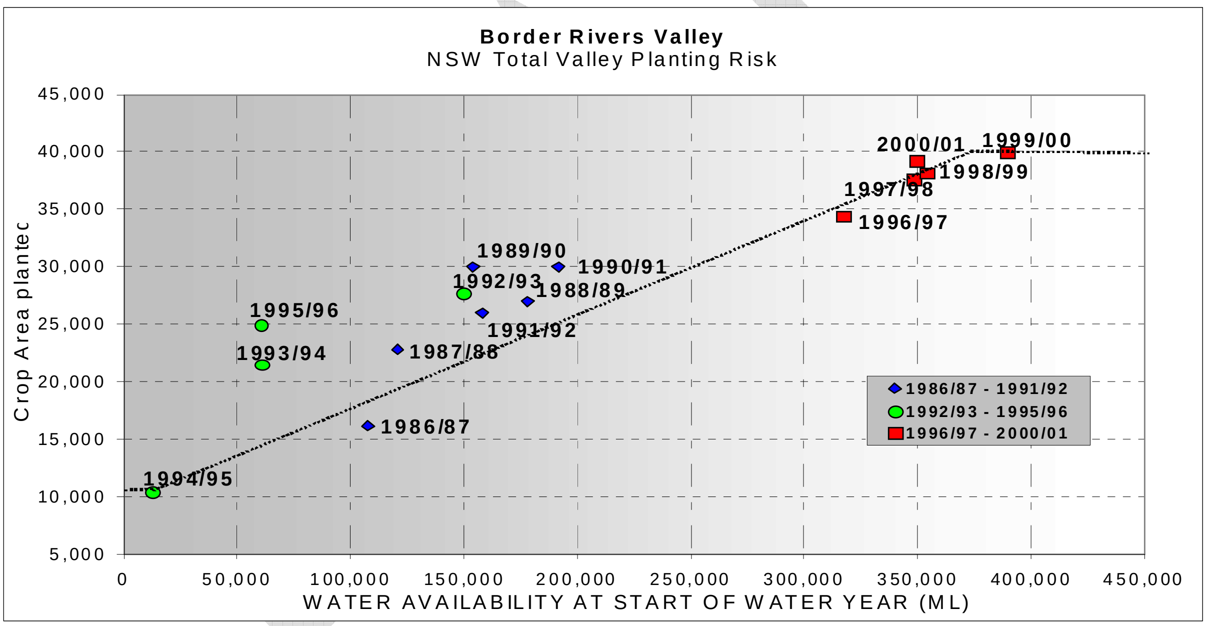


Figure 5.5 **Historical and adopted BR NSW planting risk for the Cap scenario.**

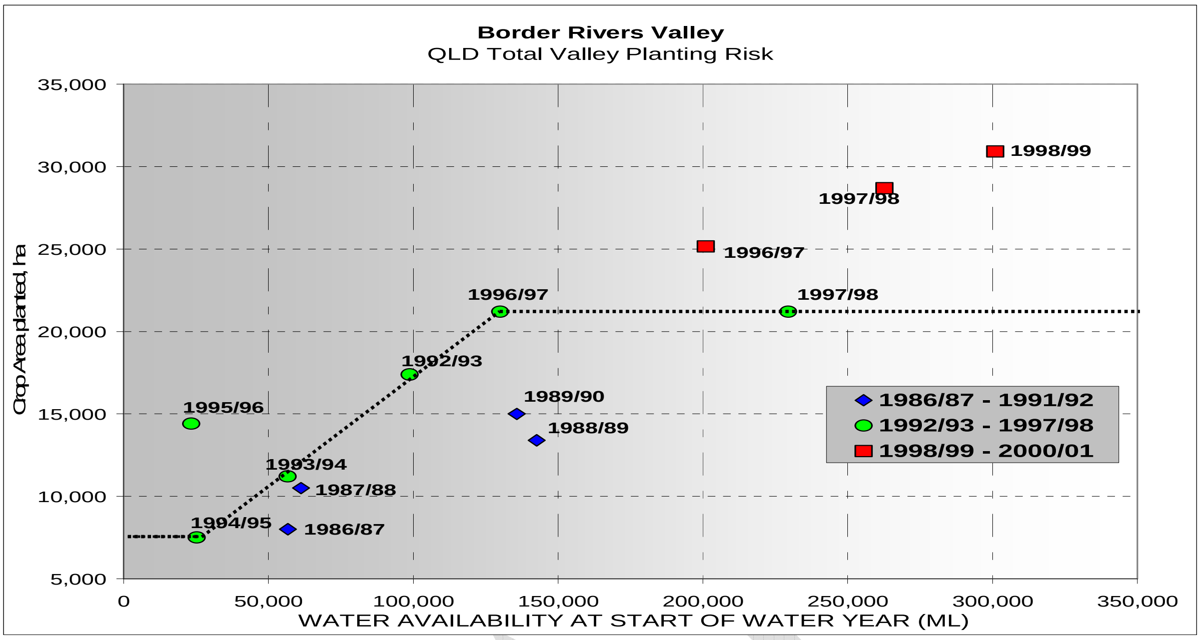


Figure 5.6 **Historical and adopted BR QLD planting risk for the Cap scenario.**

5.4.4 End-of-Year Diversions

The BRS has significant on-farm storages, and the observed diversion data shows evidence of ordering on-allocation water in September. This water is either directly applied to fallow ground prior to crop planting (pre-watering) or stored in the on-farm storage for use after the crop has been planted (watering up). This behaviour is generally for the benefit of the crops, but also due to a use-it-or-lose it mentality, which is typical under annual accounting system.

Following advice from the irrigators [DLWC, 2003-2004] we configured the BR IQQM Cap Scenario to use end-of-year diversions (in September) for pre-watering of the following season's crops. All irrigation nodes order water for pre-watering provided there is remaining balance in their accounts. The target application rate used to calibrate the model varies between 1-2 ML/ha, with the calibrated figures implemented in the Cap scenario.

5.4.5 Transfer Market

Summaries of temporary trade within the valley prior to Pindari enlargement indicate that, on average, around 1% of the total valley entitlement was traded annually, with a maximum of around 2%. Since the Pindari enlargement, temporary trade of up to 5% of valley entitlement has been traded on an annual basis. IQQM is not capable of modelling the temporary trade activities of irrigators explicitly. Nevertheless, the impacts of this trade still need to be considered as temporary trading between irrigation groups may be important to the sustainability of the observed planted areas.

Although, model calibration process did not indicate significant permanent market transfers, to achieve overall diversion calibration in some years of the calibration period, entitlement from some NSW irrigator nodes had to be transferred to nodes which appeared not to have sufficient entitlement for suggested volumes of recorded diversions. It cannot be concluded with certainty that this was a physical trade, as it is quite possible that this is a result of inaccuracies in diversion and/or planted area figures disaggregated between those reaches.

By contrast, about 12,000 ML of entitlement had to be transferred in the model from upstream of Dumaresq – Macintyre Rivers junction to downstream of it between the QLD irrigation groups in order to achieve satisfactory model validation results on irrigator by irrigator basis. Since there was no credible data on where traded licence volume may be transferred to, no market transfers were assumed in the BRS IQQM.

5.4.6 High Security Irrigation

There are only two NSW licences with high security irrigation entitlements, totalling around 350 ML. These were considered too small to represent individually in the model and have instead been amalgamated into the nearest irrigation node. Similarly, there were no HS licences with any significant entitlement in the QLD BR prior to 1993/94. As in the case of NSW BR any minor HS entitlements, which typically belong to an irrigator with larger GS entitlement, were lumped together with that GS entitlement. Consequently, no HS irrigation is explicitly represented in the BRS IQQM.

However, all licences in the NSW BR have a component of A Class GS entitlement totalling 20,880 ML, and this is configured in the Cap Scenario (Appendix F).

5.4.7 Unregulated use

NSW unregulated access entitlement holders diverting water from unregulated streams have not yet been included in the BRS IQQM. These licences have been operating on the basis of a maximum authorised irrigable area, and a lower flow limit for pumping. Tributary inflows used in the BRS IQQM have been calibrated using observed stream-flow at gauging stations over a variety of periods. The inflow data includes the effect of diversions by unregulated licences. Other than that, there is very little data collected regarding unregulated entitlement diversions and cropping.

For the purposes of determining Cap for the regulated NSW Border Rivers system, this effect has been deemed to be negligible. Consequently, the Cap Scenario described in this report only relates to the regulated system. If sufficient information should become available, the model could be expanded to represent unregulated licences.

A number of QLD unregulated licences that had been modelled in the BR IQQM in the Callandoon Creek and in the Weir River catchments. Total of six and eleven nodes have been used to represent these unregulated users in each catchment respectively.

5.5 Town Water Supply

There are seven towns of the Border Rivers Valley that have been represented in the BR IQQM with total entitlement of about 3 GL. Three of NSW towns include Ashford, Boggabilla, and Mungindi, which have a total entitlement of approximately 1,494 ML. Four Queensland towns include Yelarbon, Texas and Goondiwindi with a total entitlement of about 1,880 ML are supplied from the Glenlyon Dam, with Inglewood’s entitlement of 488 ML supplied from the Coolmunda Dam. This annual entitlement is set at 1993/94 levels, as some TWSs have increased over the years.

Records obtained from the relevant Shire Councils indicate that these TWS generally use their full entitlement, so these figures are adopted in the Cap scenario. Their diversions have been modelled using a fixed daily pattern of demand based on available monthly figures. The monthly pattern of demands for each of these TWS is shown in Table 5.1.

Table 5.1 Monthly pattern of TWS demands (ML)

TWS	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New South Wales												
Ashford	14	12	17	14	12	10	11	10	11	11	18	15
Boggabilla	36	33	36	27	17	14	14	19	23	31	33	38
Mungindi	122	111	111	69	46	46	46	50	73	103	103	138
Queensland												
Yelarbon	12	10	12	10	7	7	5	5	7	10	10	11
Texas	31	25	34	23	17	13	14	14	18	28	31	28
Goondiwindi	175	136	163	115	82	123	70	83	115	138	141	160
Inglewood	54	47	54	47	32	31	24	24	33	45	46	50

5.6 Stock and Domestic Supply

There is around 1.2 GL of stock and domestic entitlement in the Border Rivers Valley. This use has been incorporated implicitly in the representation of irrigation licences and TWS in the model. There is no explicit representation of this use within the model**.**

5.7 Industrial and Mining Diversions

There are no significant industrial or mining diversions in the BRS. Although, Johnstone's Quarry in the Macintyre Brook sub-system used often substantially more than its entitlement of just 10 ML (ex., up to about 265 ML/year in 1991/92) [DLWC, 1999[a]] there was not sufficient diversion data to allow its separate configuration in the BRS IQQM. If more diversion information becomes available, then these can be modelled explicitly in the BR IQQM. Consideration of this issue will be part of future model improvements (Chapter 6:).

"North Power" thermal station which was required about 20 ML/d from Pindari Dam ceased to exist by 1995, and therefore was not represented in the Cap scenario.

5.8 Groundwater Access

No groundwater access has been represented explicitly in the BRS IQQM Cap scenario. Consideration of this issue will be part of future model improvements (Chapter 6:).

5.9 Resource Assessment

The information required to make resource assessments for the BRS was obtained from regional sources and configured into the BRS IQQM. It should be noted that only the outflow from Macintyre Brook sub-system simulated by a specific scenario of the stand alone model is used as inflow to BR IQQM (Section 5.3.2.3). Consequently, Coolmunda Dam is not explicitly included in the Cap Scenario.

The main features of the resource assessment system considered in the Cap Scenario are listed below:

- Glenlyon Dam and the enlarged Pindari Dam are the headwater storages;
- Annual accounting with carry over reset to zero at the start of March;
- Both states have a single allocation system;
- Maximum AWD of 100% for both states;
- No borrow from the following year's balance;
- The transmission/operational losses are a function of the AWD and time of the year, with the maximum allowance being 9 GL/year for Severn-Macintyre sub-system only and 38 GL/year for river sections with access to both headwater storages;
- System resource and transmission loses are shared between the NSW and QLD 57:43;
- The maximum storage reserve for each of the two headwater storages is 150 GL between months of April and September inclusive.

More details relevant to the resource assessment are listed in Table F.1.

5.10 River and Storage Operation Rules

5.10.1 Tributary utilisation

Derived during the 2003 model re-calibration tributary utilisation parameters were adopted for the Cap Scenario. Their values are presented in Table B.6.

5.10.2 Operational surplus

The over-order factors developed during 2003 model re-calibration were adopted for the Cap Scenario

5.10.3 Flood mitigation releases

Both Glenlyon Dam and Pindari Dam are operated as the headwater storage nodes with maximum spillway discharge capacity of 380 GL/d and 1,890 GL/d respectively.. Relationship between Storage Volume and Spillway discharge for each of these dams adopted in the model calibration has been specified as advised by SW. The storage level the spillway becomes operational is 253.6 GL for Glenlyon Dam and 312 GL for Pindari Dam. The same relationship for each of the dams has been adopted for the Cap Scenario.

5.11 Supplementary Access

The Supplementary Water thresholds developed in calibration (Section 3.5.3.2) and described in Table F.5 were adopted for the Cap Scenario.

5.12 River Flow Requirements

No flow constraints were configured in the BRS IQQM Cap Scenario.

5.12.1 Minimum flows

The minimum flow requirements described in Section 2.11.1 are representative of the development condition prior to Pindari enlargement works and have been configured in the original 1998 BR IQQM calibration. The minimum flow requirements described in

Section 2.11.3 correspond to BR WSP plan. These requirements were not appropriate to be represented in the BR Cap Scenario.

The minimum flow requirements, which have been configured in the BR Cap Scenario are those recommended by the environmental study of the enlarged Pindari Dam [DWR, 1991a] are described in Section 2.11.1 and are summarised in Table 5-2.

Table 5-2 Environmental releases from enlarge Pindari Dam

July-March		April-June	
Q_{in} (ML/d)	Q_{out} (ML/d)	Q_{in} (ML/d)	Q_{out} (ML/d)
>150	150	>50	50
10-150	Q_{in}	10-50	Q_{in}
<10	10	<10	10

The study also recommended a stimulus flow of 400 ML/d for at least two days with at least two days of both rising and falling stages whenever 400 ML/d or greater releases have not occurred in the preceding three month period. This specific environmental flow release rule is not represented in the Cap Scenario, and will be part of future model improvements (Chapter 6:).

5.12.2 Stock & domestic replenishments

The stock and domestic replenishment requirements for Boomi River described in Section 2.11.2 were configured in the Cap Scenario as antecedent conditions based release volumes made over a number of days in October, January and May as required. These releases are triggered if the specified replenishment volume has not arrived at this location in the three months preceding the replenishment dates. The replenishment release is made until either the total flow volume at that location, including those in the preceding window equate to the target replenishment volume of 10,000 ML/year or there is no water left in the account for the replenishment.

5.12.3 Environmental flows

There were no specific environmental flow rules (other than those listed above in the Section 5.12.1 in the BRS under the adopted Cap Scenario management rules.

5.13 Cap simulation model validation

Because of the complexities with the Cap Scenario in which some elements representing 1993/94 historical conditions are combined with other development aspects and operational rules represent conditions after 1995/96 (Section 5.4 and Section 5.9), it is unrealistic to expect any close match between historical data over the period around 1993/94 (i.e., form the late 1980s to the late 1990s) and the simulation results from the Cap scenario model run continuously over that period. Severe drought conditions for the period 1992/93-1995/96, development constraints in years prior to that and numerous changes in the system operation rules over that period discussed in Section 3.3.2 prevented any meaningful Cap Scenario model validation. It would most certainly not do the Cap Scenario model justice.

Model parameters recalibrated or validated during the 2003 model re-calibration have been adopted as appropriate for use in the BR Cap scenario.

5.14 Cap simulation model results

5.14.1 Long term Cap annual diversions

Table 5-3 summarises the model results for the Cap Scenario simulated for the long-term period 01/01/1890-30/06/2010.

Table 5-3 Summary outputs from the Cap scenario (system file N99934R5.s7_)

Category	Component	Average Annual Result	Unit
Water usage	General Security Diversions	110	GL/y
	Supplementary Access Diversions	85	GL/y
	High security/stock & domestic/town water supply Diversions	1	GL/y
	Floodplain Harvesting	3	GL/y
	Rainfall-runoff Harvesting	-	GL/y
	Total	199	GL/y
Planted Area	Average General Security Summer Planted Area	27,018	ha/y
	Maximum General Security Summer Planted Area	33,196	ha/y
	Average General Security Winter Planted Area	4,346	ha/y
	Maximum General Security Winter Planted Area	5,821	ha/y
	Years with Total Planted Area > 35,000 ha	52	%
Stream-flow	416011: Dumaresq River @ Roseneath	343	GL/y
	416012: Macintyre River @ Holdfast	404	GL/y
	416021A: Macintyre River @ Goondiwindi	794	GL/y
	416047: Macintyre River @ Terrawah	555	GL/y
	416048: Macintyre River @ Kanowna	344	GL/y
	416028: Boomi River @ Neeworra	188	GL/y
	416202A: Weir R. @ Talwood	115	GL/y
	Little Weir River	28	GL/y
	416001: Barwon River @ Mungindi	358	GL/y

Reliability				
AWD at 1st January (%)	100	75	50	25
Years with ≥ AWD (%)	38	53	67	97

Notes: (1) Long term average annual figures are based on the (01/10/1890 – 30/09/2010) period (October – September water year).

(2) This figure is used for long-term Cap assessment in Section 5.14.2.

(3) Summer area excludes perennial crops as it is estimated as difference between the total crop and crop alive in winter.

(4) For clarification, these figures indicate that there is a 39% chance of achieving an AWD of 100% under Cap conditions in the Border Rivers Valley.

5.14.2 2010/11 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 NSW BRS, the Cap simulation commenced at the start of the 1997/98 water year (October), 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 Cap levels.

To commence the Cap Audit Scenario, the simulation 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. OFS, and both Glenlyon and Pindari Dams stored volumes are set such that they are equivalent to observed levels at the start of the 1997/98 water year. Determining accurate historical starting volumes for the OFS is difficult as there is no good quality historical data available.

However, as the calibration model uses all known historical information for the calibration period as input, the simulated OFS volume results from the calibration model were considered the best possible estimate of the starting values.

The calibration model simulates the storage volumes prior to pre-watering for the 1997/98 water year of approximately 96,500 ML and 92,600 ML in NSW and Queensland (regulated system) respectively. As these figures correspond to maximum private storage capacity of in excess of 70% and considering OFS airspace, the simulated OFS volume is consistent with overall notion that OFS at the start of the 1997/98 irrigation season were near full. Based on the above consideration and in absence of detailed data, we adopted a starting total OFS volume in the regulated part of the entire BRS of about 189 GL at the start of the 1997/98 water year for the Cap Audit Scenario simulation.

The annual Cap simulation results for the 1997/98 to 2010/2011 irrigation seasons are presented in

Table 5-4 with a comparison to the observed data. These results show for the NSW Border Rivers Valley that the cumulative observed diversions are 366 GL below the diversions predicted by the model at the end of the 2010/11 water year.

Table 5-4 NSW Border Rivers Valley Schedule E Accounting to 2010/11

Water Year	Total Annual Diversions (GL)		Difference (GL)	Cumulative Difference (GL)
	Observed	Simulated		
1997/98	188	243	-55	-55
1998/99	167	206	-39	-95
1999/00	181	196	-15	-109
2000/01	240	220	20	-89
2001/02	192	307	-115	-204
2002/03	137	132	5	-199
2003/04	104	148	-44	-243
2004/05	115	186	-71	-314
2005/06	146	179	-33	-348
2006/07	139	67	72	-276
2007/08	127	118	9	-267
2008/09	126	143	-17	-284
2009/10	99	120	-21	-305
2010/11	163	224	-61	-366
Cumulative Total	**2,124**	**2,490**		**-366**
Long term average		**195**		
20% tolerance		**39**		

Notes: (1) Based on 9-months figure from 01/10/2002 to 30/06/2003 (due to change in water year).

(2) Annual figures from this year onwards are presented on July to June water year while figures for period from 1997/98 to 2001/02 inclusive are based on October to September water year.

(3) Average based on 1890/91 to 2010/11 period, as per Table 5-3.

(4) Not applicable because the Cumulative Performance is below Cap

Chapter 6: Improvement Plans

Maintenance of the BRS IQQM is an ongoing process and includes updating the model for:

- New 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 is 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 MDBC will be informed of the changes to the results and the reason why the changes have occurred.

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

6.1 Upgrades to the flow calibration

6.1.1 Extended Stream-flow Calibration

Since the outset of implementing the BRS IQQM, it was intended that the flow calibration of the individual reaches would be reviewed based on the availability of more recent and better quality stream-flow data. It is envisaged that this upgrading process would occur on approximately a five (5) year cycle. The flow calibration has not been updated since 2003 and, therefore does not include the recent drought period. This period could provide some useful information on losses at low flows and during dry periods. Reviewing the flow calibration is a large task because it involves the collection, analysis and disaggregation of flow data and diversion data for all reaches.

The calibrated Sacramento models used to extend the inflow data to cover the simulation period could also be reviewed based on new stream-flow information at the gauged tributaries.

6.1.2 Antecedent conditions based losses

Incorporation of antecedent conditions in river losses would take into account that losses are probably higher if they are preceded by a drought period as opposed to a period of floods.

6.1.3 Variable river surface area based on stream-flow

This will provide a better representation of varying evaporation from the water surface based on stream-flow and therefore better representation of the source of losses and gains in a river reach.

6.2 Upgrades to the demand and area calibration

6.2.1 Improved modelling of rainfall and floodplain harvesting

Both floodplain harvesting and rainfall runoff harvesting appear to be significant water resources used by some Border Rivers Valley irrigators. Calibration of the BRS IQQM was achieved, however, with only FPH represented in the model (Section 3.5.3.3). At this stage however, there is no detailed information on quantities of water accessed from these sources. Better monitoring and access to data would enable us to improve our representation of these processes in the Border Rivers IQQM.

6.2.2 Extended irrigation demand data

As for the flow calibration, it is also intended that the demand calibration would be reviewed based on the availability of more recent and better quality crop area and irrigation diversion data. NOW is currently reviewing collected area data with a view to centralising the databases and analysing the quality of the data. It is also possible that remote sensing capabilities may improve in the short to medium term, providing better estimates of cropped areas. This improved data may allow for recalibration of the Border Rivers IQQM in the future. It is envisaged that next upgrading process would occur with current WSP expires after 10 years in operation in 2014.

6.2.3 Crop modelling using crop model 3

This improved crop module will incorporate varying ‘windows of opportunity’ for planting, crop growth based on degree-days and determine the effect on crop yield due to water shortage. The new module will also simulate farmer behavioural practices, such as changing crop areas and mix in response to past and present resource availability.

6.2.4 Representation of transfer market

At present, the transfers are either assumed to be insignificant or a simplified approach is used to represent this mechanism (Section 2.4).

Better information on the water trading market in terms of volumes traded, reasons for trading and locations the water is traded from and to will allow the incorporation of a dynamic water trading module in the Border Rivers IQQM.

6.2.5 Better spatial representation of rainfall used to generate crop demands

BRS IQQM performs a dual role for long term simulation and short term MDBC Cap Auditing. Therefore, only six long term rainfall sites were calibrated into the model to represent rainfall at the irrigation nodes (Table A.1), resulting in a certain amount of smoothing of orders placed by the irrigation groups, since their demands are being generated based on similar rainfall data. In reality, there is a more spatial variability in the rainfall.

Investigations could be undertaken to see if shorter term rainfall sites can provide more information on spatial variability of rainfall on the irrigation areas. These rainfall sites could then be extended to cover the long term simulation period and incorporated into the simulation model.

6.2.6 Improved representation of on-farm storage usage

On-farm storage operation in the model is currently based on reported irrigator behaviour and to achieve the best possible diversion calibration. However, as more information becomes available, it may be possible to represent explicitly on-farm activities such as reuse of irrigation tail water and division of on-farm storages into cells to reduce evaporation.

6.2.7 Explicit representation of unregulated users

Explicit representation of unregulated irrigation diversions on tributary inflows and upstream of the both headwater Dams may also require a review of inflow contributions from these tributaries.

6.2.8 Explicit representation of Stock and Domestic and other HS entitlements

The Stock and Domestic and other HS security diversions did not have sufficient annual or monthly diversion data to allow separate configuration in the BRS IQQM. However, the 1.2 GL of such entitlements incorporated into the model in the general security irrigation nodes. If more information on usage patterns becomes available, then these can be modelled explicitly in the BR IQQM.

6.2.9 Town water supply modelling

Replace the fixed monthly pattern modelling approach with a demand calibrated to climate and population.

6.3 Upgrades to the Storage Behaviour Modelling

6.3.1 Variable tributary utilisation

IQQM currently uses a fixed factor to represent recessions on current flows when estimating the flow that will contribute to meeting order requirements. In reality, this prediction is a function of many factors including the preceding flows (i.e. rising or falling) and the time of year.

6.3.2 Variable operational surplus

IQQM currently uses a fixed over-order factor to represent long-term operational surplus. In reality, this factor is a function of many factors including the magnitude of the orders, antecedent conditions and time of year.

6.4 General Upgrades

6.4.1 Water accounting model

NSW BR has been operated under the continuous accounting system since 2001/02 water year. However, due to current IQQM capabilities and BR being a two-state system, we have been unable to model accounting system as such. At present, we model continuous accounting using annual accounting system with irrigators' carry over available throughout entire year. We will be addressing this issue as soon as updated IQQM capability would enable us to do so.

6.4.2 Water Year Change for WSP scenario

The water year change from October – September to July – June in the 2003/04 water year is yet to be incorporated into the WSP scenario. At present, we still model the water year as being October – September, as simply switching the water year to July – June would have repercussion on end of year diversions and pre-watering and, consequently, modelled planted area, particularly due the fact the model is still using annual accounting system. Although, only small changes are expected in terms of long term average (LTA) of Annual Diversion Limit, the changes in short term model simulations (ex., used in annual Cap Auditing) could lead to much distortion of the simulation results. Change in water year issue is expected to be address during the next upgrading process in 2014.

6.4.3 Separation of consumptive users from environmental requirements

Currently in the model, there are a number of replenishment flows that are non-consumptive. In reality, these are provided for a combination of consumptive users, such as stock and domestic supply, and non-consumptive users, such as minimum flows for in stream habitat.

This improvement will require an assessment of current replenishment flow volumes and their intended purposes.

6.4.4 Incorporate any access to groundwater resources

Modelling of groundwater access for meeting irrigated crop water requirements, especially in low AWD years. This would require an investigation of the extent of groundwater use and a relationship with surface water access and crop water requirements.

6.4.5 Transition of the BR IQQM from DOS to GUI

At present the BRS IQQM is configured and run using DOS by both NOW and QDERM. As the model has been calibrated in DOS, changing the operating platform has resulted in altering simulated outcomes to extend, which neither agency was willing to accept. We have agreed that model's transition from DOS to GUI should be backed up by model re-calibration/fine tuning. It is envisaged that next model upgrading process which would address this issue will take place at the expiration of the current WSP in 2014.

6.4.6 Environmental water provisions

EIS on Pindari enlargement has recommended minimum Pindari releases as described in Section **Error! Reference source not found.**. The study also recommended stimulus flow of 400 ML/d for at least two days with at least two days of both rising and falling stages whenever 400 ML/d or greater releases have not occurred in the preceding three month period. This stimulus flow rule has not yet been represented in the model at.

Environmental water provisions have been reviewed significantly in the BR Water Sharing Plan (WSP) [DECCW, 2009]:

- Minimum Pindari Dam release remains 10 ML/d. However, the Pindari Dam inflow up to 50 ML/d between September and May and up to 200 ML/d between June and August can not be stored.
- The provision for stimulus flow release has been increased up to 4,000 ML/year (with maximum carry over of 100%) and release to be made if an inflow into Pindari Dam of greater than 1,2000 ML/d has occurred on any day between 1st of April and 31st of August.
- All of these minimum Pindari releases are to be protected from diversions till they reach the confluence between the Severn River and Frazers Creek.
- Unregulated stream flow up to 100 ML/d is not to be extracted between September and March inclusive.

Given better capabilities of the GUI IQQM we will be implementing all of these environmental flow provision rules in the GUI version of the BR models IQQM.

Appendix A. Climatic and Streamflow Stations

Table A.1: Coolmunda subsystem Rainfall stations used in IQQM

Location	Station No	Used for
Inglewood P.O.	041047	Primary reference gauge used as representative of rainfall on dam storage (for back-calculations) and on irrigation areas (for modelling irrigator water requirements)
Whetstone	041125	For gap filling into 041047 record, and disaggregation of accumulated records
Texas P.O.	041100	For gap filling and disaggregation of any remaining gaps or accumulated data
Inglewood (Woodspring)	041391	For gap filling and disaggregation of any remaining gaps or accumulated data
Yelarbon P.O.	041122	For gap filling and disaggregation of any remaining gaps or accumulated data

Table A.2: Pindari subsystem Rainfall stations used in IQQM

Rainfall Station Locations	Station No	Station used for gap filling/disaggregating accumulated values	Used for
Pindari Dam	054104	Emmaville P.O. (056009) Ashford (Burrabogie) (054046)	Primary reference gauge used as representative of rainfall on dam storage.
Coolatai (Orana)	054012	Ottley (Graman) (054025) Delungra (Craigmere) (054016) Coolatai (Willunga) (054032) Wallangra Station (054036)	Used as representative of rainfall on the crop areas from Pindari Dam to the Macintyre-Dumaresq Rivers confluence.

Table A.3: Glenlyon subsystem Rainfall stations used in IQQM

RAINFALL ZONE(#)		*PRIMARY RAIN GAUGE*		*Gauges used for Gap filling*		*Correlation Statistics*	
File:-	*Zone extent*	*Number*	*Name*	*Number*	*Name*	r^2	*Vol.ratio*
041430.pte	Glenlyon storage	041430	Glenlyon Dam	041087 054007 041100	Riverton N. Bonshaw P.O. Texas P.O.	0.77 0.60 0.67	1.025 1.090 1.054

054007.ptf	Roseneath to MacIntyre Brk confluence	054007	Bonshaw P.O.	054160 041101 041100 054035 054036	Bonshaw (Applewood) Texas Station Texas P.O. Yetman P.O. Wallangra P.O.	0.66 0.67 0.70 0.63 0.67	0.77 0.96 0.93 0.94 1.09
053004.ptf	MacIntyre Brk confluence to Terrewah	053004	Boggabilla P.O.	041129 041038 041010 041128	Goondiwindi (Woomera) Goondiwindi P.O. Callandoon Wondalli	0.68 0.69 0.23 0.62	0.89 0.98 0.91 0.95
052004.ptf	Terrewah to Kanowna	052004	Boomi P.O.	053042 053011 053060 053041	Garah (Ulunga) Garah P.O. Garah (Welbon) N.Star (Coolanga)	0.66 0.67 0.62 0.61	0.88 1.03 0.96 1.03
052020.ptf	Kanowna to Mungindi	052020	Mungindi P.O.	052019 052000 052010 052004	Mogil Mogil Mungindi (Abedoar) Weemelah (Crinolyn) Boomi P.O.	0.63 0.70 0.66 0.63	0.95 0.91 0.92 1.08

Table A.4: Coolmunda subsystem Evaporation stations used in IQQM

Location	Station No	Pan factor	Used for
Inglewood Tobacco Research	041341	0.9	Establishing relationship between daily rainfall and evaporation in local area (1974-1985)
Cropped irrigation area	not applicable	0.9	Daily time series file generated using relationship established from actual 041341 data (above) and using composite daily rainfall catchment file (primary gauge 041047). as input, for period 1987 to 2000
Dam storage area	not applicable	0.7	Daily time series file generated using relationship established from actual 041341 data (above) and using composite daily rainfall catchment file (primary gauge 041047). as input, for period 1987 to 2000

Table A.5: Pindari subsystem Evaporation stations used in IQQM

Location	Station No	Pan factor	Used for
Pindari Dam	054104	0.9	Used for simulating of evaporation losses from Pindari Dam.
Coolatai (Orana)	054012	0.7	Used for estimating of potential evapotranspiration of the crops for the irrigation group from Pindari Dam to Severn-Macintyre Rivers confluence Daily evaporation time series file generated using relationship established from the actual evaporation data at Wallangra Post Office station (054036), and using daily rainfall file for Coolatai (Orana) station as input.
Bogabilla P. O.	053004	0.7	Used for estimating of potential evapotranspiration of the crops for the irrigation group from Severn-Macintyre Rivers confluence to Macintyre-Dumaresq Rivers confluence. Daily evaporation time series file generated using relationship established from the actual evaporation data at Boggabilla Post Office station (053004), and using daily rainfall file for Boggabilla Post Office station as input.

Table A.6: Glenlyon subsystem Evaporation stations used in IQQM

EVAPORATION ZONE(#)		***PRIMARY EVAPORATION AND RAIN GAUGE***		***Rain gauge used for estimate (*)***		***PAN Factor(s) used***	
File:-	***Zone extent***	***Number***	***Name & Type***	***Number***	***Name***	***Fact.***	***Purpose***
glyn.evg	Glenlyon storage	054104 041430	Pindari -PAN Glenlyon - PET	041430	Glenlyon Dam	1.0	Dam storage
054012p7.evg	Roseneath to Mauro	054036	Wallangra - PAN	054012	Coolatai	0.7 1.0	Crops OFS
053004.evg	Mauro to Terrewah	053004	Boggabilla - PAN	053004	Boggabilla	0.7 1.0	Crops OFS
052004.evg	Terrewah to Kanowna	053004	Boggabilla - PAN	052004	Boomi P.O.	0.7 1.0	Crops OFS
052020.evg	Kanowna to Mungindi	052020	Boggabilla - PAN	052020	Mungindi P.O.	0.7 1.0	Crops OFS

Table A.7: Rainfall and Evaporation gauges used for establishing local zone records

RAINFALL ZONE(#)		***PRIMARY RAIN GAUGE***		***Gauges used for Gap filling***		***Correlation Statistics***	
File:-	***Zone extent***	***Number***	***Name***	***Number***	***Name***	***r^2***	***Vol.ratio***
041430.pte	Glenlyon storage	041430	Glenlyon Dam	041087 054007 041100	Riverton N. Bonshaw P.O. Texas P.O.	0.77 0.60 0.67	1.025 1.090 1.054
054007.ptf	Roseneath to MacIntyre Brk confluence	054007	Bonshaw P.O.	054160 041101 041100 054035 054036	Bonshaw (Applewood) Texas Station Texas P.O. Yetman P.O. Wallangra P.O.	0.66 0.67 0.70 0.63 0.67	0.77 0.96 0.93 0.94 1.09
053004.ptf	MacIntyre Brk confluence to Terrewah	053004	Boggabilla P.O.	041129 041038 041010 041128	Goondiwindi (Woomera) Goondiwindi P.O. Callandoon Wondalli	0.68 0.69 0.23 0.62	0.89 0.98 0.91 0.95
052004.ptf	Terrewah to Kanowna	052004	Boomi P.O.	053042 053011 053060 053041	Garah (Ulunga) Garah P.O. Garah (Welbon) N.Star (Coolanga)	0.66 0.67 0.62 0.61	0.88 1.03 0.96 1.03
052020.ptf	Kanowna to Mungindi	052020	Mungindi P.O.	052019 052000 052010 052004	Mogil Mogil Mungindi (Abedoar) Weemelah (Crinolyn) Boomi P.O.	0.63 0.70 0.66 0.63	0.95 0.91 0.92 1.08
EVAPORATION ZONE(##)		***PRIMARY EVAPORATION AND RAIN GAUGE***		***Rain gauge used for estimate (*)***		***PAN Factor(s) used***	
File:-	***Zone extent***	***Number***	***Name & Type***	***Number***	***Name***	***Fact.***	***Purpose***
Glyn.evg	Glenlyon storage	054104 041430	Pindari –PAN Glenlyon - PET	041430	Glenlyon Dam	1.0	Dam storage
054012p7.evg	Roseneath to Mauro	054036	Wallangra - PAN	054012	Coolatai	0.7 1.0	Crops OFS
053004.evg	Mauro to Terrewah	053004	Boggabilla - PAN	053004	Boggabilla	0.7 1.0	Crops OFS

052004.evg	Terrewah to Kanowna	053004	Boggabilla - PAN	052004	Boomi P.O.	0.7 1.0	Crops OFS
052020.evg	Kanowna to Mungindi	052020	Boggabilla - PAN	052020	Mungindi P.O.	0.7 1.0	Crops OFS

Table A.8: Coolmunda sub-system streamflow gauging stations used in IQQM

Location	Station No (#)	Operation Period	Area sq.km	Useage in IQQM calibration
MacIntyre Brook at Barongarook	416410 Auto	1967 to Date	533	To define headwater tributary inflow
MacIntyre Brook at Luna	416403 Manual	1948 to 1966	601	Not used - superceded by 416410
Bracker Creek at Terraine (*)	416404 Manual to Auto	1950 to Date	685	To define headwater tributary inflow
MacIntyre Brook at Greenup Weir	416408 Manual	1957 to 1969	1710	Timber weir with known leakage problems. Not used. Dam release records were however available from the operators log
Canning Creek at Woodspring (*)	416407 Manual	1954-79 (daily), 1979-Date (flood)	1221	Used to calibrate Sacramento model from which 1987 to 1996 Canning Ck tributary inflows could be estimated from recorded rainfalls. These "estimates" were supplemented with BOM flood reading records.
MacIntyre Brook at Inglewood (*)	416402 Manual to Auto	1943-53 (daily), 1953-Date (Auto)	3435	Residual catchment calibration, and flow calibration of reach to Inglewood Weir
MacIntyre Brook at Whetstone Weir	416405 Manual	1952-79e	3630	Timber weir with leakage problems. Not used in IQQM
MacIntyre Brook at Whetstone	416401 Manual to Auto	Manual: 1924-52; 1952-55	3682	Not used in IQQM
MacIntyre Brook at Ben Dor Weir	416406 Auto	1954 - 80	4124	Used to extend 416415 record in Sacramento modelling, but not IQQM. 416412 replaced this one, due to low flow uncertainty from variable valve settings
MacIntyre Brook at Booba Sands (*)	416415 Auto	1987-Date	4130	Used as "anchor" point or outlet gauge in IQQM flow calibration. This gauge replaced 416412, which was affected by variable backwater effects from Dumaresq River
MacIntyre Brook at Sunnygirl	416412 Manual	1951-54	4140e	Not used in IQQM (short records)
MacIntyre Brook at 1.6km u/s of junction	416413 Auto	1971-87	4170	Originally installed to replace the function of Ben Dor weir gauge (416406), but was found to be frequently affected by backwater effects from the Dumaresq river. Not used in IQQM

MacIntyre Brook at Coolmunda Dam(*)	416409 Auto	1968-Date	1768	Records of dam level at 1 hour intervals, which were used with valve and spillway setting records to estimate releases and to back-calculate Coolmunda Dam inflows.

Table A.9: Pindari sub-system streamflow gauging stations used in IQQM

Location	Station No	Operation Period	Catchment area (sq. km)	Used for, and/or Comments
Severn River @ Strathbogie	416039	10/05/1974 to date	1790	Sacramento modelling, and estimating residual inflows from Pindari Tailwater gauging station to Ashford
Severn River @ Pindari (Pindari Tailwater gauging station)	416019	01/07/1966 to date	2130	Sacramento modelling, and IQQM flow calibration from Pindari Dam to Pindari Tailwater gauging station
Severn River @ Ashford	416006	22/11/1933 to date	3010	IQQM flow calibration from Pindari Tailwater gauging station and Ashford
Macintyre River @ Dam Site	416018	10/06/1966 to 08/02/1989	5830	IQQM flow calibration from Ashford to Macintyre Dam Site gauging station
Macintyre River @ Holdfast (Yelarbon crossing)	416012	01/01/1951 to date	6740	IQQM flow calibration from Macintyre Dam Site gauging station to Holdfast
Macintyre River @ Boonal	416038	01/07/1973 to 21/04/1982	8370	IQQM flow calibration from Holdfast to Boonal gauging station
Frasers Creek @ Ashford	416021	07/03/1967 to 07/02/1989	804	Sacramento modelling, and estimating residual inflows from Pindari Dam to Pindari Tailwater gauging station.
Ottley Creek @ Coolatai	416020	02/03/1967 to date	402	Sacramento modelling, and estimating residual inflows from Holdfast to Boonal gauging station.
Beardy River @ Haystack No 4	416008	10/08/1934 to date	866	Sacramento modelling, and estimating residual inflows from Pindari Tailwater gauging station to Ashford
Croppa Creek @ Tulloona Bore	416034	29/06/1972 to 16/02/1989	1280	Sacramento modelling and estimating residual inflows from Macintyre Dam Site gauging station and Boonal gauging station
Campbells Creek @ Beebo	416036	02/04/1973 to date	399	Sacramento modelling, and estimating residual inflows from Ashford to Boonal gauging station

Macintyre River @ Wallangra	416010	01/01/1937 to date	2020	Sacramento modelling, and estimating residual inflows from Macintyre Dam Site gauging station and Holdfast.

Table A.10: Glenlyon subsystem streamflow gauging stations used in IQQM

Location & operator	Station No (#)	Operation Period (*)	Area sq.km	Used for, and/or Comments
Barwon River @ Mungindi (DLWC)	416001 M:- A:-	1886 - na 1953 - Date: Good	44,070	Overall model outlet gauge, used for main stream loss calibration
Beardy Ck @ Haystack (DLWC)	416008 M:- A:-	1934 - na 1937 - Date: Fair	866	Tributary inflow, and sacramento modelled catchment
Boomi River @ Neeworra (DLWC)	416028 A:-	1968 - 1994; Good	na	To derive mainstream losses
Boomi River @ Kanowna (DLWC)	416029 A:-	1968 - 1983: Good	na	Used indirectly for Newinga breakout flow calibration
Boomi River @ Offtake (DLWC)	416037 A:-	1973 - Date: Fair	na	Used for Newinga breakout flow and mainstream loss calibration
Brush Creek @ Beebo (QDNR)	416305 M:- A:-	1950 - na 1968 - Date; Good	330	Tributary inflow, and sacramento modelled catchment
Callandoon Creek @ Claries Weir (QDNR)	416203A A:-	1996 - Date: Fair	n/a	Used indirectly to calibrate mainstream losses
Campbells Creek near Beebo (DLWC)	416036 A:-	1973 - 1996; Good	399	Tributary inflow, and sacramento modelled catchment
Commoron Creek @ Comurri (BOFM)	416906 F:-	1972 - Date; Fair	1,810	Tributary inflow, and Sacramento modelling
Dumaresq (Severn) River @ Farnbro (QDNR)	416310 A:-	1962 - Date; Good	1,310	Tributary inflow, and sacramento modelled catchment
Dumaresq River @ Mauro (DLWC)	416049 A:-	1985 - 1996; Fair	8,664e	To derive mainstream losses

Location & operator	Station No (#)	Operation Period (*)	Area sq.km	Used for, and/or Comments
Dumaresq River @ d/s Glenarbon Weir (DLWC)	416040 A:-	1996 - Date; Good	9,074e	Supercedes 416049
Dumaresq River @ Roseneath (DLWC)	416011 M:- A:-	1937 - na 1951 - Date; Good	5,550	Mainstream loss calibration
Dumaresq River @ Bonshaw Weir (DLWC)	416007 M:- A:-	1934 - na 1937 - Date; Fair	7,280	Mainstream loss calibration
Macintyre River @ Holdfast (DLWC)	416012 M:- a:-	1950 - na 1978 - Date; Good	6,740	Tributary inflow
Macintyre River @ Boggabilla (DLWC)	416002 M:- A:-	1894 - na 1982 - 1990; Fair 1991 - Date; Poor	22,600	Mainstream loss calibration
Macintyre River @ Goondiwindi Bridge (QDNR)	416201A M:- A:-	1917 - na 1954 - Date; Fair	23,100	Mainstream loss calibration
Macintyre River @ Goondiwindi Weir	416201B A:-	1997 - Date; Fair	23,100e	Mainstream loss calibration
Macintyre River @ Terrewah (DLWC)	416047 A:-	1988 - Date; Fair	23,500e	Mainstream loss calibration
Macintyre River @ Boomi Weir (DLWC)	416043 A:-	1976 - Date; Fair	24,000	Mainstream loss calibration
Macintyre River at Kanowna (DLWC)	416048 A:-	1988 - Date; Fair	24,500e	Mainstream loss calibration
MacIntyre Brook at Booba Sands (QDNR)	416415... A:-	1987-Date; Good	4,130	Tributary inflow
Mole River @ Donaldson (DLWC)	416032 A:-	1969 - Date; Good	1,610	Tributary inflow, and Sacramento modelling
Oaky Creek @ Texas (QDNR)	416312 A:-	1969 - Date; Good	422	Tributary inflow, and Sacramento modelling
Ottleys Creek @ Coolatai (DLWC)	416020 A:-	1967 - Date; Fair	402	Tributary inflow, and Sacramento modelling
Pike Creek @ Clearview (QDNR)	416303 M:- A:-	1934 - na 1952-1988?; Good	950	Not used (located u/s of Glenlyon Dam)
Pike Ck @ Glenlyon Dam tailwater (QDNR)	416309B A:-	1973 - Date; Good	1,326e	Back-water calculations, and Mainstream loss calibration

Location & operator	Station No (#)	Operation Period (*)	Area sq.km	Used for, and/or Comments
Glenlyon Dam levels (QDNR)	416315 A&M	1976 - Date; n/a	1,326	Back-calculation of dam inflows
Reedy Ck. @ Dumaresq (DLWC)	416026 A:-	1968 - 1989; Fair	301	Tributary inflow, and Sacramento modelling
Tenterfield Ck @ Clifton (DLWC)	416003 M:- A:-	1921 - na 1978 - Date; Good	570	Tributary inflow, and Sacramento modelling
Weir River @ Talwood (QDNR &BOFM)	416202 M:- A:-	1949 - na 1968 - Date; Fair	12,100	Mainstream loss calibration, and Sacramento modelling

(#) the letter "M" means manually read, either daily at 9 am by a nearby resident &/or during each flood event; "F" means read manually, only during flood events, and; "A" means an automatic continuously recording instrument; "e" means estimated; (*) quality rating in brackets is from Stream Gauging Information (Department of Resources and Energy, 1984); "na" means not available or not applicable.

Appendix B. Model Calibration Parameters

Table B.1: Streamflow calibration reaches in Border Rivers IQQM

Rch	**Upstream Location**			**to**	**Downstream Location**		
	Stream	Station	No.		Stream	Station	No.
UPSTREAM OF HEADWATER STORAGES							
00a	Severn	Strathbogie	416039	to	Severn	Pindari Dam	n/a
00b	MacintyreBr	Barongarook	416410	to	MacintyreBr	Coolmunda Dam	n/a
00c	Bracker Ck	Terraine	416404	to	Bracker Ck	Coolmunda Dam	n/a
DOWNSTREAM OF HEADWATER STORAGES							
Glenlyon subsystem							
01	Severn	Glenlyon Dam	n/a	to	Dumaresq	Roseneath	416011
02	Dumaresq	Roseneath	416011	to	Dumaresq	Bonshaw Weir	416007
03	Dumaresq	Bonshaw Weir	416007	to	Dumaresq	Mauro	416049
04	Dumaresq	Mauro	416049	to	Macintyre	Bogabilla	416002
05	Macintyre	Bogabilla	416002	to	Macintyre	Goondiwindi	416201A
06	Macintyre	Goondiwindi	416201A	to	Macintyre	Terrawah	416203A
7a	Macintyre	Terrawah	416203A	to	Macintyre	Boomi Weir	416043
08	Macintyre	Boomi Weir	416043	to	Macintyre	Kanowna	416048
09	Macintyre	Kanowna	416048	to	Barwon	Mungindi	416001
7b	Macintyre	Terrawah	416203A	to	Boomi	Boomi River Offtake	416037
10	Boomi	Boomi River Offtake	416037	to	Boomi	Kanowna	416029
11	Boomi	Kanowna	416029	to	Boomi	Neeworra	416028
Pindari subsystem							
12	Severn	Pindari Dam	n/a	to	Severn	Pindari Tailwater	416019
13	Severn	Pindari Tailwater	416019	to	Severn	Ashford	416006
14	Severn	Ashford	416006	to	Macintyre	Dam site	416018
15	Macintyre	Dam site	416018	to	Macintyre	Holdfast	416012
16	Macintyre	Holdfast	416012	to	Macintyre	Boonal	416038
Coolmunda subsystem							
17	MacintyreBr	Coolmunda Dam	n/a	to	MacintyreBr	Inglewood	416042
18	MacintyreBr	Inglewood	416042	to	MacintyreBr	Booba Sands	416415

Table B.2: Ungauged inflow sites modelled in Border Rivers IQQM

Ungauged Inflows in Reach			How Derived		
Residual Name	**from**	**to**	**Gauged Inflow Station**		**Factor**
UPSTREAM OF HEADWATER STORAGES *for simulating long term Dam inflows*					
Ungauged #00a	416039	Pindari Dam	416008	Beardy R. @ Haystack No4	1.00
Ungauged #00b	416404	Coolmunda Dam	416305	Brush Ck @ Beebo	0.63
Ungauged #00c	416410	Coolmunda Dam	416040	Dumaresq R. d/s Glenarbon	0.50
DOWNSTREAM OF HEADWATER STORAGES *to match historical main-stream flows*					
Glenlyon subsystem					
Groundwater Inflow	Glenlyon Dam	416014	n/a	Simulated[#]	1.00
Ungauged #05a	Glenlyon Dam	416014	416310	Dumaresq R. @ Farnbo	0.08
Ungauged #05b	Glenlyon Dam	416014	416310	Dumaresq R. @ Farnbo	0.56
Ungauged #05c	416014	416011	416026	Reedy Ck @ Dumaresq	0.26
Ungauged #05d	416014	416011	416026	Reedy Ck @ Dumaresq	0.17
NSW Residual	416011	416007	416008	Beardy R. @ Haystack No4	0.61
QLD Residual	416011	416007	416008	Beardy R. @ Haystack No4	0.23
NSW Ungauged Tr	416007	416049	416312	Oaky Ck @ Texas	1.00
QLD residual	416007	416049	416312	Oaky Ck @ Texas	1.00
NSW resid	416049	MacintyreBrook	416036	Campbells Ck @ Beebo	0.38
QLD resid	416049	MacintyreBrook	416305	Brush Ck @ Beebo	0.53
NSW res between	MacintyreBrook	MacintyreRiver	416036	Campbells Ck @ Beebo	0.51
QLD Residual-a	416047	416043	416202	Weir R. @ Talwood	0.10
QLD Residual-2(1b)	416048	416001	416202	Weir R. @ Talwood	0.29
Mobbindry/Tackinbri	U/S Whalan Ck -Croppa Ck Junction		416034	Croppa Ck @ Tulloona Bore	0.50
NSW Residual	U/S Boomi R. - Whalan Ck Junction		416202	Weir R. @ Talwood	1.10
Boomi 1	416037	416029	416020	Ottleys Ck @ Coolatai	2.70
Boomi 2	416037	416029	416202	Weir R. @ Talwood	1.10
d/s Boomi-Whalan Jn	416029	416028	416202	Weir R. @ Talwood	0.30
Pindari Subsystem					
Residual	Pindari Dam	416019	416021	Frazers Ck @ Ashford	0.07
Residual 07	416019	416006	416008	Beardy R. @ Haystack No4	0.13
Residual 04	416006	416018	416008	Beardy R. @ Haystack No4	0.82
Residual 02	416018	416012	416036	Campbells Ck at Beebo	3.99
Residual 03	416012	416038	416036	Campbells Ck at Beebo	5.23
Coolmunda Subsystem					
Residual	Coolmunda Dam	416402	416305	Brush Ck @ Beebo	1.35
Growndwater	Coolmunda Dam	416402	n/a	Simulated[#]	1.00
ResidualA	416402	416415	416305	Brush Ck @ Beebo	0.80
ResidualB	416402	416415	416407	Canning Ck @ Woodspring	0.40

(#) To represent and calibrated groundwater contributions the flow time series mismatch was studied and a coarse level antecedent wetness index (AWI) model was derived (See BR IQQM Implementation reports [**Error! Reference source not found.**, 1999a-c] for details)

Table B.2a: Ungauged inflow sites modelled in Border Rivers IQQM (continued)

Ungauged Inflows in Reach			How Derived	
Residual Name	**from**	**to**	**Inflow File Name (**Error! Reference source not found.**)**	**Factor**
Weir River Subsystem				
Weir R. Headwaters	U/S Junction with Western Ck		whw*YY*.fl*x*	1.0000
Catchemnt WES	U/S Junction with Boomi River		wes*YY*.fl*x* (Western Ck)	1.0000
R15	U/S Weir R. – Western Ck Junction		r1*YY*.fl*x*	0.0126
R14	Western Ck Jn	416910	r1*YY*.fl*x*	0.5544
R13	416910	416204A	r1*YY*.fl*x*	0.3535
R12	416910	416204A	r1*YY*.fl*x*	0.0417
R11	416204A	416202A	r1*YY*.fl*x*	0.0378
R22	Yarrill Ck	416202A	r2*YY*.fl*x*	0.6695
Billa Billa Creek	416204A	416202A	yar*YY*.fl*x* (Yarrill Ck)	0.3004
YAR1	416204A	416202A	yar*YY*. fl*x* (Yarrill Ck)	0.0430
Catchment COM	416204A	416202A	com*YY*. fl*x* (Commoron Ck)	1.000
Catchment YAM	416204A	416202A	yam*YY*. fl*x* (Yambocully Ck)	1.000
R21	416204A	416202A	r2*YY*.fl*x*	0.2479

Table B.3: Crop factors

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Barley	0.47	0.47	0.38	0.09	0.01	0.01	0.01	0.01	0.01	0.28	0.28	0.38
Cotton 1	0.76	0.69	0.27	0.00	0.00	0.00	0.00	0.10	0.10	0.45	0.45	0.66
Cotton 2	0.60	0.75	0.65	0.55	0.10	0.10	0.01	0.35	-1.00	0.40	0.55	0.60
Lucerne 1	0.95	0.90	0.90	0.95	0.90	0.55	0.55	0.65	0.75	0.85	0.95	1.00
Lucerne 2	0.39	0.37	0.37	0.33	0.29	0.23	0.23	0.27	0.31	0.35	0.39	0.39
Lucerne 3	0.95	0.90	0.90	0.80	0.70	0.55	0.55	0.65	0.75	0.85	0.95	0.95
Lucerne 4	0.74	0.74	0.74	0.70	0.70	0.70	0.70	0.70	0.70	0.74	0.74	0.74
Oats	0.47	0.47	0.38	0.09	0.01	0.01	0.01	0.01	0.01	0.28	0.28	0.38
Others	0.66	0.70	0.70	0.60	0.60	0.52	0.45	0.50	0.41	0.53	0.56	0.76
Pasture 1	0.50	0.50	0.50	0.39	0.38	0.36	0.41	0.41	0.41	0.41	0.41	0.42
Pasture 2	0.42	0.41	0.41	0.39	0.38	0.36	0.32	0.35	0.38	0.41	0.41	0.42
Pasture 3	0.42	0.41	0.41	0.41	0.41	0.36	0.32	0.35	0.38	0.41	0.41	0.42
SCereal 1	0.75	0.70	0.50	0.20	0.00	0.00	0.00	0.00	0.00	0.40	0.50	0.50
SCereal 2	0.50	0.50	0.40	0.10	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.40
Vegetables 1	0.39	0.42	0.42	0.42	0.42	0.36	0.32	0.20	0.29	0.37	0.39	0.39
Vegetables 2	0.00	0.00	0.42	0.42	0.42	0.36	0.32	0.20	0.29	0.00	0.00	0.00

WCereal 1	0.00	0.00	0.20	0.70	0.70	0.71	0.71	0.64	0.40	0.00	0.00	0.00
WCereal 2	0.00	0.00	0.30	0.70	0.70	0.71	0.71	0.64	0.40	0.00	0.00	0.00

Notes: Negative crop factors indicate pre-watering in that month.

Table B.4: Irrigation efficiencies for the Cap scenario

Irrigation Reach		Irrigation Efficiency # (%)
NSW	QLD	
1, 3, 4, 8	3	70
2		76
7a, 7b, 9		60
5		65
6		63
10	10, 11	64
11, 12	6b (Yambocully 12)	72
	1	77
	2	75
	5, 8	69
	7, 6a, 6c, 6b: Capel Curig Yambocully Undabri Yambocully	66
	6b: Eurone Yambocully South Giddi Giddi Mobandilla Yambocully Weir River Irrigators: Tarrawatta/Kuali Merriot	68

Notes: # The listed efficiencies are for the main crop for each irrigation node.

Table B.5: Rainfall interception loss and soil moisture store parameters

Reach/ Irrigator Groups		Rainfall Interception Loss	Soil Moisture Store	Upper Fallow Depth	Infiltration Rate #
NSW	QLD	(mm)	(mm)	(mm)	(mm)
1	1	3.0	200	n/a	n/a
	4a	4.4	300	n/a	n/a
	4b	4.7	300	n/a	n/a
2, 3, 4, 5, 6	2,3,5	3.0	300	n/a	n/a
7, 8, 9, 10, 11,12	6, 7, 8, 9, 10, 11	3.0	300	50	2.0

Notes: # The infiltration rate from the upper to the lower fallow store.

Table B.6: Tributary utilisation factors

Gauge Number	Gauge Name	Utilisation,%
Glenlyon Subsystem		
Groundawater d/s Glenlyon Dam	Dumaresq River	100
416310	Severn River	100
416003	Tenterfield Creek	100
416032	Mole River	100
n/a	Tenterfield Creek Residual#	0
n/a	Reedy Creek Residual#	0
416026	Reedy Creek	100
416008	Beardy River	100
NSW Residual#	Dumaresq River: Roseneath to Bonshaw	0
Qld Residual#	Dumaresq River: Roseneath to Bonshaw	0
416312	Oaky Creek	100
416305	Brush Creek	100
416036	Campbells Creek	100
n/a	## Macintyre Brook (Coolmunda System)	100
n/a	## Macintyre River (Pindari System)	n/a
416202A	Weir River	n/a
Pindari Subsystem		
416021	Frazers Creek	50
416010	Macintyre River	30
416020	Ottleys Creek	0
All other gauged and/or ungauged tributary inflows		0

NOTES: # the losses used in River Operation of these reaches were net losses, i.e., they actually included all ungauged;inflows, therefore the ungauged residuals required a tributary utilisation of 1.0 to match operational methods; at this stage the regulated and unregulated components of total inflows were not separated, as reuiring individual tributary recession factors.

Table B.7: Over-order factors

Reach / Irrigator Group	NSW	QLD
1	1.00	1.00
2	1.00	1.00
3	1.00	1.00
4	1.00	n/a
4a	n/a	n/a
4b	n/a	n/a
5	1.00	1.00
6	1.00	n/a
6a	n/a	1.01
6b	n/a	1.01
6c	n/a	1.01
7	n/a	1.02
7a	1.01	n/a
7b	1.01	n/a
8	1.02	1.03
9	1.03	1.03
10	1.03	1.04
11	1.04	1.04
12	1.04	1.04

Appendix C. Border Rivers Node-Link Diagram

In the following node-link diagrams, the nodes are labelled with a shape, a node number and a node description. The node key indicates what the shapes refer to in terms of their node type. These node types are then further described in Table C.1.

Table C.1: Nodes types used in IQQM

Node type	Node name	Main purpose of the node
0.0	Straight	Dummy nodes used to output simulated flows at selected locations.
0.3	Straight	Dummy node used for regulated flow lag time
1.0	Tributary inflow	Unmodelled tributaries joining the main river.
1.2	Pumped inflow	Allows water pumped from Nt 3.2, 3.3, 3.4 or 3.5 nodes to inflow into a river section.
2.0	On-river storage (ungated)	Ungated on-river storage (uses storage routing procedure during flood operation); unmet orders are passed to next storage upstream.
2.1	Head-water storage (ungated)	As above, except no upstream storage to pass unmet water orders to.
3.0	Fixed demand	Fixed pattern of demands (daily or monthly), for town water supplies, industrial demands, etc.
3.1	Demand	Fixed demand constrained by flow requirements. May be pumped to a Nt 1.2.
4.0	Effluent off-take	Diversion of flows into an effluent channel, as a function of river flow.
4.1	Regulated effluent off-take	Diversions of regulated flow into an effluent channel to meet demands
5.0	Effluent return	Return of unregulated effluent flows to the river
5.1	Regulated effluent return	Return of regulated effluent flows (specified at Nt 4.1) to the top of a separate river section
8.0	Irrigation demand	Irrigation demands, ordering and diversion calculations for normal security licenses under water use debiting scheme.
8.1	Irrigation demand	Same as Nt 8.0, except for irrigators with water order debiting scheme.
8.3	Irrigation demand	Irrigation demands from unregulated streams.
9.0	Minimum flow	Orders water for maintaining minimum flows.
9.1	Minimum flow	As for Nt 9.0, except also sets the boundaries for **Error! Reference source not found.** reaches.
10.0	Wetland	Wetland requirement calculations based on irrigation **Error! Reference source not found.**'s for the year.
10.2	Wetland	Wetland demands are input as a pattern.
11.0	Confluence	Confluence of two river sections.

Coolmunda Subsystem

The previous chapter presented a review of the data available to satisfy the above modelling purposes. From this review, the scale of model representation adopted was as set out below:-

- Inflows to the model - three direct inflow catchments (416410, 416404, and 416407), and three residual catchment inflows (to 416402, 416415, and end-of-system).
- Three flow calibration reach groups with inflows to upper nodes and currently operating gauges at their lower ends (416409, 416402, and 416415), with water user extractions, transmission losses, flow routing and lagging, and residual inflows between their upper and lower points - to be the subject of calibration.
- Four water user group clusters representing water extractions from the model - Inglewood town water supply; Irrigators and the quarry in the reach above Inglewood; Irrigators downstream of Inglewood, and; a node to represent DRIP scheme irrigator extractions - as if the collective DRIP irrigators were a single MBIP scheme licence holder at the end of the system.
- Four transmission loss nodes representing losses in each reach.
- One storage node for Coolmunda Dam

Coolmunda Dam was the only infrastructure item represented explicitly with a functional node. The five small storage weirs located downstream of the dam, although not explicitly represented, have their storage-routing influence represented implicitly in the routing parameters resultant from each reach's flow calibration.

The final node-link diagram constructed for the Macintyre Brook system is as shown in Figure C.1.

Table C.2: Flow Routing Reaches and Links

Arbitrary Reach No.	Reach Description	Approximate Length (km)	Node-Links from	to	REMARKS
1a	416410 gauge to Dam	33.6	21	23	Headwater tributary
1b	416404 gauge to Dam	9.6	22	23	Headwater tributary
2a	Dam to Inglewood gauge	22.8	31	32	Regulated section u/s of Inglewood
2b	416407 gauge site to Inglewood gauge	14.0	131	132	Canning Ck. unregulated tributary
3	Inglewood to Booba Sands gauges	38.9	36	37	Regulated section d/s of Inglewood
4	Booba Sands gauge to Dumaresq junction	16.3	40	136	Regulated section to end-of-system

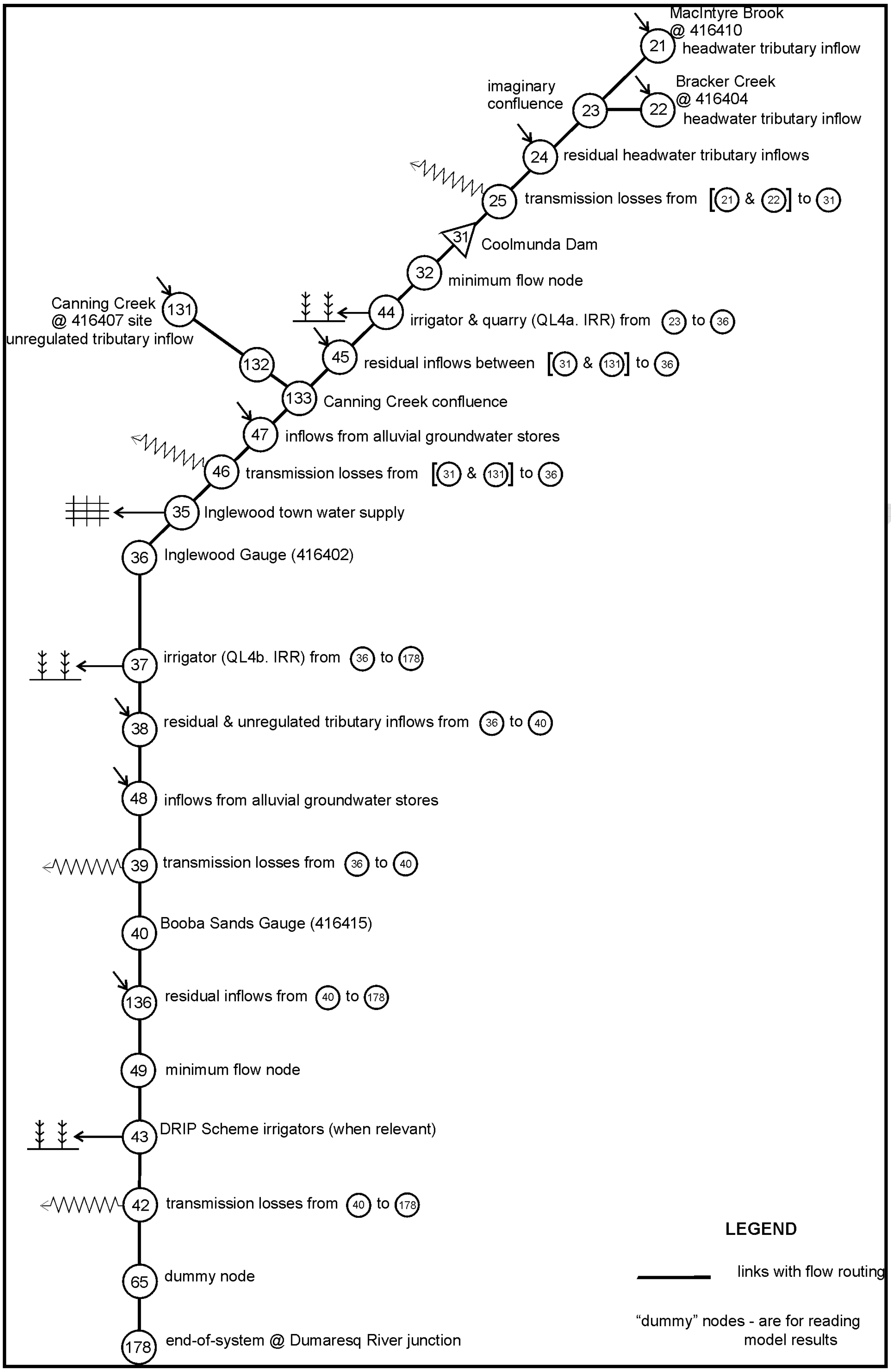


Figure C.1 Coolmunda subsystem node-link diagram as used in the original model calibration

Pindari Subsystem

The main behavioural elements represented as nodes or links are listed as dot points below:-

- Inflows to the model:- three direct inflow catchments (416021, 416010, and 416020); Pindari Dam headwater inflow (file constructed using back-calculation procedure - see Section 3.5.4.1, and; five residual catchment inflows (represented by eleven inflow nodes).
- Five calibration reaches based on the flow gauges on the main stream (416019, 416006, 416018, 416012 and 416038) with water user extractions, transmission losses, flow routing and lagging, and residual inflows between their upper and lower points - to be the subject of calibration.
- Five water user nodes representing water extractions from the dam, including Ashford town water supply, two irrigation groups (upstream and downstream of Severn-Macintyre Rivers confluence), two minimum flow requirements, to provide flows for Boomi River replenishment and a minimum flow in the river downstream of the dam - to satisfy power station needs.

- Two off-allocation reaches, one for each irrigation group; and
- Pindari Dam

To represent the Severn-Macintyre sub-system a total of 38 nodes have been used. Among them 9 flow gauging nodes, 15 inflow nodes, 1 on-river storage node, 1 town supply node, 5 loss nodes, 2 irrigation nodes, 4 minimum flow requirement nodes, and 1 end of system node. These nodes are connected by 37 main channel links. The complete node-link diagram constructed for the Severn-Macintyre system is shown in Figure C.1 Coolmunda subsystem node-link diagram as used in the original model calibration, while details on the nodes and links between them are presented in the Table C.3.

Table C.3: Node-Link Relationships in the Severn-Macintyre system

Node No*	Functional description/ representation of	Geographical Location	Node type used **	Distance from upstream node
11	Pindari Dam headwater inflow	Immediately u/s of Pindari Dam	1.1	
59	Pindari Dam	Severn River at Pindari Dam	2.1	0
66	Dam release to meet minimum flow requirements for North Power thermal power station	Immediately d/s of the dam	9.0	0
14	Residual inflow between Pindari Dam and Pindari tailwater gauge	Immediately u/s of Pindari Tailwater gauge (416019)	1.0	20
18	Transmission losses between Pindari dam and Pindari Tailwater gauging station	Immediately u/s of Pindari Tailwater gauge (416019)	4.0	0
21	Main stream gauge: Severn River @ Pindari Tailwater gauging station (416019)	Severn River at Pindari Tailwater gauge (416019)	0.0	0
22	Residual inflow No1 between Pindari Tailwater (416019)gauge and town of Ashford (416006)	Half way between Pindari Tailwater Gauge and Frazers Creek junction	1.0	20
23	Same as above No2	Same as above	1.0	0
24	Frazers Creek inflow	Severn River and Frazers Creek confluence	1.0	20
69	Dummy river gauge for checking river flow	Immediately d/s of Frazers Creek junction	0.0	0
67	Off-allocation reach between Pindari Dam and Severn-Macintyre River confluence	Same as above	9.1	0
60	Ashford TWS	Severn River at Ashford	3.0	0
28	Transmission losses between Pindari Tailwater gauge and town of Ashford	Same as above		5
31	Main stream gauge: Severn River @ Ashford (416006)	Severn River at Ashford (416006)	0.0	0
32	Residual inflow No1 between Ashford and Macintyre Dam site	Half way between Ashford and Severn- Macintyre rivers	1.0	20

Node No*	Functional description/ representation of	Geographical Location	Node type used **	Distance from upstream node
	gauge	confluence		
61	Irrigation group from Pindari Dam and Severn-Macintyre rivers confluence	Same as above	8.0	0
64	Dummy river gauge for checking river flow	Same as above	0.0	0
33	Macintyre river inflow	Severn River at Macintyre river junction	1.0	20
70	Dummy river gauge for checking river flow	Immediately d/s of Macintyre river junction	0.0	0
68	Off-allocation reach from Severn-Macintyre Rivers confluence to Dumaresq River junction	Same as above	9.1	0
34	Residual inflow No 2 between Ashford and Macintyre Dam site gauge	Same as above	1.0	0
35	Transmission losses between Ashford and Macintyre Dam site gauge (416018)	Immediately u/s of Macintyre Dam site gauge	4.0	30
41	Main stream gauge: Macintyre River @ Dam site gauge (416018)	Macintyre River at Macintyre Dam site gauge (416018)	0.0	0
42	Residual inflow No 1 between Macintyre Dam site gauge and Holdfast gauge (416012)	Immediately d/s of Macintyre Dam site gauge	1.0	0
46	Residual inflow No 2 between Macintyre Dam site gauge and Holdfast gauge (416012)	D/s of Macintyre Dam site gauge	1.0	30
47	Residual inflow No 3 between Macintyre Dam site gauge and Holdfast gauge (416012)	D/s of Macintyre Dam site gauge	1.0	10
43	Transmission losses between Macintyre Dam Site gauge and Holdfast gauge	Immediately u/s of Holdfast gauge	4.0	40
51	Main stream gauge: Macintyre River @ Holdfast (416012)	Macintyre River at Holdfast gauge	0.0	0
52	Residual flow No1 between Holdfast gauge and Boonal gauge (416038)	Immediately d/s of Holdfast gauge	1.0	0
53	Residual flow No2 between Holdfast gauge and Boonal gauge (416038)	D/s of Holdfast gauge	1.0	25
54	Residual flow No3 between Holdfast gauge and Boonal gauge (416038)	Same as above	1.0	10
62	Irrigation group from Severn-Macintyre Rivers confluence to Dumaresq River junction	Same as above	8.0	0
63	Dummy streamflow gauge for checking river flow	Same as above	0.0	0
55	Ottleys Creek inflow	Macintyre River at Ottleys Creek junction	1.0	10

Node No*	Functional description/ representation of	Geographical Location	Node type used **	Distance from upstream node
56	Transmission losses between Holdfast gauge and Boonal Gauge	Immediately u/s of Boonal gauge (416038)	4.0	5
57	Main stream gauge: Macintyre River @ Boonal gauge (416038)	Macintyre River at Boonal gauge	0.0	0
65	End of system flow requirements for supply of replenishment flows for Boomi River	Immediately d/s of Boonal gauge	9.0	0
58	End of system	Macintyre River at Dumaresq River junction	0.0	0

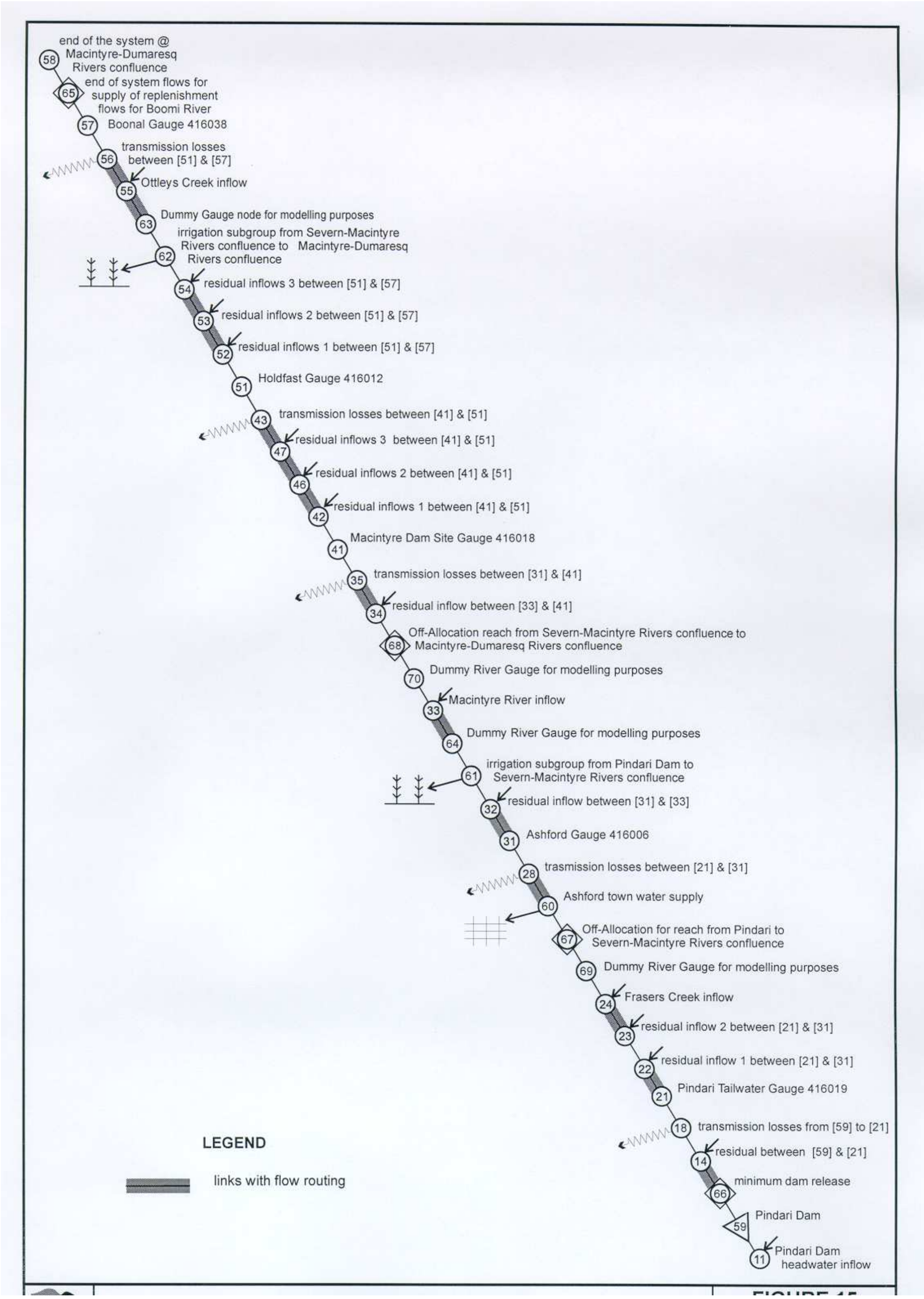


Figure C.2 Pindari subsystem node-link diagram as used in the original model calibration

Glenlyon Subsystem

The complete node-link diagram constructed for the Dumaresq-Macintyre River system is shown in Figure C.3, while details on functional elements and flow routing reaches and links represented in the IQQM are presented in the Table C.4 and Table C.5 respectively.

Table C.4: Functional elements of the Dumaresq-Macintyre system represented in IQQM

Element Type	No of Items	Description of Items
Direct tributary inflows	3	• Dam inflows from back calculation (1326 sq.km) • at gauge 416012 - Macintyre River @ Holdfast (6740 sq.km) • at gauge 416415 - MacIntyre Brk @ Booba Sands (4130sq.km)
Direct tributary inflows - routed down to junction with mainstream.	10	1. Qld, Severn River (1310 sq.km) 2. NSW, Tenterfield Creek (570 sq.km) 3. NSW, Mole River (1610 sq.km) 4. NSW, Reedy Creek (301 sq.km) 5. NSW, Beardy River (866 sq.km) 6. Qld, Oaky Creek (422 sq.km) 7. Qld, Brush Creek (330 sq.km) 8. NSW, Campbells Creek (399 sq.km) 9. NSW, Ottleys Creek (402 sq.km) 10. Qld, Weir River (12100 sq.km)
Residual catchment inflows	12	1. Qld areas between Glenlyon Dam & Roseneath -141 sq.km 2. NSW areas between Glenlyon Dam & Roseneath -328 sq.km 3. Qld area between Roseneath & Bonshaw - 233 sq.km 4. NSW area between Roseneath & Bonshaw - 625 sq.km 5. Qld area between Bonshaw & Mauro - 497 sq.km 6. NSW area between Bonshaw & Mauro - 497 sq.km 7. Qld area between Mauro & MacBrook confluence - 126 sq.km 8. NSW area between Mauro & MacBrook confluence - 94 sq.km 9. Qld, area between Booba Sands & MacBrook confluence - 83 sq.km 10. NSW, MacBrook to Macintyre River confluences - 140 sq.km 11. NSW, Holdfast to Macintyre River confluence - 1228 sq.km 12. Qld, Macintyre River confluence to Mungindi (No.30) - 3120 sq.km
Storage	2	Glenlyon Dam and Bogabilla Weir
Stream gauge points used in flow calibration	9	Roseneath; Bonshaw; Mauro; Boggabilla; Goondiwindi; Terrewah; Boomi Kanowna, and; Mungindi.
Irrigator Group extractions	23	As listed in **Error! Reference source not found.**
TWS extractions	3	Texas; Goondiwindi (including Boggabilla); and, Mungindi
Floodplain storage effluents	3	u/s Whalan Ck offtake; Callandoon Ck; u/s of Kanowna

Element Type	No of Items	Description of Items
Effluent offtakes	9	Whalan Ck; Callandoon Ck; Coomonga Ck; Boomi weir; Macintyre-Newinga breakout; Little Barwon Ck; Boomangera Ck; Weir-Newinga breakout; Little Weir River
Transmission loss allowance points	12	Consistent with flow calibration reaches used, except in the reach to Boggabilla - which has 4 loss nodes instead of 1
Confluences	4	3 actual confluences (MacBrook, Macintyre-Dumaresq, and Weir-Barwon), and one conceptual confluence to represent Dam to Roseneath residual inflow point
Off-allocation reaches	8	In each of the flow calibration reaches except the reach to Mauro

Table C.5: Flow Routing Reaches and Links in the Dumaresq-Macintyre system IQQM

Arbitrary Reach No.	Reach Description	Approximate Length (km)	Node-Links from	to	REMARKS
1	Dam to Roseneath	28	2	11	d/s gauge 416011
2	Roseneath to Bonshaw	44	11	16	d/s gauge 416007
3	Bonshaw to Mauro	5	16	24	d/s gauge 416049
4a	Mauro to MacBrook confluence	27	24	41	no d/s gauge
4b	Booba Sands to MacBrook confluence	19	40	41	no d/s gauge
4c	MacBrook to Macintyre/Dumaresq confluence	27	41	65	no d/s gauge
4d	Holdfast to Macintyre/Dumaresq confluence	30	57	65	no d/s gauge
4e	Macintyre/Dumaresq confluence to Boggabilla	20	65	69	d/s gauge 416002
5	Boggabilla to Goondiwindi	9	69	76	d/s gauge 416201A
6	Goondiwindi to Terrawah	81	76	82	d/s gauge 416047 (& 416203A on Callandoon Ck)
7	Terrewah to Boomi weir	42	82	89	d/s gauge(s) 416043 (& 416037 on Boomi)
8	Boomi to Kanowna	73	89	100	d/s gauge(s) 416048 (& 416029 on Boomi)
9a	Kanowna to Mungindi	74	100	112	d/s gauge 416001
9b	Weir River from Tallwood to junction with Barwon River	100	161	169	no d/s gauge

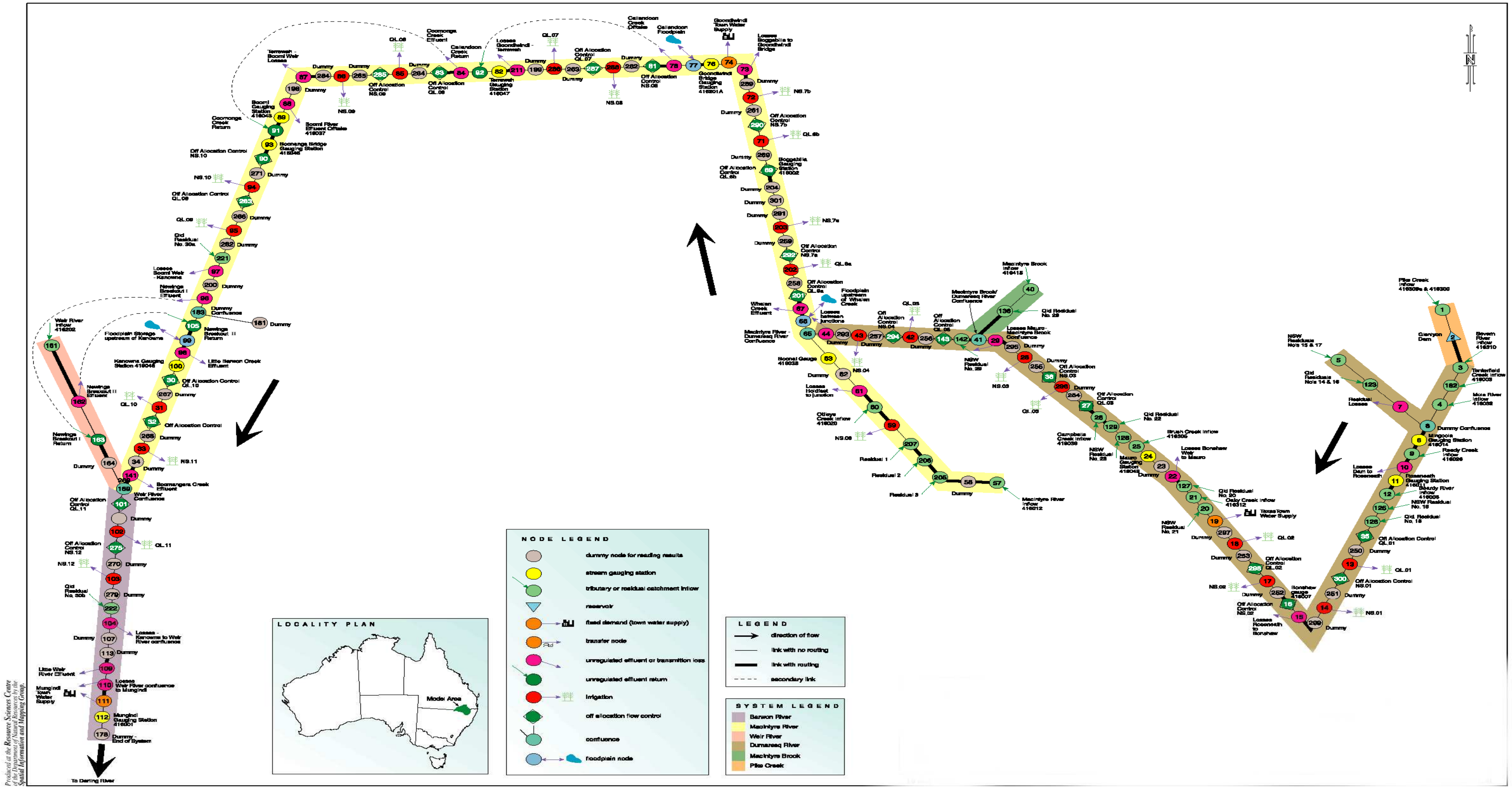


Figure C.3 Glenlyon subsystem node-link diagram as used in the original model calibration

Appendix D. Modelling the Planting Decision

D.1 IQQM PLANTING DECISION

IQQM is capable of simulating a planted area for each irrigation node, based upon water availability, for a summer and winter crop each year. Each crop type that is specified is modelled separately as either a summer crop (generally configured to commence in October) or a winter crop (generally configured to commence in March), and has a series of monthly crop factors and crop watering efficiency factors.

Analysis of irrigator behaviour has indicated that there is a complex inter-relationship between numerous climatic, economic and social influences and the decision to plant particular areas of various crop types. To attempt to represent all of these influences is considered too complex to model within IQQM. To develop the IQQM planting decision, some fundamental assumptions regarding irrigators' behaviour as a group have been made, based on observed behaviour and numerous discussions with irrigation representatives.

It has been assumed that irrigators would generally seek to plant some maximum area for a notional level of development and set of economic and social conditions, given sufficient water availability. As resources are constrained due to climatic variability, they would respond by planting smaller areas based on an apparent application rate. This application rate (or "irrigator behaviour function") would represent a number of influences not specifically modelled within IQQM. At some point of resource constraint, irrigators would seek to plant a minimum area based on possible future resources becoming available, economic pressures and the need to maintain perennial crops. This process is also called the irrigators' planting risk.

The irrigators' planting risk will reflect the influence of a number of factors including commodity prices, individual farm finances, antecedent climatic conditions and water availability in recent seasons. However, the ability to represent these influences explicitly within IQQM has not been developed yet, in part due to a lack of reliable information. It is clear, however, that the available water at the planting decision date is the most influential variable on the area planting decision. Consequently, a relationship between the planted area and water availability only has been adopted.

The total area to be planted is determined by Eq. D.1:

Total Area = f(CWA, IPR) {Eq. D.1}

Where: CWA = current water available (ML)

= AWD * licensed volume (annual accounting) + water in on-farm storage

IPR = the irrigators' planting risk (ML/ha)

= a target application rate based on the CWA at the planting decision date.

The IPR will reflect a number of influences including the actual crop water requirements, expectations that the irrigators may have in regard to further increases in AWD, future access to supplementary water, rainfall on the crop during the growing season and a range of economic considerations. Figure D.1 below explains the calculation process used in IQQM to define irrigator's expectations in regard to further increases in AWD, as being definition of dry (lower) average and wet (upper) straight line functions.

The total area is also bounded by a maximum and minimum planted area.

An irrigator's planting decision is generally regarded as being specific to a particular model scenario (ex., Cap or WSP development), and is selected as part of the scenario development.

The selection of a calibration period for a model scenario is based on the assumption that irrigator behaviour (including climatic, social and economic influences) will remain static for that period.

The mix of crop types that make up the total area and their relative proportion of the total area are also selected based on the historical information during the calibration period. These are input for a given scenario and remain static for the entire simulation period.

D.2. DERIVATION OF AN APPROPRIATE IRRIGATORS' PLANTING RISK

The irrigators' planting risk in IQQM can vary over time and can be configured separately for both the summer and winter crops. When selecting an appropriate IPR, parameters derived in earlier calibration stages are used to give an indication of appropriate parameter values for the scenario being configured. The main objective of selecting an appropriate IPR decision is to generate the planted areas that are representative of the relevant farmer behaviour at the time relevant to the scenario being configured.

In this process, there are several important factors that need to be considered, including:

- The effects of growth in utilisation of water shares;
- Changes to the crop mix and area planted;
- Availability of water resources during the calibration period;
- Effects of trade on available water at each irrigation node; and
- The representation of irrigator behaviour under resource constrained conditions.

Periods in which substantial growth is occurring will have ever increasing maximum areas (and could well have a different level of irrigators' risk in each season) and are generally considered inappropriate for planting decision calibration. Similarly, varying crop mixes will also affect the relationship between the total planted area and water availability within IQQM. For example, the total planted area in a valley may decrease for the same water availability, but this may not indicate a decrease in risk if the crop mix is changing from a low water use crop to a high water use crop.

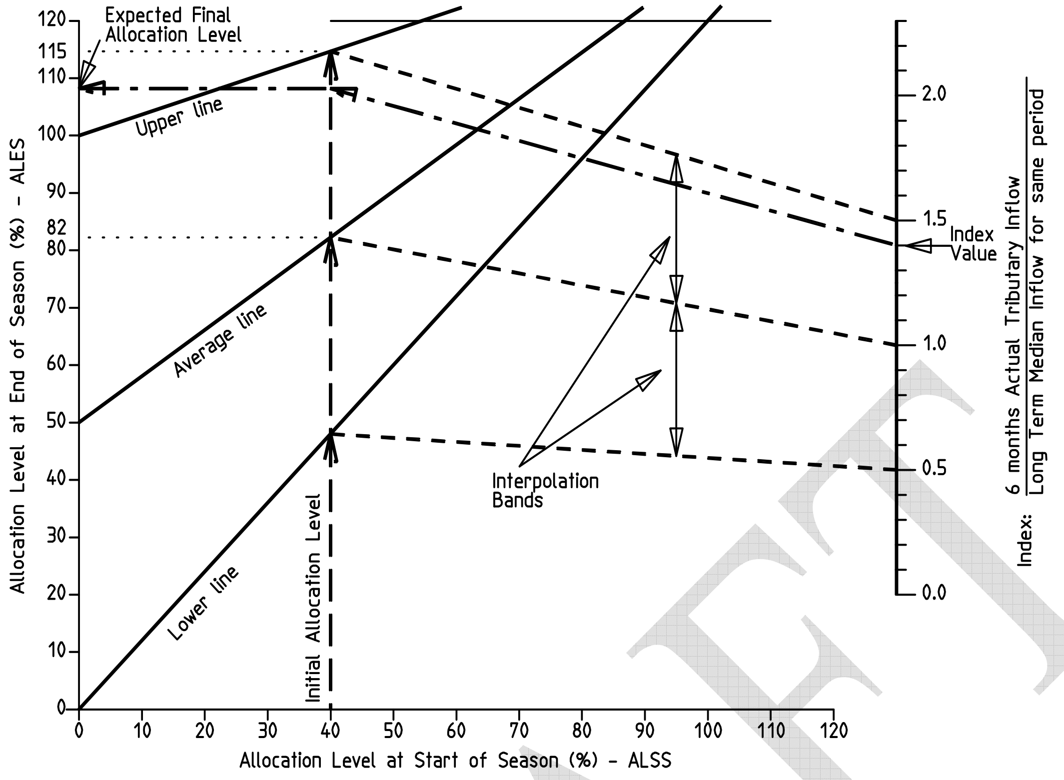


Figure D.1 Conceptual representation of IQQM calculation process regarding expectations on further increases in AWD.

Expected Allocation Level (expected water availability) at end of season for:

TII ≤ 0.5	use lower envelope
0.5 < TII ≤ 1.0	interpolate between average and lower envelope
1.0 < TII ≤ 1.5	interpolate between average and upper envelope
TII > 1.5	use upper envelope (subject to ceiling limit)

Where TII represents Tributary Inflow Index, as an indicator of antecedent wetness)

Example: If the TII equals 1.4 and the allocation level at the start of the season is 40%. The interpolation on the graph is between the average and upper line, with the intersection points between the initial allocation level and each of these lines at 82 and 115 respectively. The linear interpolation to calculate the expected allocation level is as follows:

$$ALES = ALES = 82 + \frac{115-82}{1.5-1.0} \times (1.4-1.0)$$

$$= 108.4\ \%$$

Appendix E. Quality Assessment Guidelines

This Appendix describes the methodology for assessing the quality of the IQQM model calibration. Further information can be found in [DLWC, **Error! Reference source not found.**]

The assessment system is based on rating the confidence that the model can be used to closely replicate both the time series and statistical distribution of the real system, under a specified set of development conditions. These quality rating guidelines have been developed by DNR's senior modelling staff, based on their experience and knowledge. The quality ratings are used to assess each of the major calibration steps and the overall assembled model.

The five categories used for expressing the quality rating of a particular indicator 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 these five quality ranges, to define the quality of the calibration for that indicator. The bandwidth of these categories varies to reflect the measurement uncertainty in that indicator. For example, we would expect the uncertainty in the historical flow data to be smaller than the uncertainty in the historical planted area data. The assessment indicators also vary depending on the stage being assessed.

The overall model calibration assessment also takes into account the quality achieved for each of the stages of the model calibration and the length of the calibration period.

E.1. Flow Calibration Quality Indicators and Ratings

The primary quality indicator used for assessment of flow calibration is the percentage (ratio) of the model simulated flow volume versus the historical flow volume, over the calibration period. This is intended to assess whether the mass balance in the reach is preserved. Secondly, the percentage (ratio) of the model simulated flow volume versus the historical flow volume in the low, mid and high flow ranges, over the calibration period is assessed. This is intended to assess whether the historical flow regime in the reach is reproduced. Thirdly, the correlation between the simulated and historical daily flows over the calibration period is assessed. This is intended to assess whether the timing and shape of historical flows is reproduced. Finally, the match between the simulated and historical annual flows over the calibration period is assessed. DNR developed a new statistic to quantify this comparison called the coefficient of mean absolute annual differences (**Error! Reference source not found.**) as described in ***Eq. E.1***.

$$CMAAD\ (\%) = \sum_{j=1}^{y} abs(SAV_j - OAV_j) \ / \ \sum_{j=1}^{y} OAV_j \qquad \textbf{\{Eq. E.1\}}$$

Where:	*abs*	=	the absolute value
	SAV_j	=	the simulated annual flows in year(j)
	OAV_j	=	the historical annual flows in year(j)
	y	=	number of years in the calibration period

The flow calibration can be assessed on an individual reach-by-reach basis, where the main-stream flows at the upstream site are used as inputs and the flows at the downstream site are being assessed. In this instance the accuracy of the match is expected to be much higher than for an assembled model. In the assembled model, only the historical inflows at the top end of the system are used (for example dam outflows) and the flows at all the downstream gauges are simulated and assessed relative to the historical data. The quality assessment criteria are adjusted to reflect these two situations.

The generic flow calibration quality assessment criteria are presented in Table E.1.

Table E.1: Flow calibration quality assessment criteria

QUALITY INDICATOR	***PARAMETER***	***QUALITY RATING GUIDELINES***				
		Very High	High	Moderate	Low	Very Low
VOLUME RATIO = (∑Sim / ∑Obs) %	Whole flow range individual reaches assembled model	± 2% ± 4%	± 5% ± 10%	± 10% ± 15%	± 20% ± 25%	± 30% ± 35%
	Low-flow range: 0 to X%ile [1] individual reaches assembled model	± 3% ± 5%	± 7% ± 10%	± 15% ± 20%	± 25% ± 30%	± 35% ± 40%
	Mid-flow range: X to Y%ile [1] individual reaches assembled model	± 2% ± 4%	± 5% ± 10%	± 10% ± 15%	± 20% ± 25%	± 30% ± 35%
	High-flow range: Y to 100%ile [1] individual reaches assembled model	± 4% ± 7%	± 10% ± 15%	± 20% ± 25%	± 35% ± 40%	± 50% ± 50%
TIME SERIES MATCH = (1 - **Error! Reference source not found.**) %	Daily Correlation individual reaches assembled model	± 5% ± 7%	± 10% ± 15%	± 25% ± 30%	± 40% ± 45%	± 50% ± 50%
TIME SERIES MATCH = **Error! Reference source not found.** %	Annual Match individual reaches assembled model	± 5% ± 10%	± 10% ± 15%	± 15% ± 20%	± 20% ± 25%	± 25% ± 30%

Notes: [1] The “X%ile” and “Y%ile” points are defined from examination of the ranked flow-duration plot of daily flows over the calibration period. The “X%ile” point is 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 30 to 10%ile). The “Y%ile” point is 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 90 to 95%ile).

E.2. Diversion Calibration Quality Indicators and Ratings

The primary quality indicator used for assessment of diversion calibration is the percentage (ratio) of the model simulated diversion volume versus the historical diversion volume, over the calibration period. This is done for ONA, **Error! Reference source not found.** and Total diversions. This is intended to assess whether the overall total diversion and the split between ONA and **Error! Reference source not found.** diversions in the system are preserved. Secondly, the match between the simulated and historical monthly ONA diversions over the calibration period is assessed. This is intended to assess whether the crop module is reproducing the historical pattern of use. DNR developed a new statistic to quantify this comparison called the coefficient of mean absolute monthly differences (**Error! Reference source not found.**) as described in Eq. E.2.

$$CMAMD\ (\%) = \sum_{i=1}^{m} abs(SMV_i - OMV_i) \ / \ \sum_{i=1}^{m} OMV_i \qquad \{Eq.\ E.2\}$$

Where:	*abs*	=	the absolute value
	SMV_i	=	the simulated monthly ONA diversions in month(i)
	OMV_i	=	the historical monthly ONA diversions in month(i)
	m	=	number of months in the calibration period

Finally, the match between the simulated and historical annual ONA, **Error! Reference source not found.** and Total diversions over the calibration period is assessed. To quantify this comparison we used the **Error! Reference source not found.** as described in ***Eq. E.1***.

The diversion calibration can be assessed using **Error! Reference source not found.**s and planted areas forced to the historical values. This stage is aimed at isolating the diversion calibration parameters (Section **Error! Reference source not found.**). In this instance the accuracy of the match is expected to be much higher than for an assembled model. In the assembled model, the **Error! Reference source not found.**s and planted areas are not forced to historical values and the simulated diversions are not expected to match as closely as previously. The quality assessment criteria are adjusted to reflect these two situations. The generic diversion calibration quality assessment criteria are presented in **Table E.2**.

Table E.2: Diversion calibration quality assessment criteria

QUALITY INDICATOR	*PARAMETER*	*QUALITY RATING GUIDELINES*				
		Very High	High	Moderate	Low	Very Low
VOLUME RATIO = (∑Sim / ∑Obs) %	ONA Diversions with areas forced to obs with areas simulated	± 2% ± 5%	± 5% ± 10%	± 15% ± 20%	± 25% ± 30%	± 35% ± 40%
	Error! Reference source not found. Diversions with varying monthly thresholds with fixed monthly thresholds	± 3% ± 10%	± 7% ± 20%	± 20% ± 30%	± 35% ± 40%	± 50% ± 50%
	Total Diversions with forced configuration with simulated configuration	± 2% ± 7%	± 5% ± 15%	± 15% ± 20%	± 25% ± 30%	± 35% ± 40%
TIME SERIES MATCH = CMAMD %	Monthly ONA Diversions with areas forced to obs with areas simulated	± 10% ± 20%	± 15% ± 25%	± 20% ± 30%	± 30% ± 40%	± 40% ± 50%
TIME SERIES MATCH = CMAAD %	Annual ONA Diversions with areas forced to obs with areas simulated	± 10% ± 15%	± 15% ± 20%	± 20% ± 25%	± 25% ± 30%	± 35% ± 40%
	Annual **Error! Reference source not found.** Diversions with varying monthly thresholds with fixed monthly thresholds	± 10% ± 20%	± 15% ± 25%	± 20% ± 30%	± 30% ± 40%	± 40% ± 50%
	Annual Total Diversions with forced configuration with simulated configuration	± 10% ± 15%	± 15% ± 20%	± 20% ± 25%	± 25% ± 30%	± 35% ± 40%

E.3. Storage Calibration Quality Indicators and Ratings

The match between the simulated and historical storage behaviour over the calibration period is assessed using a DNR developed statistic called the coefficient of mean absolute storage drawdown deviation (**Error! Reference source not found.**) as described in Eq. E.3.

$$CMASDD\ (\%) = \sum_{i=1}^{m} abs(SMDS_i - OMDS_i) \ / \ (MaxOD * m) \qquad \{Eq.\ E.3\}$$

Where:

Where:	*abs*	=	the absolute value
	$SMDS_i$	=	simulated monthly change in storage volume in month(i)
	$OMDS_i$	=	observed monthly change in storage volume in month(i)
	MaxOD	=	maximum observed drawdown in a single water year over the calibration period.
	m	=	number of months in the calibration period

The storage calibration can be assessed using diversions forced to the historical values. This stage is aimed at isolating the storage calibration parameters (Section **Error! Reference source not found.**). In this instance the accuracy of the match is expected to be much higher than for an assembled model. In the assembled model, the **Error! Reference source not found.**s, planted areas and diversions are not forced to historical values and the simulated storage behaviour is not expected to match as closely as previously. The quality assessment criteria are adjusted to reflect these two situations.

The generic storage calibration quality assessment criteria are presented in Table E.3.

Table E.3: Storage calibration quality assessment criteria

QUALITY INDICATOR	***PARAMETER***	***QUALITY RATING GUIDELINES***				
		Very High	High	Moderate	Low	Very Low
TIME SERIES MATCH = CMASDD %	Daily storage behaviour with diversions forced to obs with diversions simulated	 ± 2% ± 4%	 ± 5% ± 10%	 ± 8% ± 15%	 ± 15% ± 20%	 ± 20% ± 25%

E.4. Planted Area Calibration Quality Indicators and Ratings

The primary quality indicator used for assessment of planted area calibration is the percentage (ratio) of the model simulated areas versus the historical areas, over the calibration period. This is intended to assess whether the **Error! Reference source not found.** functions are reproducing the historical planted areas.

Additionally, the match between the simulated and historical annual planted areas over the calibration period is assessed. To quantify this comparison we used the **Error! Reference source not found.** as described in ***Eq. E.1***.

The generic planted area calibration quality assessment criteria are presented in **Table E.4**.

Table E.4: Planted area calibration quality assessment criteria

QUALITY INDICATOR	*PARAMETER*	*QUALITY RATING GUIDELINES*				
		Very High	High	Moderate	Low	Very Low
Area RATIO = (∑Sim / ∑Obs) %	Ratio of summer planted areas **Error! Reference source not found.**'s forced **Error! Reference source not found.**'s simulated	± 3% ± 5%	± 7% ± 10%	± 15% ± 20%	± 25% ± 30%	± 35% ± 40%
	Ratio of winter planted areas **Error! Reference source not found.**'s forced **Error! Reference source not found.**'s simulated	± 15% ± 15%	± 30% ± 30%	± 40% ± 40%	± 50% ± 50%	± 60% ± 60%
	Ratio of total planted areas **Error! Reference source not found.**'s forced **Error! Reference source not found.**'s simulated	± 3% ± 5%	± 7% ± 10%	± 15% ± 20%	± 25% ± 30%	± 35% ± 40%
TIME SERIES MATCH = CMAAD %	Match of summer planted areas **Error! Reference source not found.**'s forced **Error! Reference source not found.**'s simulated	± 7% ± 12%	± 15% ± 20%	± 20% ± 25%	± 25% ± 30%	± 35% ± 40%
	Match of winter planted areas **Error! Reference source not found.**'s forced **Error! Reference source not found.**'s simulated	± 20% ± 20%	± 40% ± 40%	± 60% ± 60%	± 80% ± 80%	±100% ±100%
	Match of total planted areas **Error! Reference source not found.**'s forced **Error! Reference source not found.**'s simulated	± 7% ± 12%	± 15% ± 20%	± 20% ± 25%	± 25% ± 30%	± 35% ± 40%

E.5. Representativeness of Calibration Period

The calibration period should be representative of the ranges of climatic conditions expected in the long term simulation run. For example, if there were no wet years or no dry years then we would have lower confidence in the model's ability to simulate the system's behaviour under these conditions. By default, a longer calibration period will be more representative of the range of climatic conditions and behaviour experienced in the valley. Therefore we use the length of the calibration period as an indication of its representativeness, as presented in **Table E.5**.

Table E.5: Climatic representativeness classification guidelines

QUALITY INDICATOR	***PARAMETER***	***QUALITY RATING GUIDELINES***				
		Very High	High	Moderate	Low	Very Low
RECORD LENGTH	Length of calibration period	> 10 years	5 – 10 years	2 – 4 years	1 year	< 1year

Another aspect that should be considered by the modeller 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 we have not developed a quantitative measure to test for this, but it is mentioned here for completeness.

E.6. Overall Calibration 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 for Cap Auditing and long term scenario comparisons the following indicators have been chosen:

1) Flow match at a key gauging station (Whole range volume ratio and $1\text{-}r^2$);
2) Total diversion match for the valley (Volume ratio and **Error! Reference source not found.**);
3) Storage behaviour match (**Error! Reference source not found.**);
4) Total planted area match for the valley (Volume ratio and **Error! Reference source not found.**);

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 reproducing farmer's risk. As each of these criteria is of equal importance they have been given an equal weighting in the overall assessment of the model.

The quality guidelines for each of these indicators have five categories of confidence with various limits. To enable the calculation of a combined quality rating these confidence intervals need to be transformed into a standard rating scale as follows:

1) Very High $0\% \le x \le 5\%$
2) High $5\% < x \le 10\%$
3) Moderate $10\% < x \le 15\%$
4) Low $15\% < x \le 20\%$
5) Very low $x \ge 20\%$

The transformation for each indicator is carried out as follows:

$$SI_i = (I_i - LL_i)*(SU_i - SL_i)/(UL_i - LL_i) + SL_i \qquad \{Eq.\ E.4\}$$

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. E.5.

$$AQI = \sum_{i=1}^{k} SI_i \ / \ k \qquad \{Eq.\ E.5\}$$

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. E.6:

$$OQI = AQI * 3.0 * NY^{-0.65} \quad \{Eq. E.6\}$$

Where: *OQI* = overall quality indicator

NY = number of years of calibration period

The adjustment for climatic representativeness (Eq. E.6) 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.6).

Table E.6: Appropriate uses for the model

POSSIBLE USE	***APPROPRIATE USES BASED ON OQI (** *Eq. E.6* **)***				
	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. Cap Scenario Parameters

Table F.1: Infrastructure & development parameters for the Cap scenario

WATER SUPPLY INFRASTRUCTURE		
Storage capacity (GL)		
Pindari Dam	312.0	As agreed by MDBMC
Boggabilla Weir	6.2	As at 1993/94
Glenlyon Dam	254.3	As at 1993/94
Coolmunda Dam	69.0	As at 1993/94
NSW OFS	130.0	As at 1993/94
Queensland OFS	99.0	As at 1993/94
Pump capacity (ML/d)		
NSW	6,863	As at 1999/2000
Queensland	6,340	As at 1993/94
Irrigation areas developed (ha)		
NSW	39,420	Based on 1999/2000
Queensland	23,265	As at 1993/94
WATER ALLOCATION AND OPERATING SYSTEM RULES		
Accounting system	Annual Water order debiting	As at 1993/94
Allocation precedence	HS > GS-A > GS-B	As at 1993/94
Water year start	October	As at 1993/94
Maximum AWD	100%	As at 1993/94
Maximum annual usage	100%	As at 1993/94
Groundwater access	No	See Section **Error! Reference source not found.**
GS Carryover		
NSW	0%	As at 1993/94
Queensland (Glenlyon)	100%	As at 1993/94
Queensland (Coolmunda)	0%	As at 1993/94

Resource Assessment		
Storage reserves at the start of water year (GL)		
Pindari	40.0	Based on revised operation
Glenlyon	40.0	As at 1993/94
Coolmunda	12.5	As at 1993/94
Transmission and operational allowance (GL/y @100% allocation)		
Pindari	19.0	Based on revised operation
Glenlyon (NSW)	16.0	As at 1993/94
Glenlyon (Queensland)	12.0	As at 1993/94
Coolmunda	13.8	As at 1993/94
Minimum expected inflows (ML/y)		
Pindari Dam	13,000	As at 1993/94
Glenlyon Dam	240	As at 1993/94
Coolmunda Dam	0	As at 1993/94
Error! Reference source not found. Error! Reference source not found. Glenlyon Dam	11,500	As at 1993/94
Error! Reference source not found. (Severn-Macintyre)	3,300	As at 1993/94
In-stream requirements		
Boomi replenishment	10 GL/year	As at 1993/94
Pindari Dam EIS releases	See Section **Error! Reference source not found.**	Based on revised operation
ENTITLEMENTS ALLOCATED AND EXTENT OF UTILISATION		
Entitlements		
NSW		
Stock and Domestic	1,200 ML	As at 1993/94
Town water supply	744 ML	As at 1993/94
High Security	1,233 ML	As at 1993/94

General Class A	20,880 ML	As at 1993/94
General Class B	243,531 ML	As at 1993/94
Supplementary	120,000 unit shares	As at 1993/94 (see **Table F.1**)
Floodplain harvesting	Unrestricted	See **Table F.6**
Queensland		
Town water supply	2,340 ML/y	As at 1993/94
Glenlyon system	84,300 ML/y	As at 1993/94
Coolmunda system	17,300 ML/y	As at 1993/94
Supplementary	Unrestricted	As at 1993/94 (see **Table F.1**)
Floodplain harvesting	Unrestricted	See **Table F.6**
Utilisation		
NSW (all)	100%	As at 1993/94
Queensland (Glenlyon)	100%	As at 1993/94
Queensland (Coolmunda)	80%	As at 1993/94
UNDERLYING LEVEL OF DEMAND FOR WATER		
As modelled in IQQM		
SYSTEM OPERATING EFFICIENCY		
End of year diversions	No	As at 1993/94
Over-order allowances	Yes	See Table B.7
Irrigation/crop efficiency	See Table B.4	As at post Pindari Dam enlargement

Table F.2: Adopted maximum and minimum area for the Cap scenario

Reach or Irrigator Number	Maximum Area (ha)		Minimum Area[3] (ha)	
	NSW[1]	QLD[2]	NSW[1]	QLD[2]
1	1,002	1,180	-	-
2	1,157	1,350	-	-
3	158	530	-	-
4	98	2,092	-	-
5	198	1,000	-	-
6	2,121	2,500	-	-
6b	-	3,364	-	-
6c	-	3,239	-	-
7a	4,050	1,650	-	-
7b	4,593	-	-	-
8	10,682	1,090	-	-
9	4,357	700	-	-
10	6,644	2,550	-	-
11	1,135	2,550	-	-
12	3,226	-	-	-
Unregulated Irrigators/Water harvesters				
Tarrawatta/Kuali Weir River	-	2,470	-	-
Merriot Weir River	-	1,000	-	-
Total	39,421	23,265	10,400	7,500

Notes: [1]- Include all NSW irrigator groups (i.e., Glenlyon and Pindari sub-system);

[2]- Include all QLD regulated irrigators (i.e., Dumaresq-Macintyre River and Macintyre Brook sub-systems);

[3]- Not specified in case of allocation based risk used in the BR IQQM;

Table F.3: Adopted Error! Reference source not found. **for the Cap scenario**

Irrigation group	*Risk equations and correspondent Antecedent Climatic Index (ACI) index ratio*			*Expected Rainfall in a growing season (mm)*
	Dry	*Average*	*Wet*	
NS1	y=0.70x+0.10 (0.75)	y=0.95x+0.60 (1.10)	y=1.10x (1.60)	290
NS2	y=0.70x+0.10 (0.78)	y=0.95x+0.52 (1.10)	y=1.10x (1.60)	260
NS3	y=0.70x+0.13 (0.78)	y=0.95x+0.72 (1.10)	y=1.10x (1.60)	250
NS4	y=0.70x+0.13 (0.78)	y=0.95x+0.72 (1.10)	y=1.10x (1.80)	250
NS5	y=0.70x+0.10 (0.75)	y=0.95x+0.60 (1.10)	y=1.10x (1.60)	260
NS6	y=1.05x+0.23 (0.77)	y=1.00x+0.59 (1.10)	y=1.10x+0.33 (5.70)	190
NS7a & b	y=0.80x+0.23 (0.77)	y=0.95x+0.59 (1.10)	y=1.10x+0.33 (5.70)	170
NS8	y=0.80x+0.37 (0.78)	y=0.85x+0.24 (4.50)	y=1.10x (11.0)	100
NS9	y=0.85x+0.26 (0.78)	y=0.90x+0.64 (1.79)	y=1.10x+0.1 (8.00)	100
NS10	y=0.85x+0.17 (0.58)	y=1.45x+0.95 (1.79)	y=1.10x+0.02 (9.00)	100
NS11&12	y=0.85x+0.16 (0.58)	y=0.85x+0.43 (1.10)	y=1.10x (10.0)	100
QL1	y=0.63x+0.05 (0.60)	y=4.75x+0.75 (1.50)	y=1.00x (1.70)	290
QL2	y=0.82x+0.15 (0.60)	y=3.25x+0.50 (1.58)	y=1.00x+0.15 (1.59)	290
QL3	y=0.72x+0.10 (0.70)	y=5.05x+0.95 (1.25)	y=1.00x (1.59)	260
QL4a,b[1]	y=0.35x+0.65 (0.50)	y=0.50x+0.75 (10.0)	y=0.65x+0.80 (50.0)	215
QL5	y=0.85+0.25 (0.58)	y=1.95x+1.25 (1.10)	y=1.0x (1.59)	170
QL6a,b,c	y=0.80x+0.15 (0.79)	y=0.95x+1.55 (1.10)	y=1.00x+0.05 (1.59)	170
QL7	y=0.87x+0.95 (0.65)	y=0.95x+1.95 (5.75)	y=1.00x (11.70)	190
QL8	y=0.62x+0.10 (0.54)	y=1.45x+2.05 (1.50)	y=1.00x (1.70)	250
QL9	y=0.85x (0.78)	y=0.95x+1.65 (1.10)	y=1.00x+0.10 (1.30)	190
QL10&11	y=0.88x+0.10 (0.78)	y=0.95x+1.65 (1.10)	y=1.00x (5.00)	200

Notes: (1) Unchanged from the original BR **Error! Reference source not found.** calibration (Section **Error! Reference source not found.**);

Table F.4: Adopted crop mix for the Cap scenario

Irrigator Node	Percentage of crop (%)							
	Cotton	Lucerne	Summer Cereal	Pasture	Barley	Winter Cereal	Vegetables	Others
				NSW				
1	8	14	1	6	0	25	30	16
2	9	44	15	7	0	12	0	13
3	0	27	52	0	0	21	0	0
4	0	0	69	0	0	31	0	0
5	0	36	11	21	0	0	0	32
6	92	0	0	3	0	5	0	0
7a	93	0	0	0	0	7	0	0
7b	89	0	0	0	0	11	0	0
8	100	0	0	0	0	0	0	0
9	98	0	0	0	0	2	0	0
10	97	0	0	0	0	3	0	0
11	88	0	0	0	0	12	0	0
12	100	0	0	0	0	0	0	0
Sub-total	**90**	**2**	**1**	**1**	**0**	**4**	**1**	**1**
				Queensland				
1	0	26	14	35	0	10	15	0
2	0	23	8	20	0	45	4	0
3	0	24	10	0	0	26	40	0
4	0	80	15	0	0	0	4	1
5	93	0	4	3	0	0	0	0
6a	86	11	2	1	0	0	0	0
6b	90	4	4	0	2	0	0	0
6c	95	0	5	0	0	0	0	0
7	90	0	4	0	0	6	0	0
8	89	0	2	0	0	9	0	0
9	75	0	0	2	0	23	0	0
10	100	0	0	0	0	0	0	0
11	90	0	2	6	0	2	0	0
Sub-total	**72**	**12**	**5**	**4**	**0**	**5**	**2**	**0**
				Unregulated Irrigators/Water harvesters				
Tarrawatta/Kuali W	100	0	0	0	0	0	0	0
Merriot Weir River	100	0	0	0	0	0	0	0
Valley Overall #	**85**	**5**	**2**	**1**	**0**	**5**	**1**	**1**

Notes: # Weighted average based on planted area.

Table F.5: Adopted surplus (Error! Reference source not found.) flow thresholds for the Cap scenario

Reach	Error! Reference source not found. **Threshold (ML/d)**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
QL1, NS1	2,200	3,000	3,000	1,000	1,000	500	500	500	500	1,400	1,400	1,650
QL2, NS2	2,200	3,000	3,000	1,000	1,000	500	500	500	500	1,400	1,400	1,650
QL3, NS3	2,200	3,000	3,000	1,000	1,000	500	500	500	500	1,400	1,400	1,650
QL4a,b	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
QL5, NS4	2,200	3,000	3,000	1,000	1,000	500	500	500	800	1,400	1,400	1,650
NS5	2,500	3,000	950	500	500	500	500	500	1,000	1,500	900	2,500
NS6	2,500	3,000	950	500	500	500	500	500	1,000	1,500	900	2,500
QL6a, NS7a	2,200	5,000	5,000	1,000	1,000	500	500	500	500	1,400	1,400	1,650
QL6b, NS7b, QL6c	2,200	5,000	5,000	1,000	1,000	500	500	500	500	1,400	1,400	1,650
NS8, QL7	2,000	5,000	5,000	1,000	1,000	500	500	500	500	1,400	1,400	1,750
QL8, NS9	1,500	5,000	5,000	1,000	1,000	500	500	500	500	800	800	900
NS10, QL9	700	5,000	5,000	700	700	500	500	500	500	300	500	600
QL10, NS11	500	5,000	5,000	700	700	500	500	500	500	300	400	500
QL11, NS12	500	5,000	5,000	700	700	500	500	500	500	300	400	500

Notes: # River flow reference point for this irrigator's SF extractions is Goondiwindi Bridge Gauge. It also has different commence pumping and stop pumping threshold. For each of the other nodes both (commence pumping and stop pumping) thresholds are the same.

Table F.6: Adopted parameters for floodplain harvesting in the Cap Scenario

Irrigator Node	Harvesting via Pumping				Harvesting via Gravity
	Flow Threshold (ML/d)	Flow Threshold Location	Pump Capacity (ML/d)		Local Flow Threshold (ML/d)
			NSW	QLD	
QL1 - QL5	n/a	n/a	n/a	n/a	n/a
NS1 – NS6	n/a	n/a	n/a	n/a	n/a
QL6a – NS7a	90,300	416002 Macintyre R. @ Bogabilla Weir	285	168	n/a
QL6b – NS7b	n/a	n/a	n/a	n/a	n/a
NS8-QL7	61,260	416047 Macintyre R. @ Terrawah	1,560	1,080	n/a
QL6b (Capel Curig)	4,201	Local (Yambocully Creek)	n/a	284	n/a
QL6c (Oonavale)	42,040	416206A Calandoon Ck @ Oonavale	n/a	240	n/a
QL6c (Oonavale Pipes)	41,800	416206A Calandoon Ck @ Oonavale	n/a	705	n/a
QL6c (Gubbagunyah)	50,600	416203A Calandoon Ck @ Carana Weir	n/a	168	n/a
QL6c (Woodoogle)	41,800	416206A Calandoon Ck @ Oonavale	n/a	440	n/a
QL6c (Strathmore)	41,800	416206A Calandoon Ck @ Oonavale	n/a	120	n/a
QL6c (Brooklyn)	41,800	416206A Calandoon Ck @ Oonavale	n/a	600	n/a
QL6c (Kilmarnock)	41,800	416206A Calandoon Ck @ Oonavale	n/a	240	n/a
QL8 - NS9	26,900	416043 Macintyre R. @ Boomi Weir	156	920	n/a
NS10	56,300	416046 Macintyre R. @ Boonanga Bridge	1,206	n/a	n/a
QL9	56,300	416046 Macintyre R. @ Boonanga Bridge	n/a	648	n/a
	2,899	local (u/s Kanowna)	n/a	240	n/a
	1,000	local (u/s Kanowna)	n/a	120	n/a
QL10 (Willarie/Worral)	3,500	local (u/s Kanowna)	n/a	120	n/a
QL10 (Tarrawatta)	3,500	local (u/s Kanowna)	n/a	120	n/a
QL10 (Newinga)	2,779	416205A Weir R. @ Jerico	n/a	240	n/a
NS11	2,779	416205A Weir R. @ Jerico	31	n/a	n/a
QL11 – NS12	10,700	416001 Macintyre R. @ Mungindi	449	219	n/a
Jericho (Weir River)	2,779	416205A Weir R. @ Jerico	n/a	240	n/a

Table F.7: Adopted parameters for OFS reserve for the Cap scenario

Reach	OFS Reserve Pattern (ML/ha stored in OFS)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
QL 1, 2, 3, 4a, 4b	n/a - no OFS											
NS 1, 2, 3, 5	n/a - no OFS											
QL5	2.60	2.30	2.20	2.10	0.10	0.10	0.10	0.10	0.80	2.60	2.60	2.60
NS4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NS6	2.60	2.10	1.80	1.80	0.30	0.30	0.30	0.30	2.30	2.60	2.60	2.60
QL6a – QL11	2.70	2.50	2.10	2.00	0.20	0.20	0.20	0.20	1.10	2.70	2.70	2.70
NS7a – NS12	2.70	2.30	1.90	1.90	0.40	0.40	0.40	0.40	2.50	2.70	2.70	2.70

Table F.8: Adopted parameters for OFS airspace for the Cap scenario

Irrigator	Airspace Pattern (% of OFS volume)											
Node	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
QL 1, 2, 3, 4a, 4b	n/a - no OFS											
NS 1, 2, 3, 5	n/a - no OFS											
NS4 – NS12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
QL6a – QL11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix G. Border Rivers Irrigator Survey

Below is a copy of the questionnaire filled in by representatives of the Gwydir irrigators during the 2004 and 2005 meetings.

Could you please indicate which of the following river reaches your extraction point/s (i.e., river pumps) are located in (if more than one, please indicate with # in descending order, ex.,., 1 for reach with the largest pump, 2 – for reach with second largest pump, etc.) *:

Could you please indicate which of the following river reaches your extraction point/s (i.e., river pumps) are located in (if more than one, please indicate with # in descending order, ex., 1 for reach with the largest pump, 2 – for reach with second largest pump, etc.) *:

Location	Indicate
Glenlyon Dam to Bonshaw Weir Pool (including Pool pumpers)	
d/s Bonshaw Weir to Glenarbon Weir Pool (including Pool pumpers)	
d/s Glenarbon Weir to Dumaresq – Macintyre Brook Junction	
Dumaresq – Macintyre Brook Junction to Macintyre – Dumaresq Rivers Junction	
Pindari Dam to Holdfast Gauge	
Holdfast Gauge to Macintyre – Dumaresq Rivers Junction	
Macintyre – Dumaresq Rivers Junction to Boggabilla Weir Pool (including Pool pumpers)	
d/s Bogabilla Weir to Goondiwindi Weir Pool (including Pool pumpers)	
d/s Goondiwindi Weir to Terrawah Gauge	
Terrawah Gauge to Boomi Weir Pool (including Pool pumpers)	
d/s Boomi Weir to Kanowna Gauge	
Kanowna Gauge to Macintyre –Weir Rivers Junction	
Macintyre – Weir Rivers Junction to Mungindi Weir (including Pool pumpers)	

(*): Please note, that there are no questions in this survey that formally identify your farm. However, due to the specific nature of the IQQM, accurate spatial representation of the irrigation development in the valley is essential for obtaining credible model results.

SECTION A

About your Farm

1.0 Please provide the following details about your enterprise as it was in the respective water year (where applicable):

1.1 Type of Irrigation Licence (surface water only) ______________________

(eg, General Security; High Security; Unregulated)

1.2 Licenced Volume ______________ ML

Water year: **1999/2000** **2002/2003**

Note: Please, indicate Units when answering questions where these are not specified for your convenience:

1.3	Area developed for irrigated production	__________	__________
1.4	Area actually irrigated	__________	__________
1.5	Maximum area you would have irrigated given unlimited water availability	__________	__________
1.6	Planted Crops *(eg, Cotton 50%*	*Lucerne 50%)*	
	______________	_________ %	_________ %
	______________	_________ %	_________ %
	______________	_________ %	_________ %
	______________	_________ %	_________ %
	______________	_________ %	_________ %
1.7	Decision date for how much area to plant	______________________	
	(eg, 1st October for Cotton)	______________________	
		______________________	
1.8	Installed pump capacity		
	From river only (1st lift pumps)	__________	__________
	2nd lift pumps (if applicable)	__________	__________
1.9	Total on-farm storage capacity	________ML	________ML

SECTION B

Your Irrigation Practices

Irrigation Methods

1.0 Do you irrigate before sowing ?

☐ No: please go to "Area Planting Decisions".

☐ Yes: please specify below

Crop Type	Approximate Application Rate (ML/Ha)

2.0 What type of irrigation methods do you typically use? (eg, spray, drip, flood, etc.)

Crop Type	Irrigation Method

Area Planting Decisions

1.0 On the planting date what factors do you consider when determining the areas of crops that you will plant ? Please indicate the level of importance by ticking one box per option.

		Importance		
	High	Moderat e	Low	N/A
1.1 Volume of water in on-farm storage(s)				
1.2 Volume of carry over water available				
1.3 Volume of allocated water available				
1.4 Recent climatic conditions				

1.5 Market Prices

1.6 Others? : ________________

2.0 Please provide the following details about your enterprise in the respective water year (where applicable):

Water year: **1999/2000** **2001/2002**

2.1 Volume of Available Carry Over on 1st October _______ML _______ML

2.2 Volume of Water in On-farm storage on 1st October _______ML _______ML

2.3 Expected Volume of Carry Over into next year _______ML _______ML

2.4 Volume of On-allocation used in a season _______ML _______ML

2.5 Volume of Off-allocation (OFA)used in a season _______ML _______ML

2.6 Number of OFA pumping days in a season _______ML _______ML

3.0 Application rates when making area planting decisions:

3.1 What application rate do you count on from your regulated water supply? *(eg, 5 ML/Ha)*	
3.2 Do you vary this application rate for varying levels of available resource? *(eg, wet year 5 ML/Ha; dry year 4 ML/Ha)*	

4.0 Could you please estimate what planted crops you would have, depending on how much water is available in the season:

	Available water on 01/10			Planted Crops	
	Allocation (%)	Carry Over (%)	On Farm Storage	Type	Planted Area (ha)
Least Water	0	0	Empty		
Available	0	0	Full		
↓	0	25	Empty		
	0	25	Full		
	0	50	Empty		
	0	50	Full		
	50	0	Empty		
	50	0	Full		
	50	25	Empty		
	50	25	Full		
	50	50	Empty		
	50	50	Full		
	100	0	Empty		
	100	0	Full		
	100	25	Empty		
	100	25	Full		
	100	50	Empty		
	100	50	Full		
Most Water	0	100	Empty		
Available	100	100	Full		

On-Farm Storage Usage

1.0 If you have an on-farm storage, do you fill it at the end of the year with unused allocation that would otherwise become carry over ?

- ☐ Yes, prior to trying to sell the unused water on the market
- ☐ Yes, after selling as much unused water as I can
- ☐ No
- ☐ Other

2.0 Do you leave any airspace in your on-farm storage after pumping an off-allocation event ? If yes, please give details below, including what use it for:

____

3.0 Do you store any water in your on-farm storage to cover short periods when your orders do not arrive when required (ie., an OFS reserve)? If yes, please give details below:

____

Ground-water Usage

1.0 Do you supplement your surface/river water supplies from ground water sources ? If yes, please give details below:

____

____

____

____

Water harvesting

1. Do you supplement your surface/ground water supplies by harvesting water from the following alternative water sources ?

1.1 Flood Plain Harvesting* ☐ Yes ☐ No: please, go to 1.2

(* - harvesting/collecting water ponding on your farm as a result of a river overbank flow)

1.1.1 Could you please estimate minimum river flow at the nearest gauge or location of your farm at which a flood plain harvesting opportunity arises (ie., 15,000ML/day)________________________________

1.1.2 Could you please estimate frequency of water years that a flood plain harvesting opportunity occurs (ie., every year, 1in 2, 9 in 10, etc):_____

1.1.3 What method do you use to harvest water from flood plain ?

☐ Gravity (water naturally flows into on farm storage)

☐ Pumping (water is pumped into on farm storage)

☐ Other: ____

1.1.4 How much flood plain harvesting water would you extract during an average year with a flood plain harvesting opportunity:

____

1.2 Runoff Harvesting* ☐ Yes ☐ No: please, go to “Other Information”;

(*- harvesting/collecting water ponding on your farm as a result of an intensive rainfall)

1.2.1 What method do you use to harvest runoff water ?

☐ Gravity (water naturally flows into on farm storage)

☐ Pumping (water is pumped into on farm storage)

☐ Other: ____

1.2.2 What area do you harvest runoff water from?

☐ Cropped area only

☐ Fallow area only

☐ Total developed area (cropped and fallow areas)

☐ Other: ____

1.2.3 Could you please estimate after how much rainfall a runoff harvesting event occurs:____

1.2.4 Could you please estimate the maximum runoff water volume you would harvest in a wet year:_________________________________

1.2.5 Could you please estimate average annual runoff water volume you harvest from your farm:_____________________________________

1.2.6 Do you store runoff harvested water before transferring it into on farm storage ? If Yes, please provide details below:

____

____

____

____

3.0 If you use pumps to harvest both flood plain and runoff water, what water would you harvest first?

☐ Flood plain

☐ Runoff

☐ None of the above: please provide details below:

____

____

____

____

Other Information

1.0 Do you feel there is any other information we have not asked you that will help us to model your farm more adequately?

Below is a copy of the questionnaire filled in by representatives of the Gwydir irrigators during the 2004 and 2005 meetings [Border Rivers Irrigators Survey and Pers.communications, **Error! Reference source not found.**-2004].

Could you please indicate which of the following river reaches your extraction point/s (i.e., river pumps) are located in (if more than one, please indicate with # in descending order, ex.,., 1 for reach with the largest pump, 2 – for reach with second largest pump, etc.) *:

Could you please indicate which of the following river reaches your extraction point/s (i.e., river pumps) are located in (if more than one, please indicate with # in descending order, ex., 1 for reach with the largest pump, 2 – for reach with second largest pump, etc.) *:

Location	Indicate
Glenlyon Dam to Bonshaw Weir Pool (including Pool pumpers)	
d/s Bonshaw Weir to Glenarbon Weir Pool (including Pool pumpers)	
d/s Glenarbon Weir to Dumaresq – Macintyre Brook Junction	
Dumaresq – Macintyre Brook Junction to Macintyre – Dumaresq Rivers Junction	
Pindari Dam to Holdfast Gauge	
Holdfast Gauge to Macintyre – Dumaresq Rivers Junction	
Macintyre – Dumaresq Rivers Junction to Boggabilla Weir Pool (including Pool pumpers)	
d/s Bogabilla Weir to Goondiwindi Weir Pool (including Pool pumpers)	
d/s Goondiwindi Weir to Terrawah Gauge	
Terrawah Gauge to Boomi Weir Pool (including Pool pumpers)	
d/s Boomi Weir to Kanowna Gauge	
Kanowna Gauge to Macintyre –Weir Rivers Junction	
Macintyre – Weir Rivers Junction to Mungindi Weir (including Pool pumpers)	

(*): Please note, that there are no questions in this survey that formally identify your farm. However, due to the specific nature of the IQQM, accurate spatial representation of the irrigation development in the valley is essential for obtaining credible model results.

SECTION A

About your Farm

1.0 Please provide the following details about your enterprise as it was in the respective water year (where applicable):

1.1 Type of Irrigation Licence (surface water only) ______________________

(eg, General Security; High Security; Unregulated)

1.2 Licenced Volume ______________ ML

Water year: **1999/2000** **2002/2003**

Note: Please, indicate Units when answering questions where these are not specified for your convenience:

1.3 Area developed for irrigated production __________ __________

1.4 Area actually irrigated __________ __________

1.5 Maximum area you would have irrigated given unlimited water availability __________ __________

1.6 Planted Crops *(eg, Cotton 50% Lucerne 50%)*

______________ _________ %_________ %

______________ _________ %_________ %

______________ _________ %_________ %

______________ _________ %_________ %

______________ _________ %_________ %

1.7 Decision date for how much area to plant ______________________

(eg, 1st October for Cotton) ______________________

____

	Water year:	1999/2000	2002/2003
1.8	Installed pump capacity		
	From river only (1st lift pumps)	_________	_________
	2nd lift pumps (if applicable)	_________	_________
1.9	Total on-farm storage capacity	_______ML	_______ML

SECTION B

Your Irrigation Practices

Irrigation Methods

1.0 Do you irrigate before sowing ?

☐ No: please go to "Area Planting Decisions".

☐ Yes: please specify below

Crop Type	Approximate Application Rate (ML/Ha)

2.0 What type of irrigation methods do you typically use? (eg, spray, drip, flood, etc.)

Crop Type	Irrigation Method

Area Planting Decisions

1.0 On the planting date what factors do you consider when determining the areas of crops that you will plant ? Please indicate the level of importance by ticking one box per option.

		Importance			
		High	Moderate	Low	N/A
1.1	Volume of water in on-farm storage(s)				
1.2	Volume of carry over water available				
1.3	Volume of allocated water available				
1.4	Recent climatic conditions				
1.5	Market Prices				
1.6	Others? : ____________________				

2.0 Please provide the following details about your enterprise in the respective water year (where applicable):

	Water year:	**1999/2000**	**2001/2002**
2.1	Volume of Available Carry Over on 1st October	_______ML	_______ML
2.2	Volume in On-farm storage on 1st October	_______ML	_______ML
2.3	Expected Volume of Carry Over into next year	_______ML	_______ML
2.4	Volume of On-allocation used in a season	_______ML	_______ML
2.5	Volume of Off-allocation (OFA) used in a season	_______ML	_______ML
2.6	Number of OFA pumping days in a season	_______ML	_______ML

3.0 Application rates when making area planting decisions:

3.1	What application rate do you count on from your regulated water supply? *(eg, 5 ML/Ha)*	
3.2	Do you vary this application rate for varying levels of available resource? *(eg, wet year 5 ML/Ha; dry year 4 ML/Ha)*	

4.0 Could you please estimate what planted crops you would have, depending on how much water is available in the season:

	Available water on 01/10			Planted Crops	
	Allocation (%)	Carry Over (%)	On Farm Storage	Type	Planted Area (ha)
Least Water Available	0	0	Empty		
	0	0	Full		
	0	25	Empty		
	0	25	Full		
	0	50	Empty		
	0	50	Full		
	50	0	Empty		
	50	0	Full		
	50	25	Empty		
	50	25	Full		
	50	50	Empty		
	50	50	Full		
	100	0	Empty		
	100	0	Full		
	100	25	Empty		
	100	25	Full		
	100	50	Empty		
↓	100	50	Full		
	0	100	Empty		
Most Water Available	100	100	Full		

On-Farm Storage Usage

1.0 If you have an on-farm storage, do you fill it at the end of the year with unused allocation that would otherwise become carry over ?

☐ Yes, prior to trying to sell the unused water on the market

☐ Yes, after selling as much unused water as I can

☐ No

☐ Other:

2.0 Do you leave any airspace in your on-farm storage after pumping an off-allocation event ? If yes, please give details below, including what use it for:

3.0 Do you store any water in your on-farm storage to cover short periods when your orders do not arrive when required (ie., an OFS reserve)? If yes, please give details below:

Ground-water Usage

1.0 Do you supplement your surface/river water supplies from ground water sources ? If yes, please give details below:

____

____

____

____

Water harvesting

2. Do you supplement your surface/ground water supplies by harvesting water from the following alternative water sources ?

2.1 Flood Plain Harvesting* ☐ Yes ☐ No: please, go to 1.2

(* - harvesting/collecting water ponding on your farm as a result of a river overbank flow)

2.1.1 Could you please estimate minimum river flow at the nearest gauge or location of your farm at which a flood plain harvesting opportunity arises (ie., 15,000ML/day)______________________________

2.1.2 Could you please estimate frequency of water years that a flood plain harvesting opportunity occurs (ie., every year, 1in 2, 9 in 10, etc):_____

2.1.3 What method do you use to harvest water from flood plain ?

☐ Gravity (water naturally flows into on farm storage)

☐ Pumping (water is pumped into on farm storage)

☐ Other: ____

2.1.4 How much flood plain harvesting water would you extract during an average year with a flood plain harvesting opportunity

:________________ ____________________________

2.2 Runoff Harvesting* ☐ Yes ☐ No: please, go to “Other Information”;
(*- harvesting/collecting water ponding on your farm as a result of an intensive rainfall)

2.2.1 What method do you use to harvest runoff water ?

☐ Gravity (water naturally flows into on farm storage)

☐ Pumping (water is pumped into on farm storage)

☐ Other: ____

2.2.2 What area do you harvest runoff water from?

☐ Cropped area only

☐ Fallow area only

☐ Total developed area (cropped and fallow areas)

☐ Other: ____

2.2.3 Could you please estimate after how much rainfall a runoff harvesting event occurs:

____

2.2.4 Could you please estimate the maximum runoff water volume you would harvest in a wet year:

____

2.2.5 Could you please estimate average annual runoff water volume you harvest from your farm

:____________________________________

2.2.6 Do you store runoff harvested water before transferring it into on farm storage ? If Yes, please provide details below:

____

____

____

____

3.0 If you use pumps to harvest both flood plain and runoff water, what water would you harvest first?

☐ Flood plain

☐ Runoff

☐ None of the above: please provide details below:

____

____

____

____

Other Information

1.0 Do you feel there is any other information we have not asked you that will help us to model your farm more adequately?

THANK-YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY.PLEASE DON'T HESITATE TO CONTACT DLWC's SURFACE AND GROUNDWATER