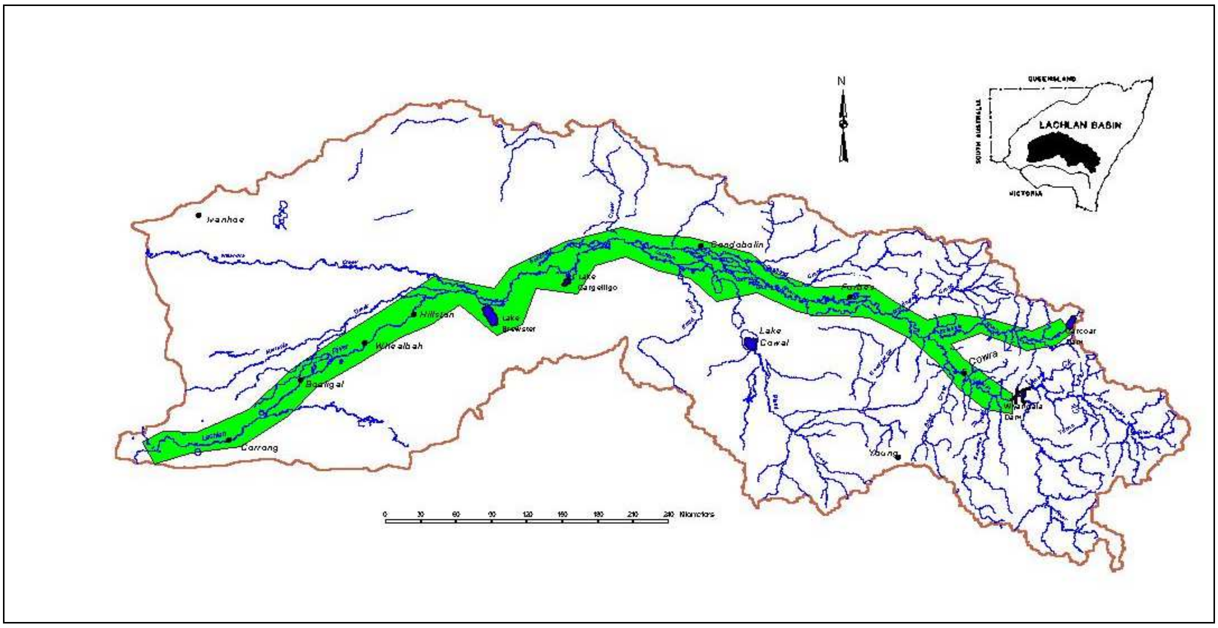
Lachlan River Valley



IQQM Cap implementation summary report

Issue: 3

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NSW Department of Land and Water Conservation

Lachlan River Valley

IQQM Cap implementation summary report

Issue: 3

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Project conducted in collaboration with the Natural Resource Products division and the Central-West Region of the DLWC.

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Contents

Page

Figures

Tables

Executive Summary

What has initiated the work?

The MDBMC Cap and NSW Water Reform initiatives have required that NSW develop a suitable planning tool to enable review of water use and sharing arrangements in the Lachlan River Valley. The tool accepted as suitable for the purpose is a calibrated water balance model that includes all relevant important features on and in the system. Such a model is called an integrated quantity quality model, or IQQM for short.

Scope of this report summarises the Lachlan –IQQM status

This report summarises and documents the IQQM calibration, validation and model use for provisional Cap runs. These data have previously been detailed and published in the set of IQQM implementation reports:

- Volume 1 : Streamflow synthesis for Wyangala Dam catchment
- Volume 2 : Streamflow synthesis for Lachlan sub-catchments
- Volume 3 : Model calibration and validation (draft)

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 flow extraction behaviour. The secondary purpose is to demonstrate that the model can be successfully used to define the 1993/94 diversion Cap.

Model construction includes all important features

Chapter 2 describes the main physical and management features included in the model. The availability and extent of time series data is also described in this chapter, as well as decisions on the number, type and arrangement of the nodes and links used to construct the Lachlan Valley IQQM.

Calibration and validation over the 1983-1998 period demonstrates model suitability

Chapter 3 describes the model calibration and validation results. Comparison is made between time series observed data and time series model simulated behaviour. Quality ratings were applied to the model calibration. The model water diversion volumes were generally a close match to the observed water diversions. Model end-of-system flows were of an “adequate” quality for comparison of alternate management options. Model storage behaviour had a “high” quality rating. Overall, the model achieved a “high” quality rating, demonstrating the model’s suitability for the intended purposes.

Statement of model adequacy for comparing management options

The Lachlan River Valley IQQM can now be accepted as calibrated and validated to a satisfactory degree. The model is suitably robust for 100 year scenario running and for comparison of impacts from alternative management scenarios.

1993/94 Cap scenario run

Chapter 4 describes the 1993/94 development conditions and the use of the Lachlan River IQQM to simulate the 1993/94 Cap scenario. Results are presented for:

a) the 103 year period from 1898 to 2001 inclusive, to estimate the average annual long term diversions for the Cap scenario;
b) the 1997/98 – 2000/01 period, to estimate diversions for auditing under the provisions of Schedule F of the Murray-Darling Basin Agreement.

Improvement suggestions

Chapter 5 lists a series of short and long term model improvement suggestions, categorised under:
- additional features;
- calibration refinements;
- research and further information, and;
- improvements to current model features.

These suggestions are not intended to reduce the credibility of the upgraded model, but should be viewed as part of DLWC's ongoing quality assurance process, promoting continuous improvement on it's key planning tools and products.

Glossary of Terms

Allocation Level – Allocation level or announced allocation is the percentage of the licensed entitlement volume that general security irrigators can divert in the current water year during on allocation periods. The first allocation level for the forthcoming irrigation season is announced at the beginning of water year and is not reduced from this announcement, noting however that it can be increased. NSW announce increased allocation levels from time to time during the irrigation season.

Allocation Sub-system – Allocation sub-system is a number of river sections that represents a group of water users who are all treated the same in terms of determining allocation levels.

Allocation System – An allocation system is a group of allocation sub-systems that have the same announced allocation announcement. The allocation level for an allocation system is defined as the minimum of the allocation levels for all the allocation sub-systems under it. This applies when irrigator groups have access to only one dam’s resources but their announced allocation level is determined by another dam’s resource criteria.

Cap – The Murray Darling Basin Ministerial Council Cap on extractions for consumptive users at the level that would have occurred under 1993/94 development levels and management rules.

Cap Scenario – An IQQM that has been configured for the long-term simulation of 1993/94 development conditions and management rules.

Cap Audit Scenario – An IQQM that has been configured for the simulation of 1993/94 development conditions and management rules. The model commences simulation in 1997/98 and provides estimates of the annual water diversions that would have occurred under Cap or 1993/94 development conditions.

Coefficient of Determination – A statistical term that describes the degree of correlation between two data sets (usually observed and simulated data points). Its value is always expressed as a decimal less than 1.0, such that the closer its value is to 1.0, the better the correlation. The symbol $\mathbf{r^2}$ is often used to represent the coefficient of determination.

DLWC – NSW Department of Land and Water Conservation.

d/s – Downstream.

ECA – Environmental Contingency Allowance; a volume of water set aside in storage for environmental purposes.

Farmer’s Risk – See irrigator behaviour.

FPH - Flood Plain Harvesting is water obtained by pumping or direct inflows of water off the flood plain. This water has not been monitored to date, and is generally considered to be that water which fills spare capacity in an on farm storage, but not via on allocation or off allocation diversions. Conceptually flood plain harvested water includes water:

- Pumped from the floodplain to the on farm storage (ie during large floods), using secondary lift pumps which are not metered.
- Entering the on farm storage because flood levels spill directly into the on farm storage, and
- From local rainfall and runoff being sufficiently intense to cause significant on farm storage filling.

General Security Licences – Licences that are supplied with 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 entitlements. Announced allocations are made each year to indicate the percentage of annual licence entitlement volume that can be supplied.

High Security Licences – Licenses that provide the highest reliability of water supply. Generally these licences are for (relatively) small amounts of water for town water supplies and permanent plantings (orchards, vineyards etc). In announcing allocation entitlements high security licences are fully satisfied prior to any allocation for general security licences.

Hot-start – To configure the model with the correct boundary or initial conditions (ie, river flows, storage volumes, soil moisture levels and releases for water orders), the model is started several weeks before the commencement of the analysis period. The purpose of this is to minimise the effect of initial assumptions on results produced by short term scenario runs.

Irrigator Behaviour (also called farmer's risk) – This relates to the irrigator's decision making process when deciding on the amount of area to plant. For example, given a drought period with dry antecedent climatic conditions, low on farm storage volume, and low announced allocation, an irrigator who plants the same area as in wet years (ie years when storages are full) is taking a higher than previous risk. That is, there is an increased likelihood that the irrigator will run out of water supplies unless additional streamflows or rainfall occurs.

Licensed Entitlement Volume – The volume of water that a licence holder on a regulated stream/river can draw on during a 100% allocation announcement. The amount drawn may be subject to other licence conditions.

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.

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.

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 – The units used to express rate of flow, in terms of megalitres (ie 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.

OFA - Off Allocation extraction is the volume of water extracted by the irrigator during an off allocation period.

Off Allocation 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 off-allocation periods may be subject to a number of other conditions such as equity, ease of access or environmental requirements. The amount of water drawn during off-allocation periods is not debited from the allocated portion of the irrigator's water entitlement for the water year.

OFS – On Farm Storage, usually referring to a large private storage constructed on an irrigator's property to store water.

ONA - On Allocation extraction is water diverted by the irrigator from regulated flows to satisfy the irrigator's crop needs or future management needs, debited against the announced allocation volume (ie allocation level times licensed volume entitlement) of the irrigator. The water supplied to the irrigator may be directly released from the dam release or by d/s tributaries, or by a combination of both.

Pump capacity – The maximum extraction rate for an irrigation node (ML/d).

Rainfall-runoff model - (see Sacramento model)

Reach – A defined length of river.

Regulated River – The section of river that is downstream from a major flow regulation storage that supplies water to irrigators.

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 streams between the gauges. The outflow from this catchment is simulated in the model as the difference between the flow of upstream and downstream gauges taking into consideration river losses and diversions.

Resource Assessment – The process of calculating announced allocation levels based on the current and predicted water resource availability and water requirements of all water users.

River Section – see river *Reach*.

Sacramento Model – A rainfall-runoff model used to estimate long term streamflows at gauging stations where there are short period of records or gaps in the flow data. The model tries to represent the physical processes that impact on runoff and it uses local rainfall and evaporation data as well as catchment details. The model was developed by Burnash et al (1973), in Sacramento California.

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 allocation announcement.

Tributary – A stream that contributes its flow to a larger stream or water body.

Tributary utilisation – The proportion of the flow from the tributary that can be used to meet water orders.

Unregulated River – A river with no major storages by which flows could be regulated.

u/s – Upstream.

Water Year – A continuous twelve-month period starting from a specified month for water accounting purposes. In the Lachlan Valley the water year commences on the 1st July and concludes on the 30th June.

1. Introduction

1.1. BACKGROUND TO IQQM

Prior to 1986 a monthly time step computer model of the Lachlan Valley had been constructed, calibrated, and used to investigate various policy and water sharing initiatives. By 1986 the first daily time step modelling software, called the WARAS model, was developed by a consultant for the DLWC and applied to the Lachlan Valley.

Building on the concepts in the WARAS model, DLWC proceeded to develop a more generalised and complete modelling tool, in the form of the IQQM software. The first implementation of IQQM was in the Lachlan Valley using the flow and loss calibration data from the original WARAS model. This model was used to investigate the conversion of general security licences to high security licences and adjust the allowances made in resource assessment for storage reserve and transmission and operation loss.

During the 1990's a large number of developments occurred in both water policy and IQQM. The advent of the MDBC Cap and the NSW River Flow Objectives led to a much greater level of model complexity.

The Lachlan model was used to investigate environmental flow rules (EFR) for the Lachlan River Management Committee in 1998. However, given the short deadline for the development of rules the original version of Lachlan IQQM was used. It was recognised that this model did have some calibration deficiencies that would need to be addressed at a later stage. However, it was considered suitable for use on a comparative basis, and that there would be a cancelling of errors such that the relative difference between model results would be valid.

The Lachlan IQQM has been substantially upgraded with greater levels of detail and it is now better able to replicate observed flow and water extraction behaviour in the valley. The Lachlan model has been subsequently upgraded to version 6.42 of IQQM with an aim to address the following issues:

- Better estimates of inflow;
- Improved calibration of losses;
- Improved representation of flow paths;
- Better conformation with the generic IQQM;
- Improved re-regulation in Lake Cargelligo & Lake Brewster operation; and
- Improved replication of end of system flows

The following tasks were undertaken to upgrade the model:

- Inflows estimations based on 10 new sub-catchment Sacramento models;
- The river system was configured to better reflect reality, in particular the multiple flow paths near Condobolin;
- Better revised flow, residual inflow and loss calibration;
- Generated daily synthetic evaporation for 100 years;
- Re-calibrated model to reflect improved crop area, crop mix and diversion data;
- Included distributed area planting behaviour;
- Improved allocation of resources between summer and winter crops; and

- Included separate soil moisture modelling for different crop types.

The upgrade of the Lachlan model to version 6.42 has meant that the model is now able to take advantage of the facilities offered by the updated version of IQQM. Some of the new features offered include:

- Carry-over of entitlements;
- ECA modelling;
- Translucent flow releases from Wyangala;
- Orders up multiple paths; and
- Modelling of new operational rules

A full description of IQQM, including details about model structure, algorithms, processes that can be modelled and assumptions are described in the IQQM Reference Manual (DLWC, 1998[b]).

1.2. AIM OF IMPLEMENTING IQQM IN THE LACHLAN RIVER SYSTEM

The IQQM has been implemented for the Lachlan Valley from the headwaters of Wyangala and Carcoar Dams to the outlet of the Lachlan River near Oxley. The aim of this IQQM implementation is to establish and define a tool that is capable of simulating daily hydrologic processes over a 100+ year period including:

- Reproducing river system behaviour over the calibration and validation periods;
- Reproducing daily flows at key locations for assessment of environmental flow rules;
- Analysing the impacts of alternative irrigation development scenarios over a long term (100+ years) simulation period;
- Developing and analysing the impacts of environmental flow and river operation rules to meet specific river flow objectives; and
- Estimating the long term average annual diversions for the Lachlan Valley under a 1993/94 Development Conditions scenario, ie *the Cap scenario*.
- Assessing current irrigation diversions relative to those that would have occurred under 1993/94 development conditions with the current climatic inputs, ie *the Cap audit scenario*. This scenario is required for the MDBMC Cap auditing process.

1.3. STATUS OF IQQM IMPLEMENTATION

The implementation plans for development and use of the Lachlan IQQM covered the following main steps:

1) Build and calibrate the IQQM.
2) Establish an agreed Cap scenario run for MDBC.
3) Define and compare alternative future management option proposals.

All stages of this implementation are now complete.

1.4. AIM AND OBJECTIVE OF THIS REPORT

The aim of this summary report is to outline the main findings and conclusions in relation to calibration, validation and 1993/94 Cap determination. This report will be presented to the Murray-Darling Basin Commission as part of the Cap model approval process.

1.5. SCOPE OF THIS REPORT

The scope of work covered in this report includes:

- Building the model system (Chapter 2).
- Calibrating IQQM (Chapter 3).
- Establishing an agreed 1993/94 run (Chapter 4).
- Outlining model improvement plans (Chapter 5).
- Describing quality assessment guidelines (Appendix A).

1.6. QUALITY ASSESSMENT SYSTEM

A set of quality assessment guidelines (Appendix A) has been used in this report to evaluate and report on the model's calibration and validation performance. The definitions are used to assess the model's ability to replicate observed data. There are five categories:

- Very high confidence;
- High confidence;
- Moderate confidence;
- Low confidence; and
- Very low confidence.

Some comments have been made in the report on the suitability and accuracy of the data to represent observed behaviour over the calibration period.

2. The Lachlan River Valley

2.1. CATCHMENT DESCRIPTION

The Lachlan Valley is shown in Figure 2.1. The Lachlan River Valley, located in central western NSW, occupies around 85,000 km^2 or about 10% of NSW. The eastern part of the catchment has higher elevations of 1000–1400 m and contributes most of the flow to the river. About 75% of the Valley is flat, having slopes less than 3 degrees. Average annual rainfall varies from 1200 mm along the elevated eastern part of the drainage basin to 250 mm in the lower western reaches. Potential average annual evaporation exceeds average annual rainfall over most of the catchment with 1000 mm/year evaporation in the east and up to 2000 mm/year in the west.

Since the early 1960s, irrigation activities have increased rapidly and according to recent data, some 90,000 ha is currently used for planting crops such as cereals, lucerne (alfalfa), and cotton. Most of the summer crops need irrigation, whereas the winter crops generally get most of their required moisture from rain.

The Lachlan is a complex regulated river system having numerous anabranches, several headwater and re-regulating storages, wetlands, major irrigation developments, and various environmental needs. DLWC operational management defines Wyangala Dam as the main reservoir in the Lachlan River System. When Lake Brewster and Lake Cargelligo are sufficiently full; the Lachlan River is divided into two sections for the purpose of regulation. Wyangala Dam is operated to supply all requirements as far as Lake Cargelligo, while Lakes Cargelligo and Brewster are operated to supply all requirements from there to the Murrumbidgee River junction near Oxley. In case of low lake storage levels, requirements are met from Wyangala. Carcoar Dam is operated to meet the needs of the Belubula River only.

Several important diversion weirs are located downstream of Wyangala Dam. These weirs have limited storage and primarily provide head for diverting water to effluents and creeks; these are Willandra Weir, Booberoi Weir, Island Ck offtake, Bumbuggan Ck offtake, and Wallamundry Ck offtake. Table 2.1 summarises the capacities of the major storages.

Figure 2.1: Lachlan Valley boundary

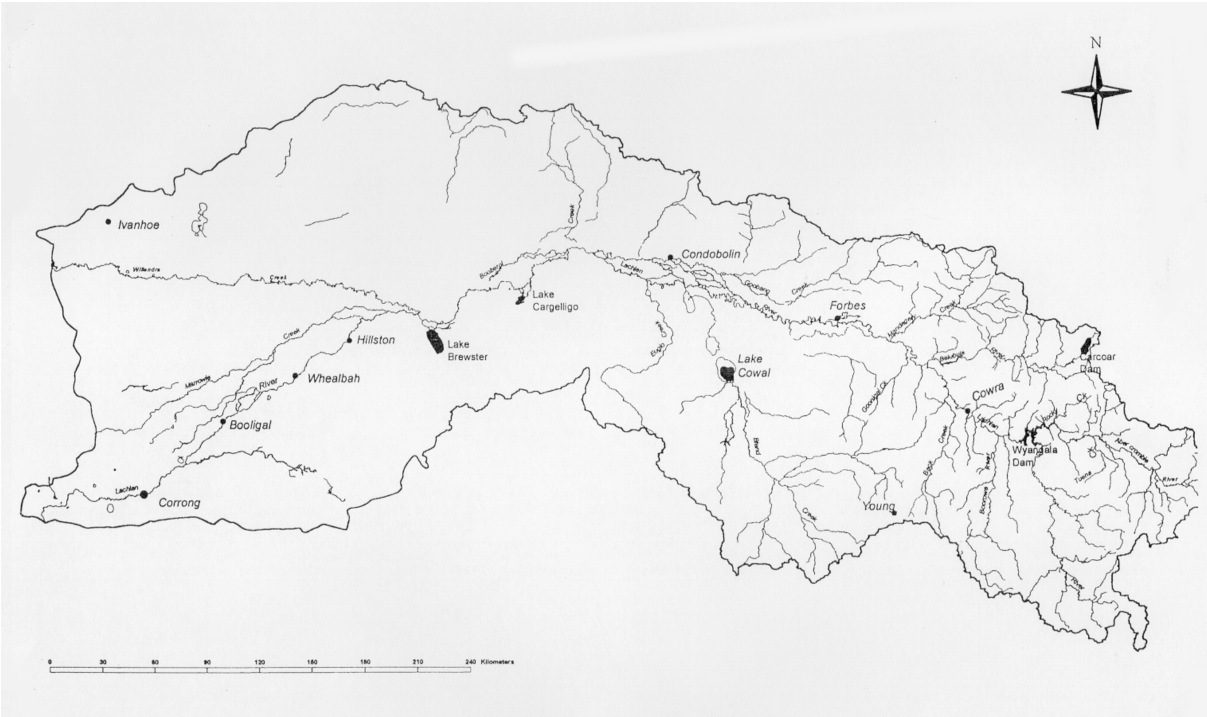


Table 2.1: Storage capacities

Storage	Total Capacity (ML)	Useable Capacity (ML)
Wyangala Dam	1,217,000	1,216,000
Carcoar Dam	36,000	35,800
Lake Cargelligo	36,000	23,000
Lake Brewster	153,000	133,000
Brewster Weir Pool	7,000	7,000

2.2. CLIMATIC DATA

The climatic data used to configure the model was obtained from Bureau of Meteorology. Every effort has been made to collate the best available data to set up and calibrate the model. The climatic data discussed in this report related to IQQM only. The climatic data used for Sacramento modelling have been discussed separately in DLWC (1998[c]) and DLWC (1999[a]).

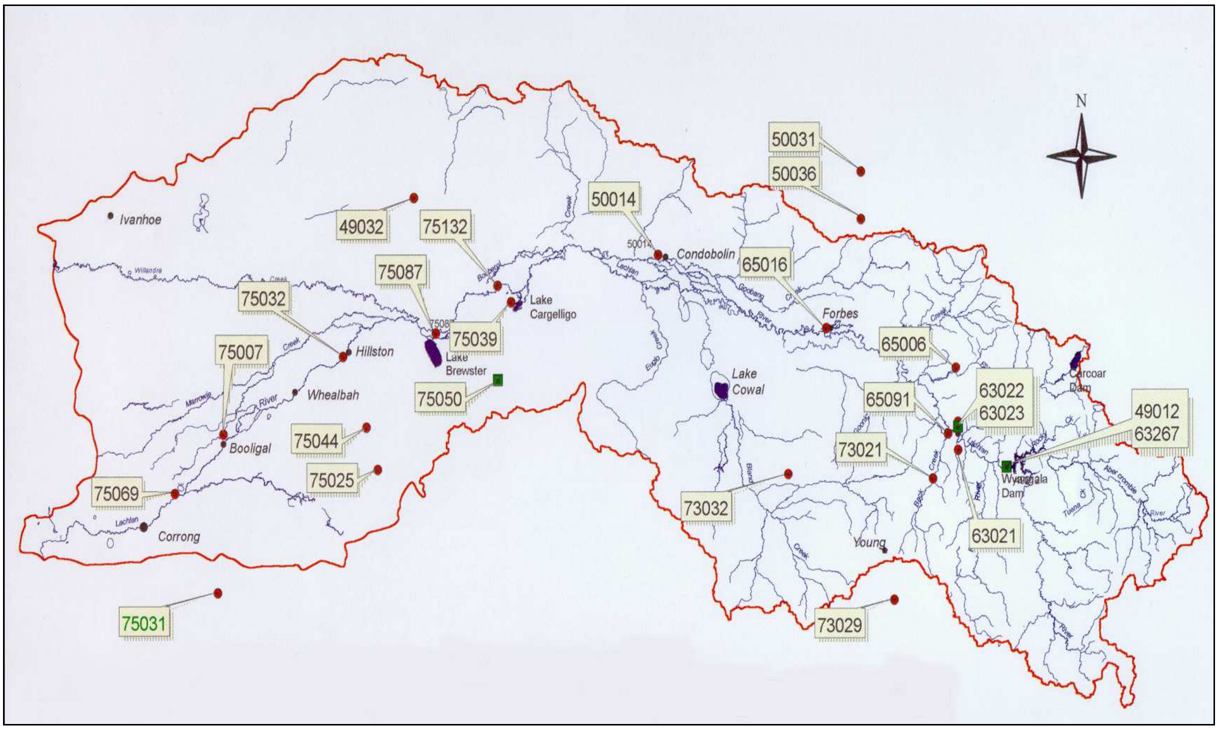
2.2.1. Rainfall

Rainfall data is required by IQQM to drive the soil moisture accounting module (Section 3.4), for computing the rainfall onto reservoir storage volumes (Section 3.6) and rainfall onto river reaches

(Section 3.3). Rainfall data is also required for generating catchment inflows using rainfall-runoff modelling (Section 5.3; DLWC 1998[c] and DLWC 1999[a]).

An extensive network of daily read rainfall gauges covers the Lachlan River Valley and selection of appropriate gauges for each of the above tasks in the Lachlan IQQM is discussed in Sections 3.4, 3.5 and 5.3 with a full listing of the gauges selected provided in Table A.1. The location of some typical rainfall gauges is shown in Figure 2.2.

Figure 2.2: Rainfall and Evaporation gauge locations



Legend

■ = Evaporation Sites

● = Rainfall Sites

2.2.2. Evaporation

Evaporation data is required by IQQM to estimate the evapotranspiration from the crops (Section 3.4), for computing evaporation losses from reservoirs (Section 3.6) and evaporation losses from river reaches (Section 3.3). Evaporation data is also used for generating catchment inflows using rainfall-runoff modelling (Section 5.3; DLWC 1998[c] and DLWC 1999[a]).

The methodology adopted for the selection, processing and extending evaporation data for IQQM modelling is discussed in Sections 3.4, 3.5 and 5.3.

2.3. STREAMFLOW DATA

Streamflow data is used for model calibration (Section 3.3) and for model simulations (Section 5.3). Time series flow data was extracted from the Department's HYDSYS database.

2.3.1. Main stream gauging stations

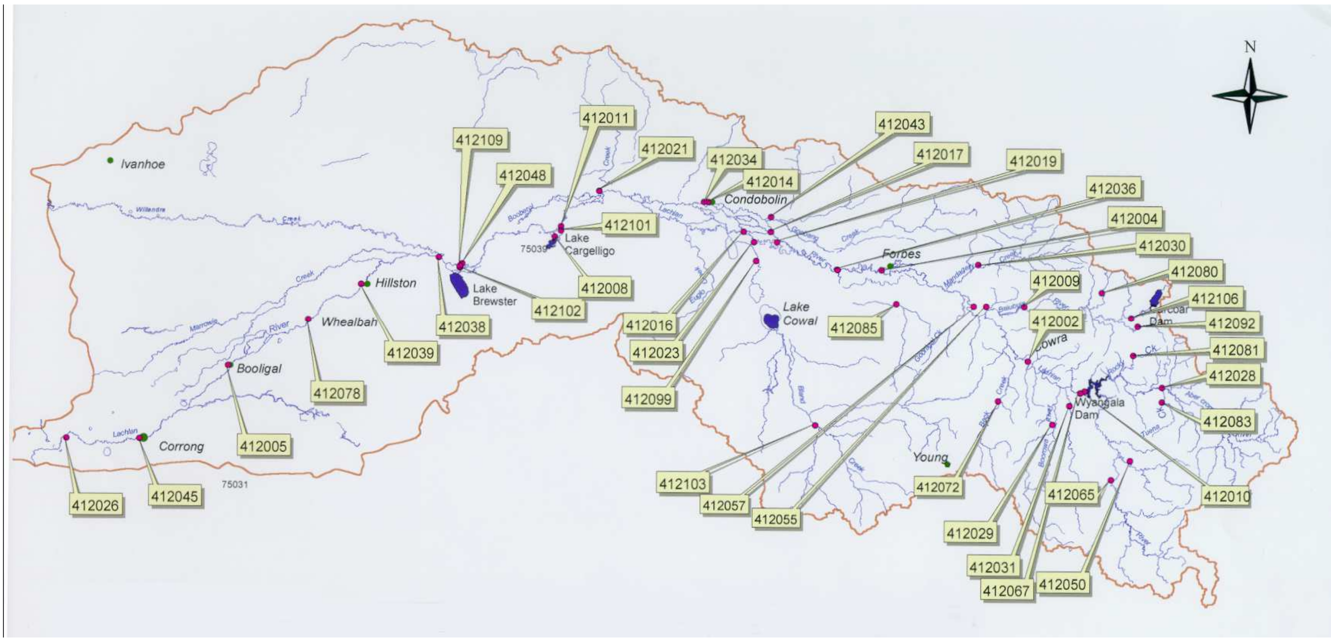
Selection of appropriate gauges to use in the Lachlan IQQM is discussed in Sections 3.3 and 5.3 with a full listing of the gauges selected provided in Table A.2. The location of main stream gauging stations has been shown in Figure 2.3.

2.3.2. Tributary inflows

The principal flow contributing tributaries of the Lachlan River enter the river upstream of Forbes. Streams below Jemalong make little or no contribution to Lachlan River flow except in extremely wet years. The gauging stations on the tributaries are generally located some distance upstream from the confluence with the main river, resulting in large areas of ungauged catchment. There are also some ungauged contributions from smaller streams and local area runoff.

The tributaries involved are also listed in Table A.2 and their locations are shown in Figure 2.3.

Figure 2.3: Streamflow Gauge Locations



2.4. IRRIGATION INFORMATION

2.4.1. Irrigation licenses

The licences supplied with water by Wyangala and Carcoar Dams were converted from area-based licences to volumetric licences at the commencement of the 1981/82 season. There has been an administrative embargo on the issuing of new licences (with the exception of stock, domestic, industrial and town water supplies) since 1980. This became a statutory embargo in 1982. The historic data on licensed irrigation volumes and licence types was analysed and separated into high security (HS) and general security (GS) licence portions.

There are licences for surface water extraction throughout the Lachlan and Belubula Rivers system, both in the regulated sections below Wyangala and Carcoar Dams, as well as in the unregulated parts of the catchment above these dams and along the tributaries. Regulated licences are closely monitored and have an annual licensed entitlement volume. Unregulated river 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). Operation of unregulated licences has not been closely monitored to date, and there has generally been very little data collected regarding extractions and cropping by these licences.

In the regulated river reaches there are some 3100 water extraction licence holders. There are 639 GL of regulated irrigation licenses within the valley, with an additional 24 GL reserved for permanent plantings. Licence holders on the regulated sections of the Lachlan and Belubula Rivers and water users in the Jemalong and Wyldes Plains Districts are required to order water in advance (up to four week in advance in dry years). However, water actually extracted may vary significantly because of changes in weather that may alter crop water requirements. Water ordered but not diverted are known as rain rejection losses.

The overall average ratio of high and general security licensed volumes to the valley total is 5% and 95% respectively. This ratio does however vary within each major irrigator group.

Historical management reports for the Lachlan Valley have reported licence statistics in four groups, these are shown in Table 2.2.

Table 2.2: Irrigator groupings and General Security Entitlements

Reporting Group	***Approx. no. of Licences***	***Location***	***General Security Entitlement (GL) at Aug 1994***
Upper Lachlan	2950	Wyangala Dam to Cargelligo Weir	260 (41%)
Lower Lachlan		Cargelligo Weir to Oxley	257 (40%)
Belubula	90	Carcoar Dam to Belubula River outlet	23 (3%)
Jemalong & Wyldes Plains	160	Irrigation area South of Jemalong Weir	100 (16%)

2.4.2. Irrigator pump capacity and storage infrastructure

Regulated licences in NSW are issued with conditions relating to the maximum authorised extraction capacity, generally referred to as the authorised pump capacity. Installed pump capacities were generally available from meter inspectors' records. Based on this data the total system pumping capacity is 33,700 ML/d. Table 2.3 shows a distribution of the pump capacities for the four irrigator groups. The Lachlan Valley does not have significant on farm storages.

Table 2.3: Distribution of Pump Capacity (ML/d)

	Belubula	Jemalong & Wyldes Plains	Upper Lachlan	Lower Lachlan
Pump Capacity	400 (2%)	600 (3%)	12825 (66%)	5540 (29%)

2.4.3. Irrigation extraction data

Individual meter readings were available on a monthly basis for regulated licences for the period 1981-98. The recorded monthly totals were disaggregated to daily totals during flow calibration (DLWC, 1998[i]).

For historic diversion records, on-allocation and off-allocation usage splits were often obscure or not available. What were usually available, were the total water usage per month, and the periods when off allocation had been declared.

2.4.4. Crop areas

Historic records of total planted areas and crop type for regulated licence holders were available from the early 1980's. From the early 1980's to 1991 field staff collected both crop area information and metering information. In 1991, a formal annual mail out survey replaced these activities. The survey requests information regarding areas and types of crop irrigated, as well as the areas developed for each type of irrigation. Return rates for the survey data after 1992 have been averaging around 80% of licensed users, and include all major water users. However the survey information has only been collated on the four reporting groups detailed in Table 2.3.

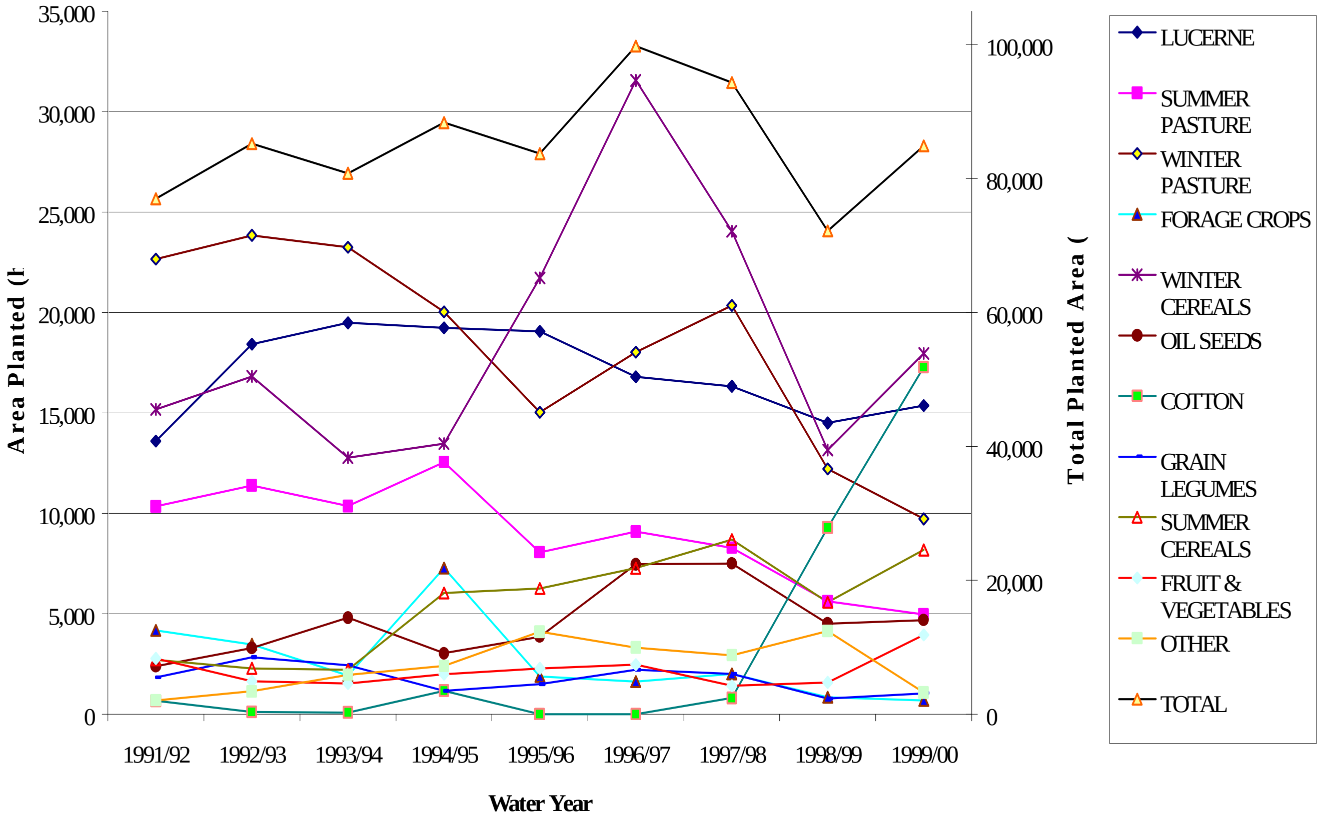
This is the only comprehensive information regarding cropped areas that is available, and it is difficult to assess the level of its accuracy. Table 2.4 shows a typical historical crop mix for 1993/94 in the four irrigator groupings.

Table 2.4: Distribution of Area Irrigated (Ha)

Crop type	*Belubula*	*Upper Lachlan*	*Lower Lachlan*	*Jemalong & Wyldes Plains*
Lucerne	1051 (70%)	12626 (35%)	1290 (5%)	4511 (26%)
Summer Pasture	0 (0%)	4775 (13%)	3372 (13%)	2214 (13%)
Winter Pasture	81 (5%)	8009 (22%)	8839 (34%)	6310 (36%)
Forage Crops	39 (3%)	1032 (3%)	580 (2%)	264 (2%)
Winter Cereal	141 (9%)	3785 (11%)	6312 (24%)	2534 (15%)
Oil Seeds	0 (0%)	1609 (4%)	2045 (8%)	1224 (7%)
Grain legumes	40 (3%)	652 (2%)	1703 (7%)	44 (0%)
Summer Cereal	48 (3%)	914 (3%)	992 (4%)	257 (1%)
Vegetables	53 (4%)	688 (2%)	72 (0%)	0 (0%)
Fruit	4 (0%)	286 (1%)	429 (2%)	0 (0%)
Grapes	0 (0%)	690 (2%)	52 (0%)	56 (0%)
Other	34 (2%)	951 (3%)	144 (1%)	30 (0%)
Total (Ha)	1491 (100%)	36017 (100%)	25830 (100%)	17444 (100%)

The recorded areas of major crops for the whole valley from 1991/92 to 1999/00 are plotted in Figure 2.4. This plot shows that there is a significant variation in crop mix and distribution within the valley from year to year. As nearly all of these years effectively had full resource availability, these variations are generally thought to be the result of changing farmer behaviour and economic influences. However, even if the economic 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. The crop area information, with the exception of cotton, does not seem to indicate a trend in overall crop growth.
Some changes in the mix of cropping can be observed in the data, particularly for winter cereals and cotton. The sharp increase in winter cereals during the 1995/96 – 1997/98 period appears to be the result of increased wheat prices, while there is emergence of cotton production from 1997/98 in the western areas of the valley.

Figure 2.4: Lachlan Valley recorded planted areas and crop mix



2.4.5. Transfer market

A scheme permitting the temporary transfer of entitlements has applied since 1983/84. The volumes of water that may be transferred are subject to various conditions such as:

- Not contributing to or creating operational, salinity or water supply problems.

- Subject to declared percentage of allocations.
- No Inter-valley transfers are permitted.
- Jemalong Wyldes Plain District (JWPD) is allowed to trade in but cannot trade out.

The historical records given in the Lachlan Annual Activity Reports indicate that transfers ranged from 10 GL in 1983/84 to 60 GL in 1996/97.

2.5. TOWN WATER SUPPLY

Town water supplies (TWS) are high security entitlements and their sum is generally less than 5% of the total water used in the valley. TWS are less variable than irrigation and are influenced by factors other than just climate. Consequently TWS has not been modelled in detail in the Lachlan IQQM and is represented as a fixed annual demand with a monthly pattern of use.

In the regulated sections of the Belubula and Lachlan Rivers, six significant towns were identified and modelled. The towns are Cowra, Forbes, Condobolin, Willandra, Hillston and Booligal, they have a combined high security annual entitlement of 15 GL, and typically use around 10 GL per year.

2.6. STOCK AND DOMESTIC REQUIREMENTS

Licensed volumes for stock watering and domestic (S&D) supply purposes are high security entitlements. These stock and domestic entitlements generally occur in two ways:

As S&D entitlements that form a small component of a licence which consists predominantly of general security irrigatoion entitlements, and

As separate S&D only licences.

Diversions by S&D licences held by general security irrigators are not recorded specifically and would be incorporated in their general security irrigation diversions. These S&D diversions are not modelled explicitly.

There is around 10,000 ML of entitlement specifically licensed for S&D purposes in the Lachlan and Belubula River systems and this been represented in the model as a fixed annual demand with a monthly pattern of use.

2.7. INDUSTRIAL AND MINING EXTRACTIONS

The total of high security industrial and mining licences on the regulated system is 2300 ML, 400 ML on the Belubula River and 1900 ML on the Lachlan River (DWR, 1989. These demands are considered to be small and not included in the model.

2.8. GROUNDWATER ACCESS

Groundwater supply bores are located throughout the irrigation areas, and are used as an alternative water supply particularly in dry periods. For example, groundwater use was higher than normal in 1982/83 due to the drought. Surface water irrigators use groundwater to balance shortfalls in surface water allocations. Groundwater use is not modelled in the Lachlan IQQM.

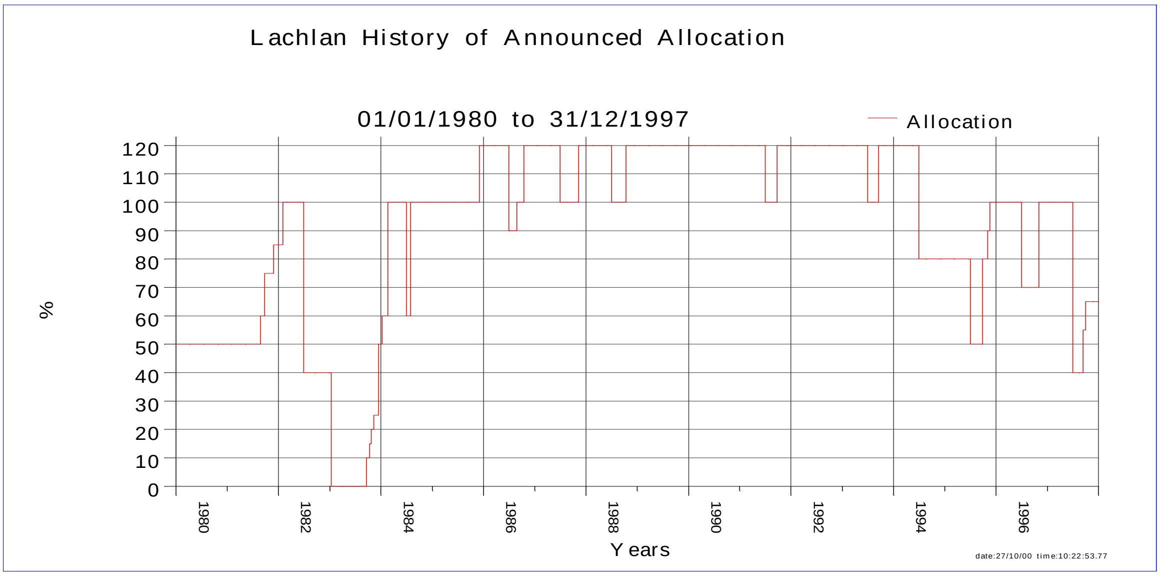
2.9. RESOURCE ASSESSMENT

Under a managed volumetric allocation schemes all licences are issued for an annual entitlement volume. In any irrigation season, the amount of water available for general security irrigation is the announced allocation percentage times the annual entitlement volume.

The allocation announcement is the result of a resource assessment process that takes into account:

all available water resources at that time
water resources expected to become available for the remainder of the water year and
essential requirements for high security supplies, environmental and other reserves and expected losses
The remaining resources are then declared available for general security irrigation use and is expressed as a percentage of the total general security entitlement. The estimate of expected water resources is conservative and uses the driest recorded sequence to estimate expected resources for the remainder of the water year.
Some of the items used in the resource assessment process are subject to change over time for a variety of reasons. From time to time transmission losses expected under drought conditions may be reviewed, or contingency reserves for supply or environmental purposes may be reassessed.
The allocation assessments are made at the beginning of the water year (1st July for Lachlan Valley), and may be updated when there is significant inflow to Wyangala Dam.
The historical allocation announcements for the Lachlan Valley are presented in Figure 2.5. These records show allocation levels of 100% or more were experienced 60% of the time.

Figure 2.5: Historical announced allocations



2.10. RIVER AND STORAGE OPERATION

The Lachlan River system is operated to ensure that maximum conservation of resource is achieved during regulated operation, and that flows in excess of the target at the end of the system are kept to a minimum. During normal regulated operations, flows in excess of requirements at the end of the regulated river system usually occur as a result of:
tributary inflows below the storage being in excess of requirements;
rainfall on crops reducing extraction of ordered water in transit; and
errors in forecasting system requirements.

2.10.1. Tributary utilisation

When making releases from storage to satisfy consumptive requirements, the river operator forecasts what flow contributions they expect from downstream tributaries and adjusts the releases from the major storage(s) accordingly. 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.

Tributary flow utilisation in the upper Lachlan is dependent on a number of issues involving the announcement of off-allocation and the capacity available in the storages at Lakes Brewster and Cargelligo. In the past this tributary utilisation has been relatively high in the upper Lachlan. The lower Lachlan has a minimal number of downstream tributaries available to contribute to the total flow. In the last few years, with the introduction of environmental flow rules with off-allocation restrictions and minimum flow targets, tributary utilisation has reduced significantly. IQQM representation and calibration of tributary utilisation is discussed further in Section 3.7.

2.10.2. 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 general over-ordering by irrigators. IQQM representation and calibration of over-ordering is discussed further in Section 3.7.

2.10.3. Storage operating rules

When Lake Brewster and Cargelligo are sufficiently full, the Lachlan River is divided into two sections for the purpose of regulation. Wyangala Dam supplies all requirements as far as Lake Cargelligo weir, while Lake Cargelligo and Lake Brewster fulfil all the requirements from there to the Murrumbidgee junction near Oxley.

When the Lake Brewster storage level falls to between 30 to 40 percent of its capacity during dry periods, Wyangala Dam releases are supplemented with releases from Lake Brewster and Lake Cargelligo. In extreme dry periods, when Lake Brewster is dry, Wyangala Dam supplies all requirements for the full length of the river plus tries to maintain a volume of about 23 GL in Lake Cargelligo for short term supply flexibility. During these dry times regulation downstream of Lake Brewster can be improved by installing temporary shutters in Brewster Weir (on the Lachlan River) and raising its full supply level.

2.10.4. Flood mitigation releases

Wyangala Dam does not have a specific flood mitigation storage, nevertheless, the dam has achieved reductions in downstream flooding on occasions. This was largely due to the volume of the flood being contained within the available empty storage volume. Careful operation of the spillway gates can also reduce flooding downstream.

2.11. SURPLUS FLOW ACCESS

Off allocation periods may be announced in the Lachlan River Valley downstream of Wyangala Dam when flows are in excess of demands (surplus flows). Surplus flows may comprise operational excess flows, tributary inflows and flood releases from Wyangala Dam. Surplus flows can be extracted for irrigation as off-allocation supply and diverted into various effluent creeks to satisfy domestic requirements and mitigate downstream flooding.

Whilst historical records of total diversions are available, details regarding the off allocation extraction volumes were not readily available. What was available were the off allocation announcement periods, reach by reach. Announcements for access to off allocation water are generally made on a reach by reach basis, depending on the amount of surplus flow available and the access that each reach has previously received in the water year.

2.12. RIVER FLOW REQUIREMENTS

2.12.1. Minimum flow

Between 1981 and 1997 a number of significant changes to operational and environmental flow rules were made that are described in this section.

2.12.1.1 Corrong and Great Cumbung Swamp

Up until 1990 river operations targeted a minimum flow of 50 ML/d past the flow gauge at Corrong (412045). This flow was to maintain several S&D users downstream of Corrong, and to maintain a small flow to Cumbung Swamp. By the late 1980's the 50 ML/d flow was insufficient to reach either Cumbung Swamp or the S&D water users because of channel siltation.
Trials to test both the flow required and the biological needs of the Cumbung Swamps saw the old flow requirement replaced with:
a target of 200 ML/d for the 6 summer months (ie October to March),
then a one month burst of higher flow (400 ML/d) in April, and
in the 5 winter months – no requirements.

2.12.1.2 Wyangala Dam

Historic Wyangala Dam release records showed a target operational release flow of about 70 ML/d during the record period covering model calibration and validation. This release keeps the river wet (for more effective delivery of water orders, and meets downstream minimum flow requirements.

2.12.1.3 Carcoar Dam

An operational minimum flow target of 10 ML/d was maintained, by operation of Carcoar Dam, for flows past the Bangaroo Bridge gauge.

2.12.1.4 Booberoi Weir

Booberoi Weir (constructed in 1913) diverts a continuous stock and domestic supply down Booberoi Ck effluent offtake. In practice this occurs by maintaining a minimum flow target of around 50 ML/d over the weir.

2.12.1.5 Lake Cargelligo

To enable efficient delivery of water orders placed on Lake Cargelligo, a minimum operational flow target of 15 ML/d (on top of orders) is maintained downstream of the lake's outlet.

2.12.1.6 Lake Brewster

To enable efficient delivery of water orders placed on Lake Brewster, a minimum operational flow target of 20 ML/d (on top of orders) is maintained downstream of Brewster Weir.

2.12.2. Replenishments

After Wyangala Dam was enlarged in 1970, it was agreed to make high security S&D replenishment releases to some of the effluent systems that had relied on flood flows for replenishment (when necessary). These systems are:

- Merrowie Creek,
- Merrimajeel Creek, and
- Willandra Creek

Replenishments of up to 9GL are generally made into each of these systems during the late summer and autumn period.

2.12.3. Wetlands

Higher flows in the lower Lachlan valley break out onto the floodplain and into numerous effluents, supporting wetland areas of national and international significance. A number of sites have been nominated as being nationally important sites for native and migratory birds, including the Booligal wetlands, Lake Brewster, Merrowie Creek/Cuba Dam, and the Great Cumbung Swamp. Flows into many of the wetland areas are not able to be directly monitored.

3. Model Calibration and Validation

3.1. MODEL CONFIGURATION

An IQQM for the Lachlan system was configured for the data and for the system described in Chapter 2. The number and types of nodes and links were selected in accordance with the aims of the modelling detailed in Section 1.2. A model containing 150 nodes and about 20 links with hydrologic routing was adopted. Details of the model set-up and presentation of the node-link diagram are contained in Appendix B.

Inflows were estimated for Wyangala and Carcoar Dams, 7 gauged tributary inflows (extended by Sacramento rainfall-runoff models) and 5 residual catchment inflows. General and high security irrigators were represented respectively as 26 and 8 groups based on river reaches.

Daily rainfall data was obtained from the Bureau of Meteorology, with more than one hundred rain gauge sites throughout the valley. Data from around fifty of the sites with long term records were used to derive eight gap-filled time series of daily rainfalls (Fig. 2.2 and Table A.1) representing eight zones. Daily evaporation data was generated for the eight climatic zones using the three evaporation sites available (see Section 3.4.1) and the gap-filled rainfall records. The flow sites selected to calibrate the IQQM are listed in Table A.2 and shown in Fig. 2.3.

A number of processes were not configured as part of the model, or configured in a simplified form, as outlined below:

A single set of parameters for resource assessment that covered the calibration period was not possible. Consequently, announced allocations have been forced to observed levels. The resource assessment parameters will be configured to suit particular scenarios. Parameters for the Cap scenario are discussed in Section 4.9.

Unregulated licence cropping and usage have not been represented explicitly in the model, based on their relatively small impact on river flows and a lack of suitable information to allow model calibration. The effects of unregulated licence activity will be present in the flow records used to produce inflows to the regulated system, especially in more recent years. No adjustment of inflows for unregulated licence activity has been made.

Town water supplies were modelled using a fixed pattern of demand, representing the average use over the chosen calibration period.

Stock and domestic licence usage was modelled using a fixed pattern of demand, representing the average use over the chosen calibration period.

Groundwater use was not represented (due to insufficient data and the relatively small impact on river flows and diversions)

3.2. CALIBRATION OVERVIEW

Calibration of computer models involves the adjustment of the variables in the model until the model satisfactorily reproduces historical data over a selected period of time. IQQM is a complex model and there are a number of different parameters that are used to represent the major river valley processes. For this reason, the calibration process has been developed to proceed sequentially, progressively eliminating unknowns. The sequential process adopted in the Lachlan Valley involves four major steps. Each step estimates specific parameters for the step, whilst forcing all other parameters to observed data. At the end of the four stage process, all the estimated parameters are brought together to see how well the overall model calibration reproduces historical information. The four steps are summarised below, with an indication of which parameters are calibrated during each one:

- Flow calibration - to reproduce the observed flow hydrographs at key locations, given observed storage releases, tributary inflows and water extractions. For this process, irrigation and other water extractions are fixed to those observed historically. Routing parameters and transmission losses are calibrated.
- Irrigation diversion (demand) calibration - to reproduce observed irrigation extractions from the river, given observed crop areas and crop mix. Crop factors and irrigation efficiency are calibrated.
- Area planting decision - calibrates an irrigator's decision making process to reproduce observed crop planted areas. Maximum and minimum area, crop mix and farmers planting decision process are calibrated.
- Storage calibration - to reproduce the observed volumes in the four major storages, throughout the calibration period. This involves calibration of the processes relating to irrigation ordering and river operation.

The selection of the calibration and validation periods was constrained by the availability of data, especially for irrigation data such as diversions, areas and crop mixes. Within this constraint, the calibration period was chosen to be representative of as wide a range of climatic conditions as possible. The crop data prior to 1983 is not reliable and therefore could not be used for calibration. However, that data was used for validation of the final assembled model.
The periods chosen for the various stages of the calibration process varied depending on data availability, are shown in Table 3.1 and summarised below:

- Flow calibration – different for various reaches, ranging from 1/1/1941 up to 31/12/1997
- Diversion calibration – from 1/7/1992 to 30/6/1998
- Crop area calibration could not be carried out due to the lack of recent allocation constrained years. This has meant that it was impossible to separate farmers planting behaviour from growth. Consequently areas were forced to recorded values.
- Storage behaviour calibration – from 1/7/1992 to 30/6/1998
- Overall model validation – 1/7/1983 to 30/6/1998

Calibration results for each of these individual components are reported in the full calibration and validation report. Presented here is the degree of replication achieved by the final model after the completion of above mentioned calibration process for the validation period. The details of procedures adopted are described in calculation folders (DLWC, 1993-98) and the calibration report (DLWC, 2000). The analysis of results are also discussed in the calibration report (DLWC, 2000).

Table 3.1: Calibration periods used for different components

SUBJECT	Period definition from	Period definition to
Flow calibration	see	below
Reach Bel-1 to Canowindra	01/01/1983	31/10/1992
Reach Bel-2 to Bangaroo Bridge	01/11/1956	01/01/1975
Reach 1 to Cowra	01/01/1970	31/12/1992
Reach 2 to Nanami	01/01/1970	31/12/1992
Reach 3 to Forbes	01/01/1975	31/12/1989
Reach 4 to Jemalong weir	01/01/1943	31/12/1969
Reach 5 to Island Ck offtake	01/01/1959	31/05/1968
Reach 5b to Fairholme	01/01/1959	31/12/1967
Reach 5c to Wallamundry offtake	01/06/1942	01/02/1961
Reach 5d to Worrongorra weir	01/06/1942	30/06/1985
Reaches 6 & 7 to Condobolin	01/01/1941	31/12/1982
Reach 8 to Booberoi weir	01/01/1970	31/12/1982
Reaches 9 & 10 to Brewster weir	15/12/1956	30/09/1968
Reach 12 to Hillston	01/07/1970	30/06/1982
Reaches 13 & 14 to Whealbah	01/01/1970	31/12/1992
Reach 15 to Corrong	01/04/1952	31/12/1970
Reach 16 to Oxley	01/04/1956	31/05/1965
Diversion calibration	01/07/1992	30/06/1998
Crop area calibration	Not done	
Storage calibration	01/07/1992	30/06/1998
Overall model validation	01/07/1983	30/06/1998

3.3. FLOW REPLICATION

The objective of this step is to calibrate the river system flows module over the calibration period (DLWC, 1998[c]). All known components of the water balance within the river valley are forced to the observed data. Known system inflows (gauged tributaries and reservoir inflows (DLWC, 1998[g]) are used as inputs to the model. Irrigation demands are extracted from river reaches as per the observed data. Demands such as town water and stock & domestic supplies are extracted from river reaches as per fixed patterns. The stock and domestic demands are extracted at four locations as per pattern given in Table B.3. The remaining unknowns (river routing (DLWC, 1998[k]), residual catchment inflows (DLWC, 1998[h]) and transmission losses (DLWC, 1998[e])) are calibrated by trial and error to achieve the best overall match to main-stream gauges (DLWC, 1998[d]).

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

- limit the length of river reaches;
- isolation of key features such as tributary inflows and effluent outflows;
- availability of good quality records to cover the intended calibration period, with a minimum number of missing periods.

After a review of the available main stream gauging stations and consideration of these criteria, there were nineteen gauging stations selected for use in the model, thus creating seventeen flow calibration reaches in the Lachlan and Belubula systems (Table 3.1 and Appendix B).
There are also streamflow gauging stations located on most of the major tributary inflows in the Lachlan River catchment. Of these available gauging stations, the following criteria are used to select an appropriate sub-set to represent the tributary flow contributions:

- significance of flow contribution;
- maximise gauged coverage of the contributing catchments;
- availability of good quality records to cover the intended calibration period and long term model simulation period;
- availability of nearby long term stream flow stations to be used to gap-fill and extend the stream flow data set;
- availability of nearby rainfall and evaporation stations that could be used to set-up rainfall-runoff models to gap-fill and extend the stream flow data set.

Streamflow data for gauging stations along the main river was used to compare the model results with the observed records, therefore, no processing was carried out for this data and any gaps due to missing data were left as such. Rainfall and evaporation onto the river surface were not modelled explicitly and have therefore been lumped into the losses.
Presented below in Figure 3.1 to 3.8 are the results obtained from the final calibrated assembled model for river flow replication at three gauging locations. Objective measures of the quality of model fit achieved are presented in Table 3.2 based on the quality assessment guidelines described in Appendix D (DLWC, 1999).

Figure 3.1: Lachlan River at Forbes – Flow Frequency

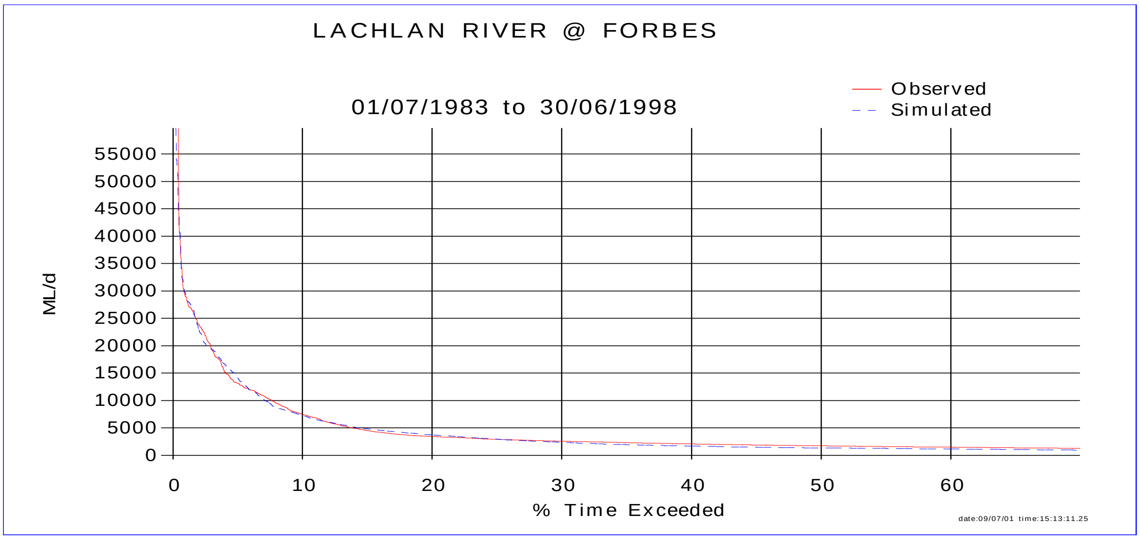


Figure 3.2: Lachlan River at Condobolin Bridge – Flow Frequency

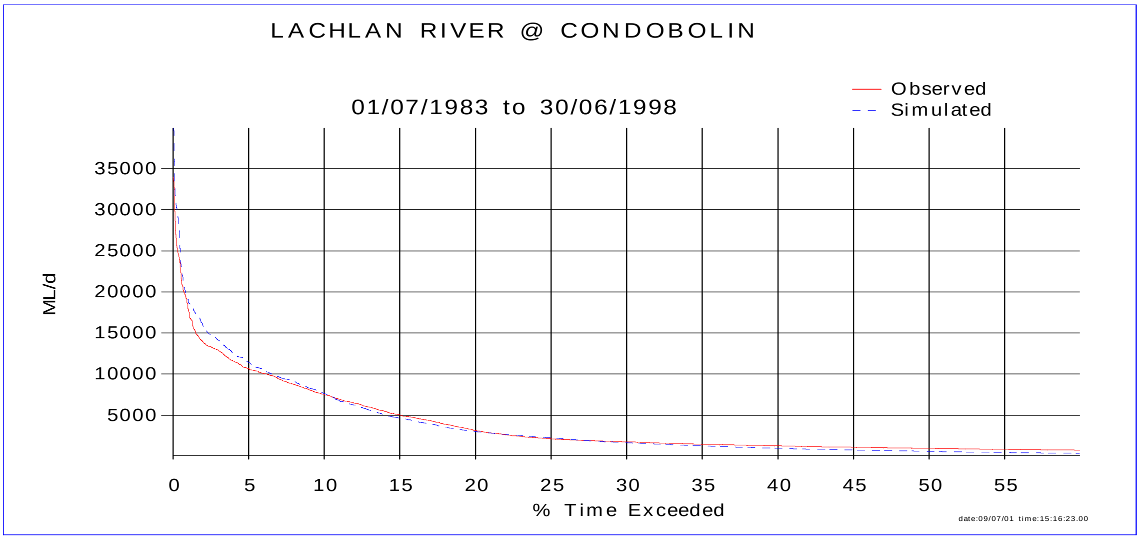


Figure 3.3: Lachlan River at Booligal – Flow Frequency

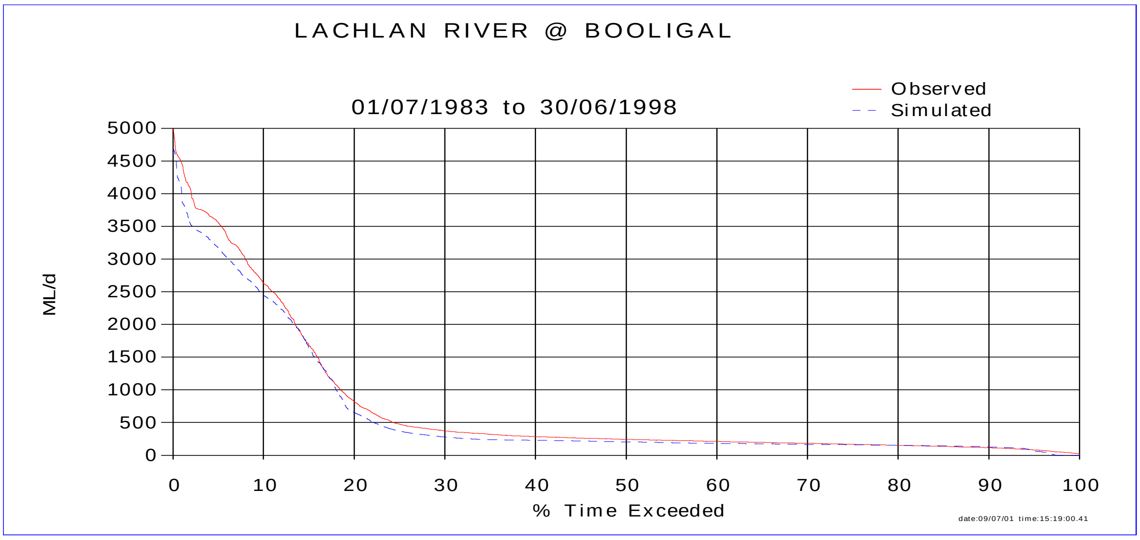


Figure 3.4: Lachlan River at Forbes – Annual flow volume comparison

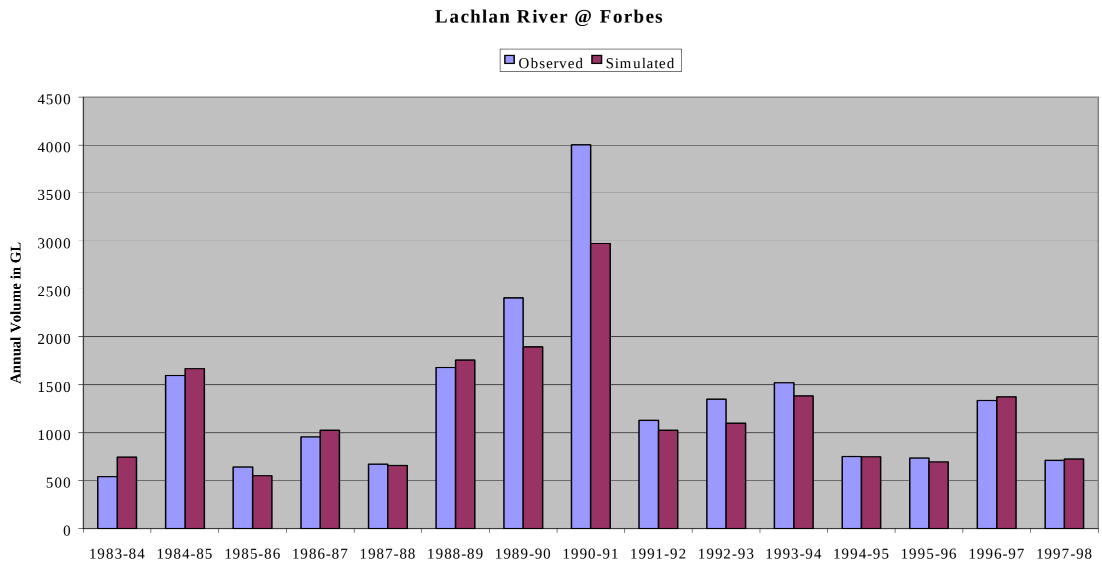


Figure 3.5: Lachlan River at Condobolin – Annual flow volume comparison

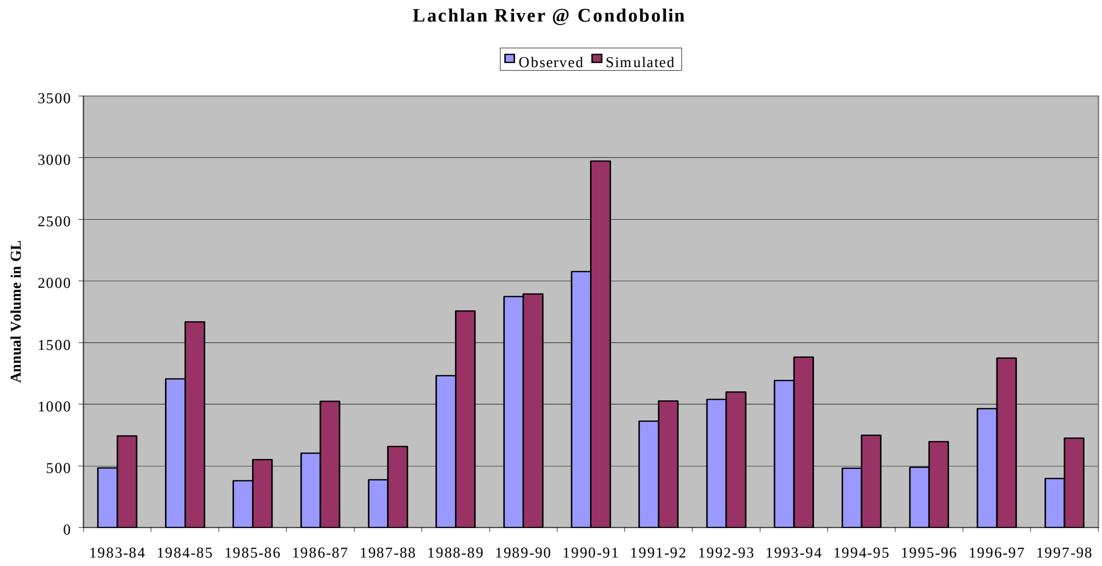


Figure 3.6: Lachlan River at Booligal – Annual flow volume comparison

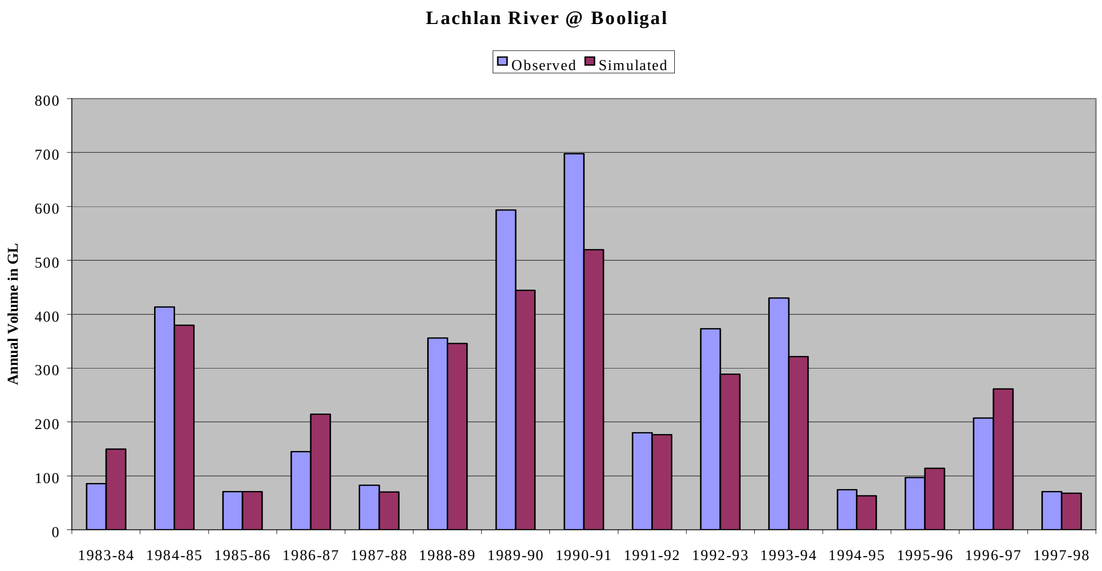


Figure 3.7: Lachlan River at Booligal – Driest year in period

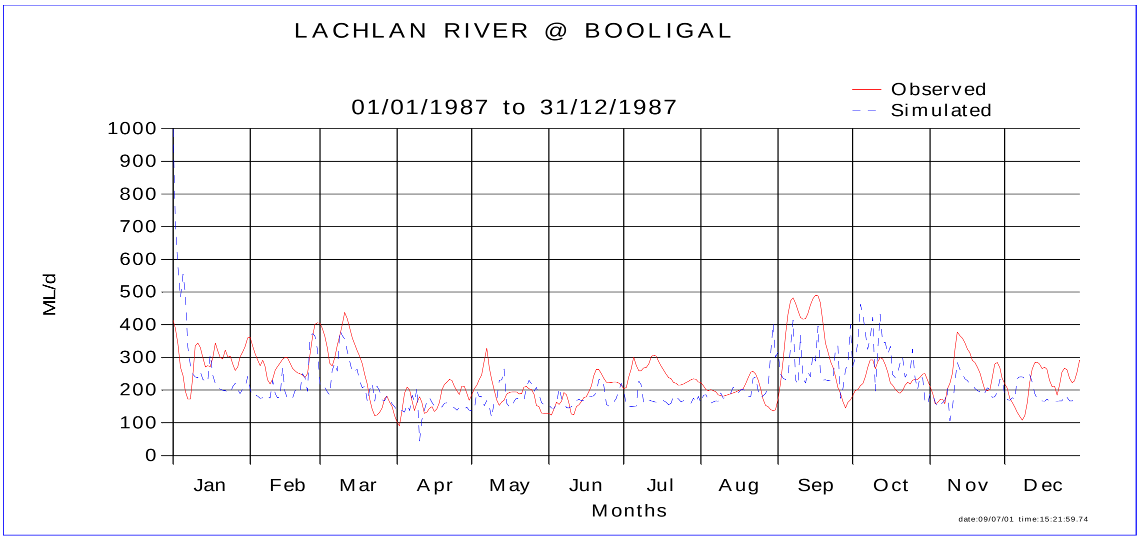


Figure 3.8: Lachlan River at Booligal – Wettest year in period

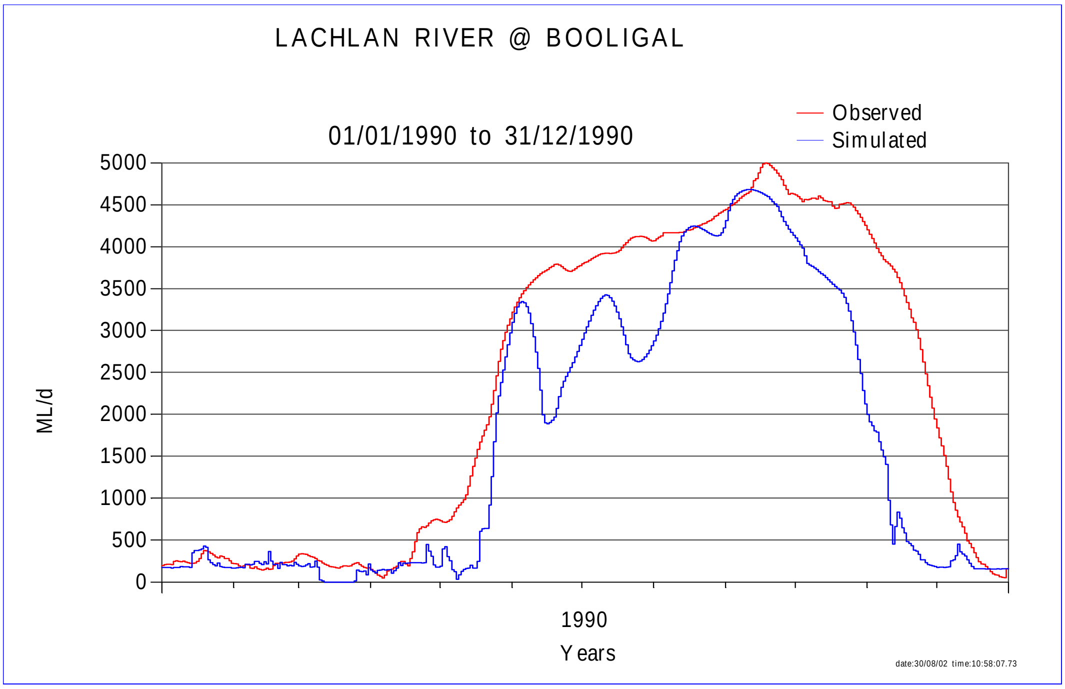


Table 3.2: River flow replication quality

SUBJECT		FLOW FREQUENCY: VOLUME RATIO %'s (#)				TIME SERIES MATCH	
Comparison point	Aspect Reported	Whole Range	Low Range	Mid Range	High Range	"1-r^2"	CMAAD
Lachlan River @ Forbes	Observed GL:- Simulated GL:- Appar't Error:- Rating:-	20030 18314 -8.6% Moderate	- - -16.6% Moderate	- - 0.9% V.High	- - -19.1% Moderate	- - 23% Moderate	- - 13.2% High
Lachlan River @ Condobolin	Observed GL:- Simulated GL:- Appar't Error:- Rating:-	13664 12889 -5.6% Moderate	- - -27.7% Low	- - 1.8% V.High	- - 13.2% Moderate	- - 21% Moderate	- - 11.6% High
Lachlan River @ Booligal	Observed GL:- Simulated GL:- Appar't Error:- Rating:-	3876 3486 -10.1% Moderate	- - -13.7% Moderate	- - -9.2% Moderate	- - -9.1% High	- - 18% Moderate	- - 20.6% Low

(#) for period from 1/06/1981 to 30/06/1998

3.4. DIVERSION VOLUME REPLICATION

3.4.1. Background and methodology

IQQM uses a soil moisture accounting model and estimated 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 (DLWC, 1998[b]).

The objective of this step is to calibrate the crop demand module over the calibration period (DLWC, 1998[c]). The parameters calibrated during flow calibration (routing, losses and residuals) are used, crop areas and types and off-allocation extractions are forced to observed data. Appropriate rainfall and evaporation data is selected to drive the crop demand module, which is then calibrated to replicate the observed diversions based on the observed areas planted. The IQQM uses theoretical crop factors (Allen, et. al., 1998), with the unknowns being the size of the average "effective" soil moisture store, rainfall interception loss for each irrigator group and the crop watering efficiency for each crop type. Values for these parameters are adjusted until the simulated crop water demands best match the observed data (DLWC, 1998[d]).

Of the available rainfall stations in the Valley, the following criteria are used to select an appropriate sub-set to use in the Lachlan 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 modelling period; and
- continuity and quality of data;
- availability of nearby gauging stations that could be used to substitute missing data and/or disaggregate accumulated records.

After a review of the available rainfall stations and consideration of these criteria, there were eight long term rainfall stations (Table A.1) selected to drive the crop demand module in the model.

IQQM needs long-term evaporation data to derive crop water demands. Unfortunately evaporation data is generally available over relatively short periods and needs to be extended. The following criteria were used to select appropriate short-term stations to be used for long-term evaporation generation:

- adequate representation of spatial variability of the evaporation;
- continuity and quality of data;
- availability of records longer than 15 years to allow generation of evaporation sequences (DLWC, 1998[l]) to cover the intended long term modelling period; and
- availability of nearby rainfall stations that cover the intended long term modelling period. These will be used to generate long term evaporation sequences (DLWC, 1998[l]).

After a review of the available evaporation stations and consideration of these criteria, the following three short-term evaporation were selected to be used in long-term evaporation generation:

- Wyangala Dam (063267)
- Cowra (063023), and
- Naradhan (075050)

Using the DLWC (1998[l]) evaporation generation module, the selected three short-term evaporation stations and eight long-term rainfall stations, long-term evaporation records were generated for the eight geographic zones listed in Table A.1.

Crop factors for cotton, lucerne and cereals were estimated from guidelines published by the United Nations Food and Agriculture Organisation (Allen, et. al., 1998). Some changes were then made to these crop factors (±10%) to fine tune the calibration. The crop factors used for different crops and irrigation efficiency factors are presented in Table B.4.

The pump capacities used in each of the irrigation nodes are based on the total of the estimated installed pump capacities of irrigators in that reach. These estimated installed pump capacities were also compared for consistency with the maximum observed order placed for each irrigation licence.

Because of the data uncertainty, the decision was made to focus the IQQM diversion calibration on total diversions and not on separate ONA and OFA diversion calibrations. This simplification was considered appropriate given the absence of significant on-farm storage development in the Lachlan valley. In such cases diversions during off-allocation periods tend to be a substitution of on-allocation water use that would have occurred in any case.

3.4.2. Results

Figures 3.9 shows the modelled and observed total diversion volumes over whole valley. Table 3.3 summarises the calibration using the quality guidelines outlined in Appendix D.

Figure 3.9: Lachlan Valley - Observed and simulated diversions

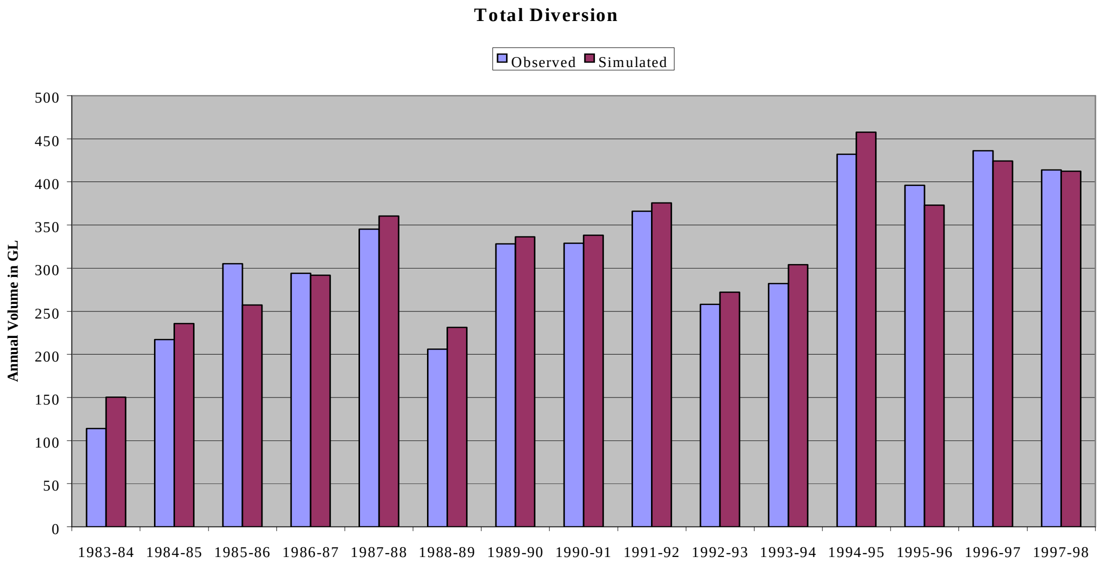


Table 3.3: Diversion calibration quality achieved

SUBJECT		ANNUAL DIVERSION TIME SERIES MATCH				QUALITY RATING
Irrigator Group	**Quality Indicator**	**Observed GL**	**Simulated GL**	**Indicator Value**	**Apparent Error**	
Whole subsystem	Volume ratio	4723	4821	102.1%	2.1%	High
	CMAAD	-	-	-	5.6%	V.High

3.5. STORAGE BEHAVIOUR REPLICATION

Storage behaviour replication by the model is the best numerical check of the model's overall performance. All elements of the system contribute to the pattern of drawdown and releases in the dam behaviour.

A number of model parameters are calibrated in the storage calibration process (DLWC, 1998[c]). To calibrate these parameters, the calibrated parameters from flow and demand calibration are used, while the crop areas and off-allocation extractions are still forced to observed data. The river operation parameters are then adjusted until the simulated storage behaviour, storage releases and end-of-system flows best match the observed data. The following details the different processes in storage calibration.

3.5.1. Inflow to dams

For the calibration of storage behaviour, dam inflows must first be derived. This is done using a back-calculation procedure (DLWC, 1998[g]) based on information obtained from dam Officer in Charge (OIC) sheets (DLWC, 1940-2000). The back-calculation technique is based on a water balance of dam inputs and outputs as follows:

```
Inflow   =  Change in Storage + Releases + Spills + Losses - Direct Rainfall
```

After a review of the available rainfall and evaporation stations and consideration of the criteria outlined in Section 3.4.1, the rainfall and evaporation stations listed in Table A.1 were selected to drive the storage behaviour in the model. Daily OIC sheets were obtained (Wyangala Dam = 1940 to 2000; Carcoar Dam = 1970-2000) and were used to estimate dam inflows. These inflows were used for calibrating the storage behaviour.

3.5.2. Tributary utilisation

The forecast of the expected flow from a tributary on a future day is modelled as a fixed fraction of the known flow on the current day (i.e. a recession assuming no rainfall). Tributary utilisation is generally quoted in terms of 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 (where the release is being computed for the current day) to the tributary. Releases from the storage to meet downstream demands are reduced to allow for this predicted tributary inflow.

Typically, the tributary recession factors reduce progressively down the main river because of the increasing uncertainty with predicting further into the future. The factors for all ungauged tributaries was set equal to zero. In reality, the factors are not fixed, but they vary with time and recent climatic conditions. The fixed tributary utilisation factors that produce the best calibration of storage behaviour over the calibration period are presented in Table B.5.

3.5.3. Operational surplus

IQQM represents operational surplus by applying a fixed *over-order factor* to the orders placed by each of the irrigation groups. As the orders are passed upstream they are multiplied by the over ordering factor to increase dam release.

Typically, the over-order factors increase progressively down the main river because of the increasing uncertainty in transmission losses and greater flow attenuation with increased travel distance.

For the Lachlan IQQM, the fixed over-order factor of 1.0 produced the best calibration of storage behaviour over the calibration period.

3.5.4. Results

The following Figures 3.10 to 3.12 show the storage calibration for each of the major storages. Table 3.4 summarises the calibration results in terms of the quality guidelines outlined in Appendix D.

Figure 3.10: Wyangala Dam – Observed and simulated storage volume

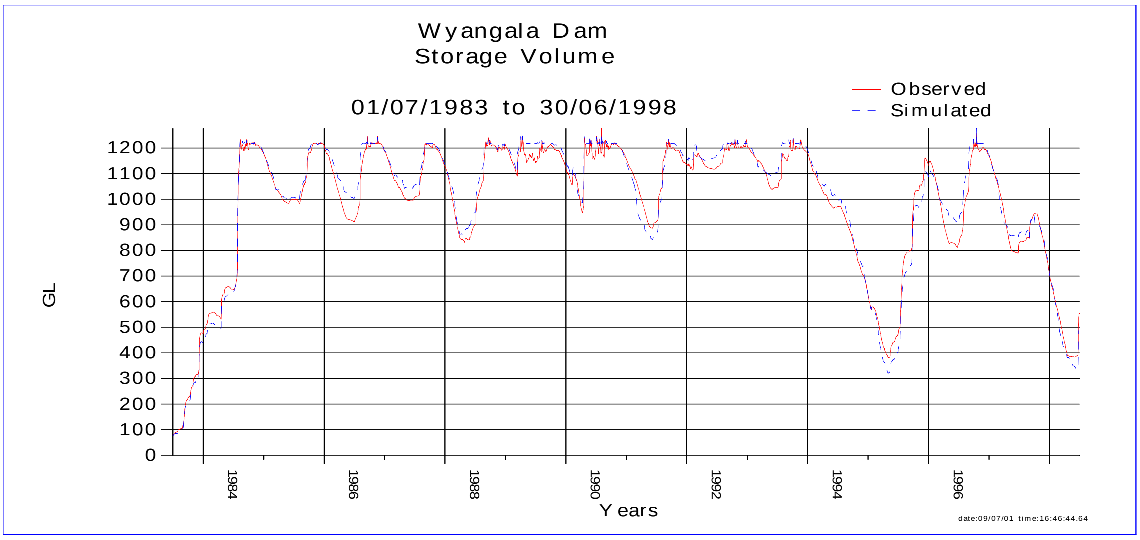


Figure 3.11: Lake Cargelligo – Observed and simulated storage volume

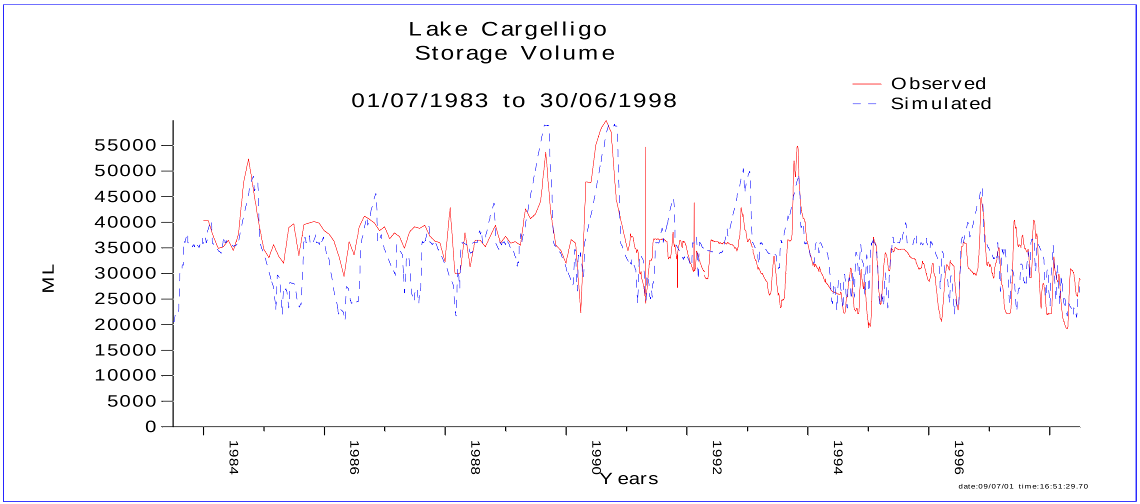


Figure 3.12: Lake Brewster – Observed and simulated storage volume

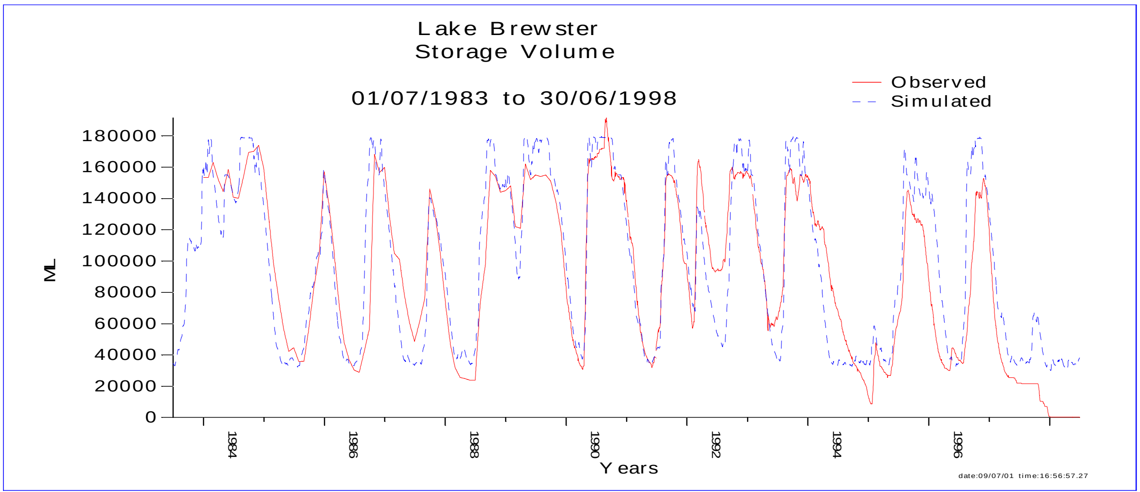


Table 3.4: Storage calibration quality achieved

SUBJECT		Apparent Error	QUALITY RATING
Irrigator Group	**Quality Indicator**		
Wyangala	CAASDD	1.9%	Very High
Brewster	CAASDD	8.0%	Moderate
Cargelligo	CAASDD	16.1%	Very Poor
Carcoar	CAASDD	4.4%	High
Whole subsystem	CAASDD	3.0%	High

3.6. PLANTED AREA REPLICATION

It has been recognised that the planting decision derived during the calibration process is unlikely to be appropriate for use in Cap simulations. For the Lachlan IQQM, the period from 1983 to 1995 encompasses too much variability in terms of the planting behaviour to be represented by a single planting decision. Consequently, a discussion of the planting decision process in IQQM, and its calibration, are presented in Appendix C. The derivation of a planting decision for Cap simulations is discussed in detail in the chapter describing the Cap simulation (Chapter 4).

3.7. OFF ALLOCATION REPLICATION

There was a lack of detailed data for off-allocation diversions during the calibration period and the surplus flow announcements were often made on an event by event basis. There was a large degree of variation in the factors used to declare access to surplus flows from event to event. However, there appears to have been a general practice of announcing off-allocation to equalise the access to surplus flow for all the irrigators as much as possible, usually by making the number of off-allocation days roughly the same for all irrigators.

IQQM models off-allocation periods using defined off-allocation reaches, which have surplus flow thresholds above which off-allocation is made available. As flows in excess of downstream requirements exceed the threshold level, off-allocation is made available to that off-allocation reach. Complete off allocation data was not available and therefore off allocation calibration was limited to replicate the announced off allocation periods. Table B.6 shows the off allocation thresholds for various river sections.

3.8. RESOURCE ASSESSMENT

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

- Current volume available in the dam; and any downstream weirs;
- minimum expected inflow 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 the essential requirements placed on the dam.

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. The aim was to derive a single algorithm that could be used in IQQM. It was found that no single set of algorithms were adequate to replicate the observed allocation behaviour during the calibration period. For model calibration the allocation percentages were then fixed to their actual recorded values.

3.9. OVERALL MODEL CALIBRATION

The overall model calibration quality has been assessed using a combination of selected key indicators (see Appendix D). The results of applying this evaluation process are summarised in Table 3.5.

Table 3.5: Overall model quality rating

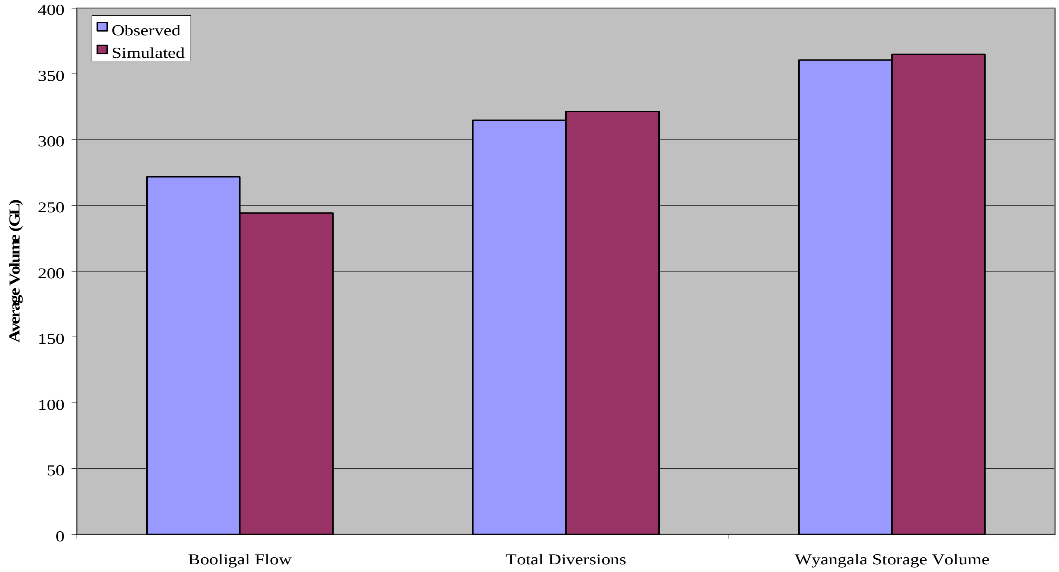
Replicated Item	*Key Indicator*	*Indicator value % "I" (see note 1)*	*Associated Quality Rating*	*Standardised Lower range limit"SL"*	*Standardised Upper range limit"SU"*	*Lower limit of "I" range: "LL"*	*Upper limit of "I" range: "UL"*	*Standardised Indicator "SI"*
Total Diversions	Volume ratio	2.7	High	5	10	2	5	6.2
	CMAAD	5.6	Very High	0	5	0	10	2.8
EOS flow @ Booligal	Volume ratio	10.1	Moderate	10	15	5	15	12.6
	CMAAD	20.6	Low	15	20	20	25	15.6
Storage Volume	New indicator	3	High	5	10	2	5	6.7
Mid-system Flow @ Condobolin	Mid flow range vr	1.8	Very High	0	5	0	2	4.5
	CMAAD	11.6	High	5	10	10	15	6.6

Note 1:- Negative values converted to absolute values

Overall Quality Indicator Outcome			
Aspect or Item		*Indicator*	*Quality*
	AI % =	7.8	High
	Calibration period length =	15.0	years
	OI % =	4.0	***Very High***

Another way of viewing the overall calibration is to look at the main indicators of mass balance in the system, as show below in Figure 3.13.

Figure 3.13: Average annual water balance in Lachlan River system (1983 to 1998)



4. 1993/94 Development Conditions (Cap) Scenario

The Lachlan River Valley is a designated river valley under Schedule F of the Murray-Darling Basin Agreement (MDBMC, 2000), and is consequently required to be managed to ensure that diversions do not exceed those expected under 1993/94 levels of irrigation infrastructure and management rules (ie the MDBMC Cap). The DLWC will use the Lachlan IQQM (DLWC, 1998) to estimate this diversion limit and therefore provide an indication of the valley's compliance with the MDBMC Cap.

The previous chapters of this report have outlined how the IQQM has been configured, calibrated and validated for the Lachlan Valley. This chapter outlines how the IQQM has been further developed to perform a simulation of the valley with 1993/94 levels of development and long term climatic conditions (ie the *Cap scenario)*. This chapter also outlines how the Cap scenario has been used for short term Cap auditing, ie the *Cap audit scenario*.

Licensed water users extracting water from unregulated streams have not been included in the Lachlan Valley IQQM. To date these licences have been operating on the basis of a maximum authorised irrigable area and a commence to pump and/or cease to pump limit for pumping (usually a visible flow at the nearest flow gauging station). Past operation of these licences has not been closely monitored and there has generally been very little data collected on water extractions and cropping by these licences. Consequently, the Cap benchmark described in this report only relates to the regulated system. It is intended that, if sufficient information should become available, the model would be expanded to represent unregulated licences.

It should also be noted that the tributary inflows used in the Lachlan Valley IQQM have been calibrated using observed streamflow at gauging stations for the periods of their records. Inherent in the stream flow data is the effect of extractions by unregulated licences that are outside the influence of regulated flows from Wyangala and Carcoar Dams. For the purposes of determining Cap for the regulated Lachlan system, this effect has been deemed to be negligible.

4.1. CAP IN BRIEF

The Lachlan River IQQM was used to simulate Cap conditions over the 103 year period from 1898 to 2001 to determine long term average annual diversions. For Cap auditing purposes under Schedule F, the model has been run for the 1997/98, 1998/99, 1999/2000 and 2000/01 water years. The following assumptions were used to represent Cap conditions:

- Wyangala and Carcoar Dams infrastructure and operation policy as per 1993/94 conditions;
- Pump capacity as installed in the 1993/94 irrigation season;
- The crop mix as observed during the 1993/94 irrigation season;
- Maximum planted areas based on observed data for 1993/94 irrigation season;
- Management rules applicable in the 1993/94 irrigation season.

4.2. CLIMATIC DATA

4.2.1. Rainfall

For the long term simulations, the rainfall stations selected based on the criteria outlined in Section 3.4.1 are extended and gap-filled to cover the intended simulation period.

4.2.2. Evaporation

For the long term simulations, the evaporation data is generated based on a relationship between monthly evaporation totals and number of rain days in the month (DLWC, 1998[l]). As explained in Section 3.4.1, eight long-term rainfall stations were used for generation of evaporation data for the eight geographic zones (Table A.1).

4.3. FLOW DATA

4.3.1. Streamflows

The observed data for the tributary gauging stations selected for use in the model (Table A.2) were collated, gap-filled and extended using Sacramento rainfall-runoff models (DLWC, 1998[c] and DLWC, 1999[a]) such that they covered the intended simulation period.
The ungauged catchment contributions were then derived based on applying the methodology outlined in Section 3.3 to the long-term gauged tributary inflows.

4.3.2. Inflows into the dams

To derive the required long-term inflow sequence to Wyangala and Carcoar Dams, the OIC sheet mass balance approach could no longer be sufficient (as these records only begin once the storage has been built about 1940).
Therefore, to derive the long-term inflow sequences; a comprehensive model representing all of the upstream catchments was assembled. This model uses observed data for each of the upstream catchments with records extended using Sacramento rainfall-runoff models. The upstream Wyangala Dam model was then calibrated to the back-calculated inflows for the period 1940 to 2000. This model was then used to extend Wyangala Dam inflows back from 1940 (DLWC, 1998[c]).
For Carcoar Dam, back-calculated inflows were used for a single Sacramento model calibration that was then used to extend the pre 1970 back-calculated inflows (DLWC, 1998[a]).

4.4. IRRIGATION INFORMATION

Where possible, observed data was used to configure the model for physical infrastructure including pump capacities and on-farm storages (Section 2.4).
Parameters such as crop irrigation efficiencies and tributary utilisation factors have been determined during calibration and validation periods (1983– 1998) (DLWC, 2000). A full listing of parameters describing the Lachlan IQQM Cap scenario is included in Appendix E.

4.4.1. Irrigation licences

Data for the 1993/94 irrigation season was used for the total regulated entitlement (Section 2.4.1 and Table E). The 1993/94 Cap scenario described in this report only relates to the regulated system at present. It is intended that, if sufficient information should become available, the model would be expanded to represent unregulated licences explicitly.

4.4.2. Irrigation extraction and storage infrastructure

The regulated pump capacities observed data for the 1993/94-irrigation season were used for 1993/94 Cap scenario.

4.4.3. Crop areas (planting decision determination)

As noted previously, an examination of historical planted areas suggested that the area planting decision taken by irrigators was changing over time, and that a single planting decision could not be calibrated to represent observed behaviour over any extended period. Accordingly, an appropriate planting decision would be determined as part of scenario configuration. Further discussion of the planting decision process in IQQM, and its calibration, are presented in Appendix C.

4.4.3.1 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 around 1993/94 before determining the best crop mix to represent 1993/94 Cap conditions. Figure 2.4 indicates the crop mix for 1993/94 was reasonably similar to those for 1992/93 except for winter cereal (lower in 93/94) and oil seeds (higher in 93/94). However, the crop mix for 1994/95 was slightly different from 1993/94, with a general trend toward more summer crops. This has been associated with the very dry conditions in the region at that time, and the increased demand for livestock fodder. Therefore, averaging of 92/93, 93/94 and 94/95 crop mix might not represent the long-term 1993/94 Cap conditions.

A sensitivity analysis showed that there was no significant difference in long-term average annual diversions when using either 92/93, 93/94 or an average crop mix and areas over the 92-95 period. Consequently, the crop mix observed in the 1993/94 water year has been assumed to represent Cap conditions, as shown in Table 4.1. The adopted crop mix for each irrigation node is held static for the duration of the simulation.

Table 4.1: Percentage crop mix

Crop Name	Belubula River	Upper Lachlan	Lower Lachlan	JWPD
Lucerne	65	32	6	24
Summer Pasture	4	15	14	12
Winter Pasture	3	22	30	36
Forage Crops	6	6	4	3
Wheat	0	5	14	6
Winter Cereals	8	9	9	9
Cotton	0	0	2	0
Oil Seeds	2	3	6	6
Summer Cereals	4	3	7	2
Vegetables	6	4	0	0

4.4.3.2 Maximum area

The general lack of resource constrained years in the Lachlan Valley has resulted in observed irrigated areas that only provide an indication of the maximum planted areas. The maximum planted area specified in IQQM is planted when there are sufficient resources available.

Using the approach outlined above for crop mix, the observed planted area for 93/94 year was assumed to be the maximum planted area for Cap Conditions. The total maximum planted area adopted for the Lachlan IQQM 1993/94 development conditions was 80,700 ha.

4.4.3.3 Minimum area

In severely resource constrained years there is likely to be a minimum area planted. Using observed irrigation area data up to and including the 1998/99 irrigation season and advice from regional representatives, an estimate was made of the total minimum area that would be planted in the Valley for the Cap scenario in resource constrained years. Preliminary modelling results indicated there would be numerous resource constrained periods over the long term.

Based upon data from the 1982/83 water year, where there was essentially a zero allocation, a minimum area of 20% of the total area was adopted. This estimate was also based upon consideration of the amount of perennial crops (lucerne) in the valley. Therefore, the total minimum planted area for the Lachlan IQQM Cap scenario is approximately 17,000 ha.

4.4.3.4 Planting decision determination

To determine a planting decision that covered the full range of resource availability, the following points were taken into consideration:

1) As already stated there is a minimum of 20% (17,000 ha) of the maximum area that will be planted.
2) The valley can plant maximum area when announced allocations are more than 65%. Therefore when announced allocations are 65% or higher (wet climate), farmers do not have to take any risk.
3) The lack of data and valley growth in area planted did not permit a farmer’s planting behaviour to be derived in medium years (between dry and wet). In the model it is assumed that irrigators will

not take any risk in medium years. This means that crops are planted based on the water that is available at planting date (including any estimates for purchasing transfer water) and that no allowance is made for increases in allocation or access to off allocation.

4) When allocating water for summer and winter crops it was assumed that priority was given to summer crops. This means that summer crops were planted on the basis of using as much of the entitlement as was required to plant maximum summer area. The balance remaining at the winter decision date was used to determine the area to plant in winter. Note no allowance was made for using the next year allocation for finishing winter crops. This is also demonstrated in recent crop mix data for 1998/99 water year where there is a steady trend away from winter crops towards summer crops.

Based on the above mentioned observations, the functions adopted for summer and winter planting behaviour crops are shown in Figures 4.1 and 4.2. The observed summer planting behaviour indicated a minimum area planted of about 17 000 ha of lucerne for announced allocation levels of 20% or less. The observed total maximum area planted was about 45 000 ha. The minimum and maximum areas planted are joined by a line indicative of a crop water requirement of about 7.5 ML/ha. The winter planting behaviour is based on the amount of water available at the start of March; this water is referred to as the Balance in Figure 4.2. The observed maximum area planted in winter was about 38 000 ha. No risk is assumed to apply with a crop water requirement of about 5.5 ML/ha being used to estimated area planted.

Figure 4.1 Summer planting behaviour

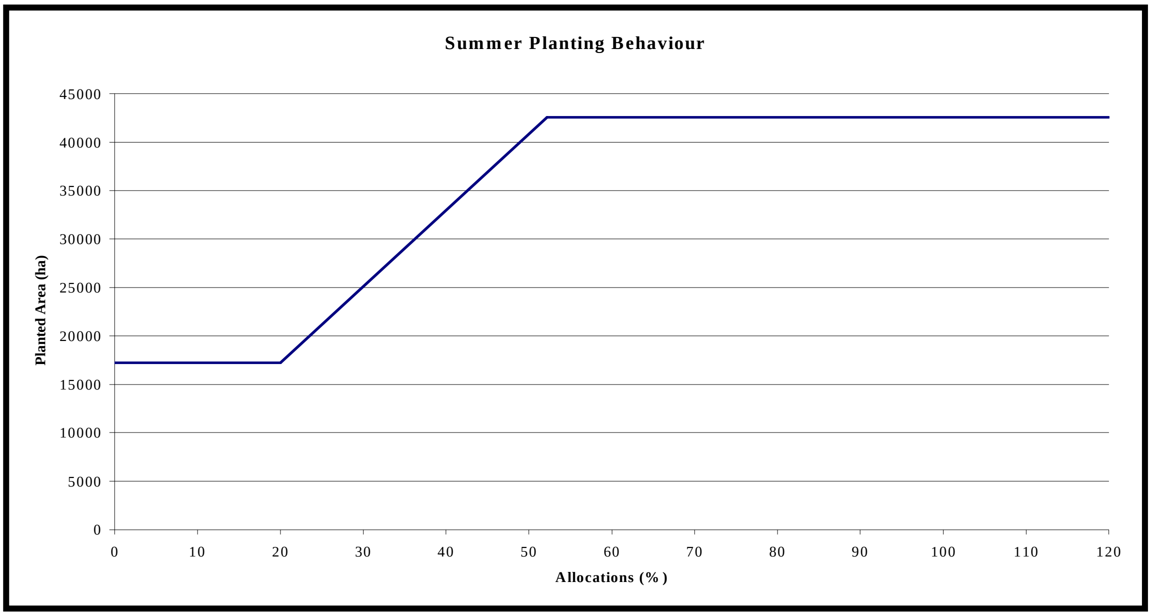
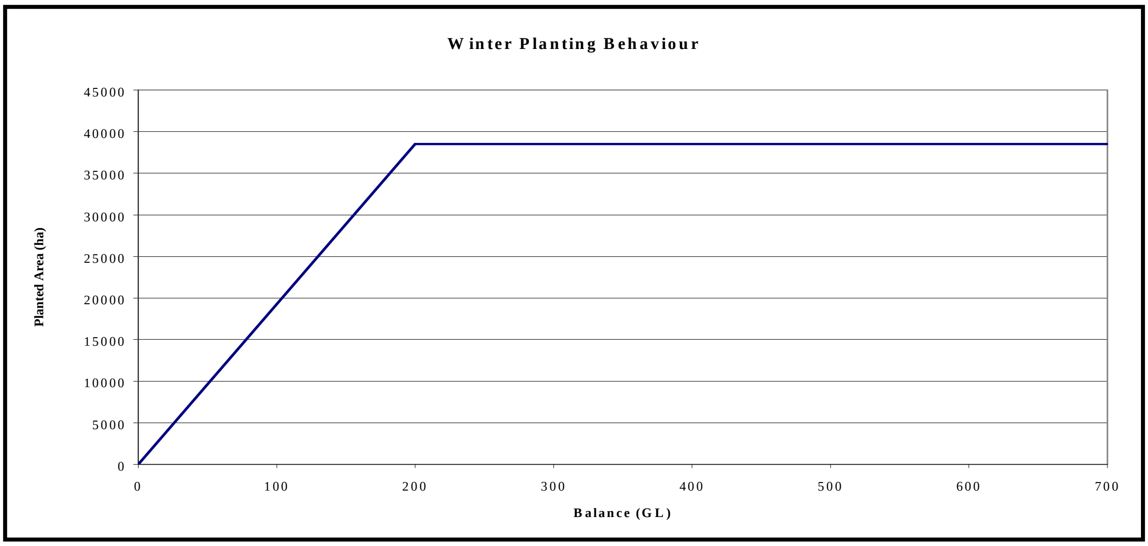


Figure 4.2 Winter planting behaviour



4.4.4. End-of-year diversions

Since the Lachlan Valley does not have significant on farm storages, the diversion data did not show any significant end of year diversions in June.

4.4.5. Transfer market

For the Lachlan valley, it has been assumed that the intra-valley water trading market is sufficiently mature that irrigators would trade any under-utilised entitlement to ensure that observed areas could be sustained as long as possible during periods of resource constraint. This is represented in the model by the adjustment of entitlement at the irrigation nodes in the model to ensure that the maximum areas can be planted until the valley entitlement is fully committed.

An analysis of model results has indicated that the irrigation groups represented in the model generally have reducing areas planted across the valley relatively equally in resource constrained years. The small amount of trade indicated by the observed data was considered too small to warrant adjustment of entitlements for the various irrigation groups. However, it was observed that Willandra Creek irrigators did not have enough entitlement to sustain their recorded areas. Therefore 12 GL of licensed entitlement was transferred from under-users in Willandra-Hillston irrigators towards Willandra Creek irrigators.

4.4.6. High security irrigation

Similar to general security irrigators, the 1993/94 planted area was adopted for high security irrigators as well. The maximum high security irrigator area of 1,900 ha was used for the Cap run.

4.4.7. Unregulated use

The unregulated licences have not been included explicitly in the Lachlan IQQM. Consequently, the 1993/94 Cap scenario described in this report only relates to the regulated system at present.

It is important to note, however, that the tributary inflows used in the Lachlan IQQM have been calibrated using observed streamflow at gauging stations over a variety of periods. Inherent in the observed streamflows is the effect of extractions by unregulated licences that are upstream of the gauging stations. For this reason, some of the unregulated extractions have been included implicitly in the model. For the purposes of determining the Cap for the regulated Lachlan system, this effect has been deemed to be negligible.

It is intended that, if sufficient information should become available, the model would be expanded to represent unregulated licences explicitly, as discussed in Chapter 5.

4.5. TOWN WATER SUPPLY

The average annual TWS diversions observed in the 1992-95 period were approximately 10 GL and this was adopted for Cap Run. The calculated average monthly town water supply requirements adopted for the various towns are shown in Table B.2 in Appendix E.

4.6. STOCK AND DOMESTIC

Based on DLWC Regional estimates for 1992-95 period, an overall average annual demand was estimated for each of the five reaches with an identified demand. An annual demand of 9 GL was adopted with monthly use patterns developed to match nearby TWS patterns (Table B.3, Appendix E).

4.7. INDUSTRIAL AND MINING EXTRACTIONS

These amounts are negligible relative to irrigation amounts and have not been represented explicitly in IQQM.

4.8. GROUNDWATER ACCESS

In this present IQQM calibration process no allowance was made for groundwater or groundwater interaction with surface water usage. Such allowances will however be considered as part of future model calibration refinements.

4.9. RESOURCE ASSESSMENT

The typical information required to make resource assessments for the Lachlan Valley was determined and the model configured appropriately. The main features of the resource assessment system that were in place for the 1993/94 season are listed below:

- Wyangala and Carcoar Dams operated as separate systems, with a standard target flow at the end of the Belubula system.
- Maximum allocation of 120%
- No carryover of unused allocation
- No borrow from the following year's allocation;
- Storage reserve is a function of total storage and time of year, with a volume of 201 GL in Wyangala storage and 8 GL in Carcoar storage in July.
- Three annual stock & domestic replenishments (total of 27 GL)

A full listing of parameters used can be found in Appendix D.

4.10. RIVER AND STORAGE OPERATION RULES

4.10.1. Tributary utilisation

Appropriate tributary utilisation factors were determined during the calibration and validation period 1983 – 1998 (DLWC, 2000). The adopted factors for the Cap scenario are listed in Table E.1.

4.10.2. Operational surplus

For the Lachlan IQQM, the fixed over-order factor of 1.0 produced the best calibration of storage behaviour over the calibration period. The same factors are adopted for the Cap scenario as well.

4.11. SURPLUS FLOW ACCESS (OFF-ALLOCATION)

The off allocation threshold described in Table B.6 were adopted for the Cap scenario.

4.12. RIVER FLOW REQUIREMENTS

4.12.1. Minimum flows

Table 4.2 shows the adopted minimum flow requirements at various locations for the Cap case.

Table 4.2: Minimum flow requirements

Location	Minimum flows
Wyangala Outlet	70 ML/d
Belubula R at Bangaroo	10 ML/d
D/s of Cargelligo	15 ML/d
Brewster Weir Outlet	20 ML/d
Booligal	160 ML/d
Hillston	Oct-Mar 200 ML/d Apr 400 ML/d

4.12.2. Stock and domestic replenishments

Based on regional operational practice, replenishment flows are represented (in Table 4.3) as a regular annual diversion, spread over the three effluent systems each of 60 days duration.

Table 4.3: Stock and Domestic Replenishment Flows

Wetland	*Replenishment Flow rate ML/d*	*Period (days)*	*Period starting*
Willandra Creek	150	60	1st of February
Merrowie Creek	150	60	1st of May
Merrimajeel Creek	150	60	15th of March

4.12.3. Wetland Diversions

Flows into three wetlands along the lower Lachlan River have been represented in the Cap scenario; the Middle Billabong, Muggabah Creek and Unamed Creek (near Hillston). These are all in the Hillston – Booligal section of the Lachlan River. These wetlands do not represent all wetlands that receive flows, but have been included as indicative wetlands to allow assessment of the effects of various flow rules.

Other wetland areas not directly simulated will contribute to simulated transmission losses in the river sections where they are situated.

4.13. COMPARISON WITH 1992-1995 PERIOD

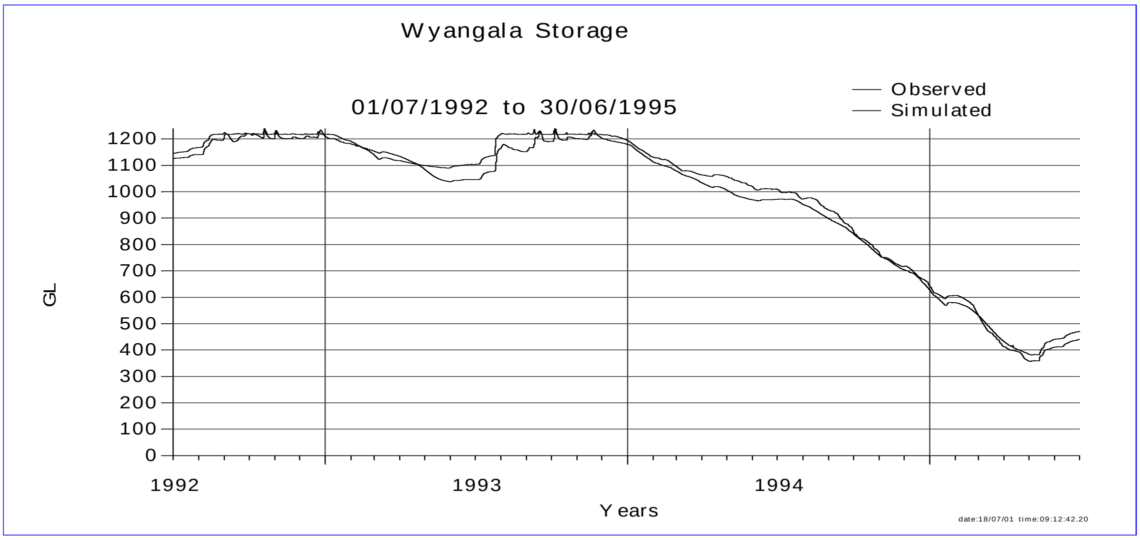
To assess the robustness of the Cap scenario, a simulation was performed over the period where irrigation development was closest to Cap conditions. The 1992/93, 1993/94 and 1994/95 seasons were considered most appropriate. The observed and simulated results were compared for a number of processes including: announced allocations, planted areas, diversions, storage behaviour and end-of-system flows. The results are presented in Table 4.4. The Wyangala storage behaviour for the 1992-95 period is shown in Figure 4.3. Note that the observed and simulated storage volumes on 1 July 1992 differ because the simulation was started on 1 May 1992 to cater for the initial conditions.

Table 4.4: Key observed vs modelled parameters for 1992/93 – 1994/95

Parameter		***1992/93***	***1993/94***	***1994/95***
Announced Allocation (%)				
September	Modelled	120	120	80
	Observed	120	120	80
	Difference	0%	0%	0%
Areas (Ha)				
Total	Modelled	80,600	80,600	75,700
	Observed	85,200	80,600	84,900
	Difference	-5%	0%	-11%
Summer	Modelled	40,600	40,600	40,600
	Observed	40,400	40,600	48,400
	Difference	+0.5%	0	-16%
Winter	Modelled	38,100	38,100	33,200
	Observed	42,800	38,100	34,400
	Difference	-11%	0	-3%
Diversions (GL)				
	Modelled	255	293	414
	Observed	259	284	432
	Difference	-4 -2%	+9 +3%	-18 -4%
Application Rate (ML/Ha)				
	Modelled	3.2	3.6	5.5
	Observed	3.0	3.5	5.1
Flows (GL)				
Wyangala releases	Modelled	770	825	710
	Observed	815	813	650
Tributary contribution		596	1057	235
	Difference	-45 -6%	+12 +1%	+60 +9%
End-of-system:	Modelled	282	330	91
(Oxley* + Willandra#)	Observed	320	365	100
	Difference	-38 -12%	-35 –10%	-9 -9%

* Observed Oxley flows estimated based on a correlation with Booligal flows
# Observed Willandra flows estimated based on a correlation with Oxley flows

Figure 4.3: Observed vs simulated Wyangala storage behaviour for 1992/93 – 1994/95



4.13.1. Modelled and Observed Allocations

The observed and modelled announced allocations are exactly the same for all of the three years 1992/93, 1993/94 and 1994/95.

4.13.2. Modelled and Observed Areas

When comparing the observed and modelled planted areas over the 1992-95 validation period, there are three major factors that need to be considered:

the differences between observed and modelled allocation announcements will produce an expected difference in the planted areas;

the irrigator's risk function in the model;

the adopted maximum area in the model.

The observed and model allocations are identical and therefore should not be a factor for differences. A comparison of the observed and modelled areas indicates that the model planted 5% less area than observed in 1992/93, the same in 1993/94 and 11% less in 1994/95. The lower modelled area in 1992/93 is due to limitation imposed by the maximum area that is lower than observed for that year. The significantly higher difference in 1994/95 is also due, in part, to the observed areas exceeding the maximum area configured within the model and the fact that, whilst the model planted the maximum summer area, it curtailed winter areas. The reason for the reduced winter areas was that the model did not simulate sufficient available water on the winter decision date to plant the maximum winter areas and has been configured to for minimal risk. Modelled and Observed Diversions

When comparing the observed and modelled diversions over the 1992-95 validation period, there are two major factors that need to be considered:

the differences between observed and modelled planted areas will produce an expected difference in the diversions;

the differences between observed and modelled diversions produced during the calibration of the model (Section 3.4) will also produce an expected difference in the diversions.

The calibration of 1992-95 period is very good and any differences in diversions chave not been attributed to calibration inadequecies.

In both 1992/93 and 1994/95 years, the modelled diversions were lower than those observed. In both years the lower modelled diversions are due to lower modelled planted areas. However 1992/93 has less winter area while 1994/95 has less summer area. The difference in area in winter crops during 1992/93 show a small proportional change in diversions compared to 1994/95 where the difference in area is pre-dominantly summer area.
In 1993/94 the same modelled and observed area was planted and only a small extra diversion was observed (+3%).
The differences between the observed and modelled diversions during the 1992-95 validation period can be accounted for by variations in the planted areas and are not considered significant enough to indicate that there are any major inaccuracies in the Cap scenario relative to the model calibration.

4.13.3. Modelled and Observed storage behaviour and end-of-system flows

When comparing the observed and modelled storage behaviour over the 1992-95 validation period, there are two major factors that need to be considered:
the differences between observed and modelled regulated demands will produce an expected difference in the storage releases;
each individual event release for environmental or flood mitigation purposes is difficult to model due to the variability in the timing of actual management decisions.
Both the storage releases and the end-of-system flows were analysed for each of the three irrigation seasons.
The minimum modified licence volume distribution to represent the transfer market should not have any impact on storage release and end-of-system flows.
During the 1992 to 1995 period, modelled Wyangala Dam releases for 1992/93 and 1993/94 were consistent with modelled diversions. That is when modelled diversions were more than observed diversion, the storage released more water and when modelled diversions were less than observed the dam releases less. However 1994/95 is different with lower model diversions resulted in higher storage releases. The reason for this is that model transmission losses are based on average conditions and 1994/95 was a dry year when modelled losses would have under-estimated those actually occurring. However, even with this error the storage releases for 1994/95 were only out by 9%.
The modelled end of system flows are always lower than those of observed. There could be various reasons for this discrepancy, namely
There was no observed data for Oxley and Willandra for 1992-95 and observed flows are based on relationships with neighbouring stream gauging stations.
In the model, diversions to the wetlands are based on a fixed pattern that may not necessarily be what happened in reality.
The major discrepancies in flow volumes are in higher flows. Generally higher flows have lower accuracies due to rating table problems.

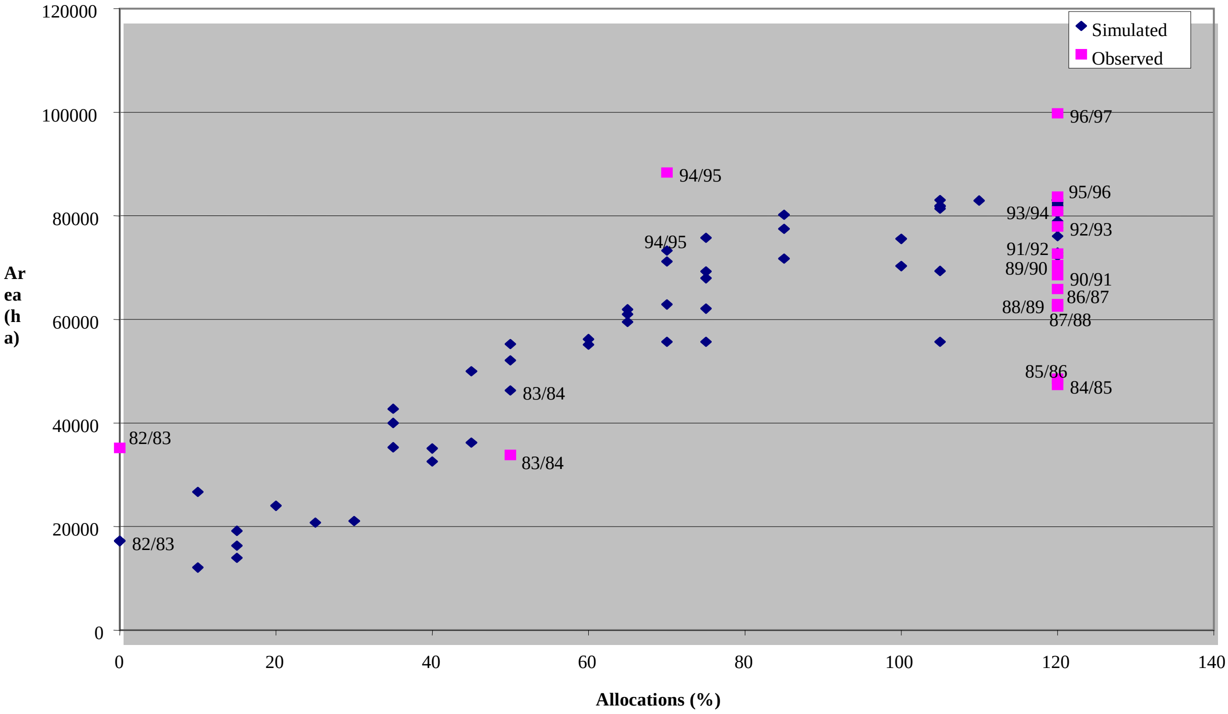
Taking into consideration these factors, the storage releases and end-of-system flows in 1992-95 are considered reasonable.

4.14. RESULTS

4.14.1. Comparison of modelled and observed planted area

Figure 4.4 shows a comparison of the long-term simulated planted area and observed planted area for the Lachlan Valley (1981/82 – 1996/97 period) versus March allocation levels.

Figure 4.4: Simulated relationship between resource availability and planted area



The observed data pre-1991/92 and post-1994/95 irrigation season is considered to be misrepresentative of the irrigator's behaviour during the 1993/94 irrigation season. However, the 1991-95 period is not resource constrained and therefore cannot be used to check the adopted risk function behaviour for dry years. However a good match between the simulated and observed planted areas is achieved for the period from 1991/92 to 1995/96 (Figure 4.4).

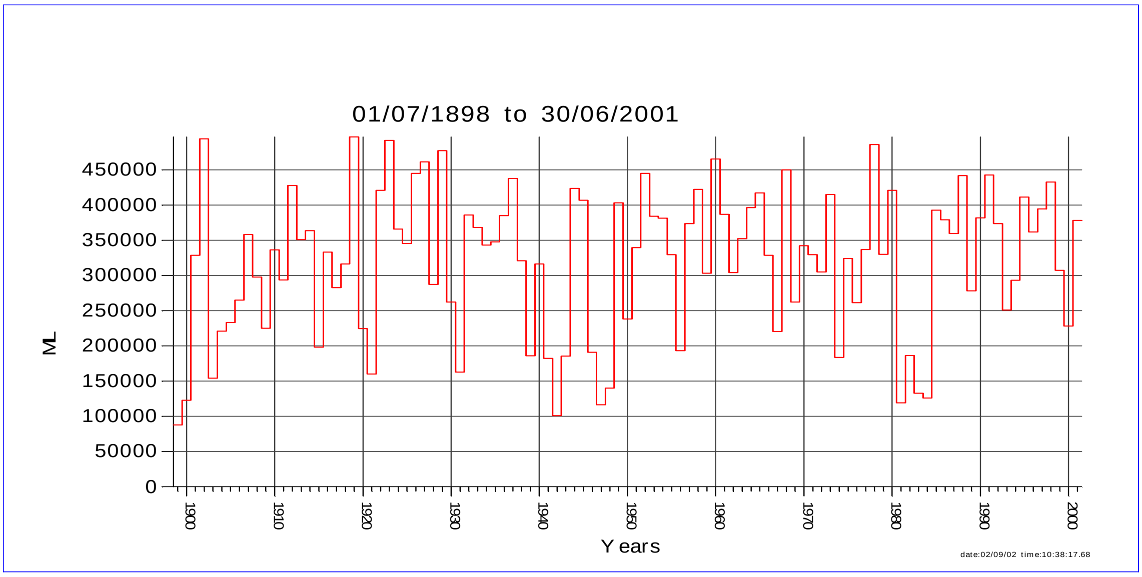
4.14.2. Summary of the Cap scenario results

The summary results for the 103 year IQQM Cap simulation are presented in Table 4.5. Figure 4.5 shows annual time series general security diversions.

Table 4.5: Summary of the Cap scenario results (as set up in *Run C71a*)

Summary Aspect	***Sub-aspect***			***Average (ML/year)***
Water usage	General security on allocation (ONA)			227.8 GL
	General Security off allocation (OFA)			61.0 GL
	High security			11.8 GL
	Stock and domestic			9.2 GL
	Town water supply			10.0 GL
	Total			319.8 GL
Crop model	Average total planted area			65600 ha
	Maximum total planted area			80600 ha
River flows	Lachlan at Condobolin			761 GL
	Lachlan at Booligal			197 GL
	Lachlan at Oxley			110 GL
Wyangala Supply Reliability on 01/01	100%	75%	50%	5%
(% of years that achieved ≥ stated % allocation)	61	67	79	95

Figure 4.5 Lachlan Valley Cap scenario simulated total annual diversions



4.14.3. Cap audit (Schedule F accounting simulation)

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

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

At the commencement of the simulation, IQQM will plant an area based on the resources available at that time. For Lachlan Valley, the water year commences in July, allowing for the possibility of inappropriately simulated winter planted areas carried over from the end of the previous (1996/97) water year.

To avoid this problem, the initial crop areas in the first season of the Cap audit scenario are the winter crop areas planted in the previous March (1997). Ideally they should be the areas that would have been planted under Cap conditions. The Cap audit scenario has not been configured to start with these areas, as they are not known. The diversions and areas in the first three months in the Cap audit scenario have been compared with the observed data, where available to determine the likely error.

The annual Cap simulation results for the 1997/98 – 2000/2001 irrigation seasons are presented in Table 4.6, with a comparison to the observed data.

Table 4.6: Lachlan Valley IQQM annual cap simulation – summary results

Water Year	Total Planted Areas (ha)		Announced Allocation (1 Oct / 1 Mar)		Total Diversions (GL)	
	Observed	Simulated	Observed*	Simulated	Observed	Simulated
1997/98	93574	69100	85% / 85%	70% / 70%	414	409
1998/99	75623	80600	100% / 100%	120% / 120%	278	300
1999/00	84455	80600	96% / 100%	80% / 120%	285	228
2000/01	88000	80600	100% / 100%	80% / 120%	408	378

*Combination of announced allocation and carryover from the previous season for comparison purposes.

+Planted areas include both HS and GS irrigators

^Total diversions comprise GS and HS irrigators, TWS and S&D.

Schedule F accounting for Cap compliance is presented in Table 4.7 below.

Table 4.7: Lachlan Valley preliminary Schedule F account

Water year	Total diversions (GL)	Cap estimate from IQQM (GL)	Difference (GL)
1997/98	414	409	-5
1998/99	278	300	+22
1999/00	285	228	-57
2000/01	408	378	-30
Cumulative total	1385	937	-70
Long-term average Cap estimate:			319
20% of Long-term average Cap estimate:			64
Cumulative Cap performance:			Above Cap

5. Improvement Plans

Maintenance is a dynamic process and covers updating the model to account for:

- New model capabilities
- Improvements to existing model capabilities
- Further information becoming available to facilitate improved calibration
- More time and resources to refine calibration

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

5.1. UPGRADES TO THE FLOW CALIBRATION

5.1.1. Extended streamflow records

Since the outset of implementing the Lachlan IQQM, it has been intended that the flow calibration of the individual reaches would be reviewed based on the availability of more recent and better quality streamflow data. It is envisaged that this upgrading process would occur on approximately a five (5) year cycle.

5.1.2. Additional tributary gauges

There are some additional tributaries for which gauged information is now available. Currently, these are lumped into the estimate of the contribution from residual catchments. A careful review of the available data is required before deciding to include these separately, because they will require the use of Sacramento models for gap filling and data extension.

5.1.3. Routing of tributary inflows

For most tributaries, the gauging station is located some distance from the junction with the main river. The inflow contribution for each tributary is typically based on the streamflow data recorded at the relevant gauging station, with the catchment area downstream of the gauging station lumped into the residual catchment estimation for the reach. This could be improved by routing the tributary estimates from the gauging station down to their junction with the mainstream and re-derive the estimated contribution from their associated residual catchments.

5.1.4. Incorporation of Brewster Weir data

Investigate and establish if accurate records of Brewster Weir overflows and underflows exist, and if so use these to break up and improve the flow calibration of reaches 9, 10 and 11.

5.1.5. Antecedent conditions based losses

Incorporation of antecedent streamflow conditions on loss estimates; ie losses at low flows are higher if there has been a long period of drought relative to being on the recession of a flood.

5.1.6. Variable river surface area based on streamflow

This will provide a facility for better representation of varying evaporation from the water surface based on streamflow and therefore better representation of the loss processes in a river reach. Inclusion of this feature will require refining of the flow calibration.

5.2. UPGRADES TO THE DEMAND AND AREA CALIBRATION

5.2.1. 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 extraction data. The DLWC 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 re-calibration of the IQQM in the future. It is envisaged that this upgrading process would occur on approximately a five (5) year cycle.

5.2.2. 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 determines 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.

5.2.3. Improved modelling of planting decisions

At present there is only limited information available on the planting decision processes. Once more detailed information becomes available; it is envisaged that the planting decision module will also be improved to better represent the variability and complexity that occurs in reality.

5.2.4. Representation of transfer market

At present there is no way of dynamically representing the transfer market within the model. The transfers are either assumed to be insignificant or a simplified approach is used to represent this mechanism.

5.2.5. Better spatial representation of rainfall used to generate crop demands

Currently in the Lachlan IQQM, there are only a limited number of rainfall stations are used to cover the major demand centres in the Lachlan Valley. This results in smoothing of orders placed by the irrigation groups, since their demands are all being generated based on the same or similar rainfall data, whereas in reality, there is a large degree of spatial variability in the rainfall.

5.2.6. 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 rainfall harvesting, reuse of irrigation tailwater and division of on-farm storages into cells to reduce evaporation.

5.2.7. Explicit representation of unregulated users

Inclusion of irrigation nodes to represent the unregulated water users on tributaries. This may also require a review of inflow contributions from these tributaries.

5.2.8. Town water supply modelling

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

5.2.9. Improved representation of the Belubula irrigation scheme

There was a reasonably high degree of variation between the simulated diversions and the observed data for this scheme. This indicates that further work could be done to review and improve the representation of this scheme in the model.

5.2.10. On-farm storage operation

On farm storage operation is not significant in the Lachlan Valley at present. However in the future if on farm storage operation becomes significant and data becomes available they may be explicitly modelled to represent on farm activities such as increased access to off allocation flows, rainfall harvesting and reuse of irrigation tailwater.

5.3. UPGRADES TO THE STORAGE BEHAVIOUR MODELLING

5.3.1. Back-calculated Wyangala Dam inflows

Some anomalies between Wyangala Dam release records and observed streamflow at the downstream gauging stations were identified. These should be investigated and if the storage releases are found to be in error, then the back-calculated storage inflows will need to be revised (as these were based on a mass-balance using storage releases and volumes).

5.3.2. Variable tributary utilisation

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

5.3.3. 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.

5.4. UPGRADES TO OFF-ALLOCATION MODELLING

5.4.1. Improved off-allocation modelling

At present, off-allocation is modelled in each reach based on a single threshold that is applied for all months of the year. In reality, announcing off-allocation is a much more complex and variable process. The minimum amount of work required would include using a threshold that is variable depending on month of the year.

5.5. GENERAL UPGRADES

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

5.5.2. Incorporate the significance of access to groundwater resources

This would require an investigation of the extent of groundwater use and a relationship with surface water access and crop water requirements.

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Appendix A. Climatic and Streamflow Stations

Table A.1: Geographic zones for rainfall and evaporation records

Geographic zone for rainfall and evaporation records	Primary Rain Gauge		Secondary gauges used for gap filling/disaggregating accumulated and missing values in the primary gauge
	Name	Number	
Lake Wyangala and environs	Wyangala (Dam)	063267	Cowra Soil Conservation Service (063023) Canowindra (065006) Koorawatha Post Office (073021) Murrumburrah Old Post Office (073029)
Lake Carcoar & Irrigated crop areas in Belubula sub system & immediately u/s & d/s of Cowra	Cowra (Agricultural Research Station)	063022	Cowra Post Office(063021) Cowra Soil Conservation Service (063023) Cowra Airport (065091)
Irrigated crop areas immediately u/s of Forbes	Grenfell	073014	Parkes Post Office (065026) Eugowra (065013) Forbes Post Office (065016) Wyalong Post Office (073054)
Irrigated crop areas immediately d/s of Forbes	Forbes (Camp Street)	065016	Peak Hill Post Office (050031) Trundle Post Office (050036) Cowra Agricultural Research St. (063022) Quandialla Post Office (073032)
Irrigated crop areas immediately u/s of Forbes and Jemalong Wylde Plain Irrigation District	Wyalong	073054	Parkes Post Office (065026) Eugowra (065013) Forbes Post Office (065016) Grenfell (073014)
Irrigated areas nearby Waroo (u/s of Condobolin)	Waroo (Geeron)	050020	Condobolin Post Office (050014) Trundle (050036)
Condobolin, Lake Cargelligo and nearby irrigated areas	Lake Cargelligo	075039	Euabalong Post Office (049012) Lake Brewster (075087) Lake Cargelligo (075132)
Lake Brewster, Willandra, Willandra Creek, Hillston and nearby irrigated areas	Lake Brewster (Naradhan)	075050	Booligal (Belmont; (075007) Lake Cargelligo (075039)
Irrigated crop areas nearby Booligal Weir	Booligal (Belmont)	075007	Hay (Miller Street; 075031) Hillston Post Office (075032) Booligal (Ulonga; 075069)

Table A.2: Streamflow stations used for IQQM model calibration

Location	Station No.	Operation Period	Catchment area (sq. km)	Used for, and/or Comments
Lachlan River @ d/s Wyangala Dam	412067	1913 to date	8290	For estimating residual inflows from Wyangala Dam catchment through IQQM flow calibration
Lachlan River @ Cowra	412002	1893 to date	11100	IQQM flow calibration from d/s Wyangala Dam to Cowra gauging station
Lachlan River @ Nanami	412057	1958 to date	16100	IQQM flow calibration from Cowra to Nanami
Lachlan River @ Forbes	412004	1892 to date	19000	IQQM flow calibration from Nanami to Forbes
Lachlan River @ Jemalong Weir	412036	1941 to 1982	19400	IQQM flow calibration from Forbes to Jemalong Weir
Lachlan River @ Island Creek Offtake	412058	1958 to 1984	20000	IQQM flow calibration from Jemalong Weir to Island Creek Offtake
Lachlan River @ Condobolin Bridge	412006	1896 to 1939 1964 to date	25200	IQQM flow calibration from Jemalong Weir to Condobolin
Lachlan River @ Condobolin Weir	412034	1939 to 1964	25200	IQQM flow calibration from Jemalong Weir to Condobolin
Lachlan River @ Booberoi	412021	1928 to 1990	42500	IQQM flow calibration from Condobolin to Booberoi
Lachlan River @ Brewster Weir	412048	1955 to 1967	51800	IQQM flow calibration from Booberoi to Brewster Weir
Lachlan River @ Willandra Weir	412038	1941 to 1986	52300	IQQM flow calibration from Brewster Weir to Willandra Weir
Lachlan River @ Hillston	412039	1941 to date	54100	IQQM flow calibration from Willandra Weir to Hillston
Lachlan River @ Whealbah	412078	1968 to date	55200	IQQM flow calibration from Hillston to Whealbah
Lachlan River @ Booligal	412005	1907 to date	55900	IQQM flow calibration from Whealbah to Booligal
Lachlan River @ Coorong	412045	1952 to date	60600	IQQM flow calibration from Booligal to Coorong
Lachlan Riv @ Oxley	412026	1930 to 1982	61400	IQQM flow calibration from Coorong to Oxley
Boorowa River @ Prossers Crossing	412029	1980 to date	1530	Sacramento modelling and estimating residual inflow in d/s Wyangala Dam-Cowra; Cowra-Nanami; Nanami-Forbes; Jemalong-Island Ck Offtake reaches
Mandagery Creek @ u/s Eugowra	412030	1938 to date	1630	Sacramento modelling and estimating residual inflows in Nanami-Forbes; Forbes-Jemalong; d/s Carcoar Dam-Canowindra reaches
Crookwell River @ Narrawa North	412050	1955 to date	740	Sacramento modelling and estimating residual inflows in d/s Carcoar Dam-Canowindra reach
Abercrombie River @ Abercrombie	412028	1930-1998	2770	Sacramento modelling and estimating residual inflows in d/s Wyangala Dam-Cowra reach
Island Creek @ Lachlan Offtake	412097	1958 to 1967	Effluent	IQQM flow calibration from Island Creek Offtake at Lachlan to Fairholm
Island Creek @ Fairholm	412023	1927 to date	Effluent	IQQM flow calibration from Island Creek Offtake at Lachlan to Fairholm

Island Creek @ abv. Wallamundry Offtake	412044	1951 to 1963	Effluent	IQQM flow calibration from Fairholm to Wallamundry Offtake
Island Creek @ bel. Wallamundry Offtake	412015	1918 to 1960	Effluent	IQQM flow calibration from Fairholm to Wallamundry Offtake
Wallamundry Crk @ Offtake Island Crk.	412016	1942 to date	Effluent	IQQM flow calibration from Fairholm to Wallamundry Offtake and Wallaroi Creek from Island Crk Offtake to Worrongorra Weir
Wallaroi Creek @ Worrongorra Weir	412046	1917 to 1984	Effluent	IQQM flow calibration from Wallaroi Creek from Island Crk Offtake to Worrongorra Weir
Booberoi Creek @ Lachlan Offtake	412022	1928 to 1982	Effluent	IQQM flow calibration from Booberoi to Brewster Weir
Belubula River @ Canowindra	412009	1908 to date	2180	IQQM flow calibration from d/s Carcoar Dam to Canowindra
Belubula River @ Bangaroo Bridge	412055	1956 to 1974	2650	IQQM flow calibration from Canowindra to Bangaroo Bridge
Coombing Creek @ Near Neville	412092	1971 to 1993	132	Sacramento modelling and estimating residual inflows in Canowindra-Bangaroo Br. reach

Appendix B. Model Configuration

Table B.1: Functional elements represented in IQQM

Element Type	*Number of Items*	*Description of Items*
Direct tributary inflows	7	• Wyangala Dam inflows from back-calculation (8300 sq.km) • Carcoar Dam inflows from back calculation (230 sq.km) • At gauge 412029 – Boorowa River @ Prossers Crossing (1530 sq.km) • At gauge 412072 – Back Creek @ Koowaratha (840 sq.km) • At gauge 412092 – Coombing Creek near Neville (132 sq.km) • At gauge 412080 – Flyers Creek at Beneree (98 sq.km) • At gauge 412030 – Mandagery Creek @ u/s Eugowra (1630 sq.km)
Direct tributary inflows - routed to mainstream junction.	1	♦ From gauge 412043 – Goobang Creek @ Darbys Dam (~4000 sq.km)
Residual catchment inflows	7	➢ 12,70 sq.km area between Wyangala and Cowra ➢ 1,950 sq.km area between Carcoar Dam and Canowindra ➢ 520 sq km area between Canowindra and Belubula River system outlet ➢ 1,460 sq.km between Cowra and Nanami ➢ 1,270 sq.km between Nanami and Forbes ➢ 400 sq.km area between Forbes and Jemalong ➢ 1,500 sq.km area between Booberoi and Lake Cargelligo (Note – all other d/s residual areas were considered to be non-contributing)
Mainstream river flow calibration reaches	23	▪ Wyangala Dam to 412002 (Cowra) Reach 1 ▪ Carcoar Dam to 412009 (Canowindra) Reach Bel-1 ▪ 412009 to 412055 (Bangaroo Bridges) Reach Bel-2 ▪ 412002 to 412057 (Nanami) Reach 2 ▪ 412057 to 412004 (Forbes) Reach 3 ▪ 412004 to 412036 (Jemalong Weir) Reach 4 ▪ 412036 to 412058 (Island Ck offtake) Reach 5 ▪ 412058 to 412024 (Mulgutherie) Reach 5a ▪ 412058 to 412023 (Fairholme) Reach 5b ▪ 412023 to 412044 (Wallamundry offtake) Reach 5c

		▪ 412044 to 412046 (Worrongorra Weir) Reach 5d ▪ offtake to 412014; (Goobang Ck) Reach 5e ▪ 412058 to 412006 (Condobolin) Reaches 6 ▪ 412006 to 412021 (Booberoi Weir) Reach 7 ▪ 412021 to 412011 (Lake Cargelligo) Reach 8 ▪ 412011 to 412048 & 412047 (Brewster Weir) Reach 9 ▪ 412048 to 412038 (Willandra) Reach 10 ▪ 412038 to 412039 (Hillston) Reach 11 ▪ 412039 to 412078 (Whealbah) Reach 12 ▪ 412078 to 412005 (Booligal) Reach 13 ▪ 412005 to 412045 (Corrong) Reach 14 ▪ 412045 to 412026 (Oxley) Reach 15 ▪ 412038 to 412012 (Willandra Ck) Reach 16
Storages (on and off-river types)	5	❑ Wyangala Dam ❑ Carcoar Dam ❑ Brewster Weir ❑ Lake Cargelligo, and ❑ Lake Brewster
Stream gauge points suitable for transmission loss & flow calibration	26	These are the 22 gauge points listed above under mainstream river reaches, plus the following:- 412058, 412015, & 412022. This list does not include the 7 tributary inflow gauge points (see beginning of table, above).
General security Irrigator Group extractions	24	One group cluster in each defined river flow reach, plus Jemalong & Wyldes plains irrigation districts.
High security Irrigator Group extractions	7	Only the following reaches had HS licences:- Wya-Cow (1), Cow-Nan(2), Nan-For(3), For-Jem(4), Cad-Fai(5b), Wil-Hil(12), and Hil-Whe(13).
Stock and Domestic (subsistence) extractions	6	In the following reaches – UBelb(Bel-1), LBelb(Bel-2), Boo-Car(9), Car-Bre(10), Wil-Hil(12), and Hil-Whe(13).
Wetland replenishments	3	Willandra, Merrowie, and Merrimajeel.
TWS extractions	6	Cowra, Forbes, Condobolin, Willandra, Hillston, and Booligal
Effluent offtakes that return	4	Little Lachlan River to Lachalan River, Wallamundry Creek to Lachlan River, Bumbuggan Creek to Lachlan River, and Booberoi Creek to Lachlan River
Effluent offtakes that don't return	2	Muggabah Creek, and Willandra Creek (regulated)
Transmission loss	13	In each of the flow calibration reaches except:- Hil-Whe, and Boo-

allowance points		Car – that did not require loss allowances
Confluences	2	One actual confluence (Belubula and Lachlan Rivers) and one "virtual" confluence at the end of the system, to bring Willandra effluent back into a single outlet node point
Off-allocation reaches	20	In each of the flow calibration reaches except:- Boo-Car, Whe-Boo, Cor-Oxl
Minimum Flow control nodes	5	Immediately d/s of Wyangala Dam At Booberoi Weir D/s of Lake Cargelligo At Brewster weir D/s of Hillston

Table B.2: Average Town Water Supply Requirements (ML/day)

Month	Cowra	Forbes	Condobolin	Willandra	Hillston	Booligal
January	15.54	15.85	5.16	0.72	0.72	0.36
February	14.70	15.85	5.16	0.76	0.76	0.38
March	15.54	14.63	4.20	0.72	0.72	0.36
April	11.34	12.19	3.84	0.36	0.36	0.18
May	8.82	7.73	1.92	0.36	0.36	0.18
June	6.72	7.73	1.92	0.36	0.36	0.18
July	8.82	6.91	1.92	0.36	0.36	0.18
August	6.72	7.32	1.92	0.36	0.36	0.18
September	9.24	6.91	1.92	0.36	0.36	0.18
October	8.82	8.13	1.92	0.72	0.72	0.36
November	13.86	14.23	4.32	0.74	0.74	0.37
December	17.64	16.67	5.16	0.72	0.72	0.36
Annual diversion in cap scenario (ML)	**4200**	**4100**	**1200**	**200**	**200**	**100**

Table B.3: Average Stock and Domestic subsistence requirements (ML/day)

Month	"Belb"	"Boo-Car"	"Car-Bre"	"Will-Hill"	"Hill-Boo"
January	0.90	6.45	4.13	9.61	14.41
February	0.98	6.45	4.13	10.15	15.21
March	0.50	5.25	3.36	9.61	14.41
April	0.48	4.80	3.08	4.81	7.20
May	0.43	2.40	1.54	4.81	7.20
June	0.25	2.40	1.54	4.81	7.20
July	0.25	2.40	1.54	4.81	7.20
August	0.25	2.40	1.54	4.81	7.20
September	0.53	2.40	1.54	4.81	7.20
October	0.55	2.40	1.54	9.61	14.41
November	0.59	5.40	3.46	9.88	14.81
December	0.90	6.45	4.13	9.61	14.41
Annual diversion for calibration and cap scenario (ML)	**200**	**1500**	**960**	**2670**	**4000**

Table B.4: Crop factors and irrigation efficiency

	Efficiency	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Lachlan*													
S Cereals	0.85	0.80	1.00	0.60	0	0	0	0	0	0	-0.30	0.40	0.60
Lucerne	0.85	0.85	0.80	0.70	0.60	0.50	0.45	0.50	0.50	0.70	0.80	0.80	0.90
S Pastur	0.85	0.60	0.80	0.60	0.50	0	0	0	0	0	0.30	0.40	0.50
W Cereals	0.75	0	0	-0.40	0.40	0.50	0.80	1.00	1.00	0.80	0.50	0	0
Wheat	0.75	0	0	0.01	-0.01	0.30	0.50	0.80	1.00	0.80	0.40	0.10	0
W Pastur	0.75	0	0	-0.50	0.50	0.80	0.80	0.80	0.85	0.90	0.95	0.70	0
S Vegtbl	0.85	0.90	0.90	0.85	0	0	0	0	0	0	0.75	0.80	0.80
Vineyard	0.85	0.85	0.80	0.70	0.60	0.40	0.29	0.21	0.29	0.40	0.60	0.70	0.80
OilSeed	0.85	0.60	0.60	1.10	0.90	0	0	0	0	0	0	0.30	0.40
Citrus	0.85	0.80	0.80	0.80	0.80	0.80	0.70	0.70	0.70	0.70	0.80	0.80	0.80
Cotton	0.73	0.75	0.95	0.90	0	0	0	0	0	0	-0.40	0.40	0.50
Other	0.80	0	0	0.01	0.01	0.30	0.50	0.80	1.00	0.80	0.40	0.10	0
Forage	0.85	1.00	0.90	0.80	0.80	0.60	0.50	0	0	0	0.40	0.50	1.00
Legumes	0.85	0.70	0.70	0.70	0.60	0.60	0.50	0	0	0	0.55	0.65	0.70
Lower Lachlan													
S Cereals	0.85	0.70	0.85	0.60	0	0	0	0	0	0	-0.30	0.40	0.60
S Pastur	0.90	0.50	0.70	0.50	0.40	0	0	0	0	0	0.30	0.40	0.50
W Cereals	0.75	0	0	-0.40	0.40	0.50	0.80	1.00	1.00	0.80	0.50	0	0
Wheat	0.75	0	0	0.01	-0.01	0.30	0.50	0.80	1.00	0.80	0.40	0.10	0
W Pastur	0.85	0	0	-0.50	0.50	0.60	0.70	0.80	0.85	0.85	0.90	0.70	0
OilSeed	0.90	0.50	0.60	0.80	0.70	0	0	0	0	0	0	0.30	0.40
JWPD													
Lucerne	0.75	0.85	0.80	0.70	0.60	0.50	0.45	0.50	0.50	0.70	0.80	0.80	0.90
S Pastur	0.75	0.60	0.80	0.60	0.50	0	0	0	0	0	0.30	0.40	0.50
W Cereals	0.65	0	0	-0.40	0.40	0.50	0.80	1.00	1.00	0.80	0.50	0	0
Wheat	0.70	0	0	0.01	-0.01	0.40	0.60	0.90	1.10	0.90	0.50	0.20	0
W Pastur	0.65	0	0	-0.50	0.50	0.80	0.80	0.80	0.85	0.90	0.95	0.70	0
OilSeed	0.70	0.60	0.80	1.10	0.90	0	0	0	0	0	0	0.30	0.5

*Upper Lachlan includes some of the crops (such as Cotton) which are not listed separately under Lower Lachlan and JWPD

Table B.5: Tributary utilisation factors

Dam	Tributary utilisation
Wyangala orders	100% Borrowa River 100% Belubula River 50% Back Creek
Carcoar orders	30% Combing Ck 30% Flyers Ck

Table B.6 Adopted average flow surplus thresholds for OFA announcement

River reaches using those OFA thresholds	Flow (surplus) thresholds in ML/d											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wyangala-Nanami	400	300	300	500	500	200	300	300	300	400	400	400
Nanami-Jemalong	500	500	500	500	300	300	100	100	100	500	300	300
Jemalong-Island Creek	700	700	700	700	600	600	50	100	150	700	700	900
Island Creek-Oxley	500	500	500	500	500	500	50	100	150	300	400	600
Belubula	300	300	300	300	300	300	300	300	300	300	300	300

Appendix C. Modelling the Planting Decision

C.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 "Irrigators' Planting Risk") 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.

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 the following relationship:

Total Area = Current Water Available / Irrigators' Planting Risk

Limited to a maximum and minimum planted area, where:

Current Water Available = Current Announced Allocation * Licensed Entitlement + Water in Storage on Farm + Carryover water (from last season)

Irrigators' Planting Risk = An "apparent application rate" based on the Total Area and the Current Water Available at the planting decision date. This apparent application rate will reflect a number of influences including: the actual crop water requirements, expectations that the irrigators may have in regard to further increases in announced allocation, future access to off-allocation, rainfall on the crop during the growing season and a range of economic considerations.

An irrigator's planting decision is generally regarded as being specific to a particular model scenario (eg 1993/94 development), and is calibrated 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) not specifically addressed within IQQM will remain constant. The further away from the chosen scenario period the data used to base the IQQM planting decision, the less likely the assumption regarding stability with regard to the external influences is to remain true.

The mix of crop types that make up the total area and their relative portion of the total area are specified as input for a given simulation and remain unchanged for the entire simulation period.

C.2. CALIBRATION

As mentioned above, the area planting decision in IQQM can be performed separately for both the summer and winter crops. When calibrating the planting decision module, parameters derived in earlier calibration stages are used, while off-allocation extractions are forced to observed data. The main objective of this calibration stage is to generate the observed planted areas (DLWC, 1998[d]) over a period of time that is appropriate for the scenario in which it will be used. Consequently, the planting decision is intended to be calibrated such that it is appropriate for each scenario run.

There are several important factors that need to be considered in this process, including:

- The effects of growth in utilisation of entitlement;
- Changes to the crop mix;
- 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.

C.3. IRRIGATORS' PLANTING RISK

As resources are constrained due to climatic variability, they would respond by planting smaller areas based on an apparent (or planned) application rate. This application rate (or "Irrigators' Planting Risk") would represent a number of influences not specifically modelled within IQQM. Clearly, the major factor is resource availability, and it is upon this variable that IQQM makes its planting decision. Each grouping of irrigation is separately configured to plant area using the apparent application rate that provides the best calibration with observed data.

C.4. MAXIMUM AREA

The maximum planted area specified is planted in IQQM every time there are sufficient resources available to do so. In practice, it is observed that this is not the case and that 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 date. To best represent this variation, the average maximum area for the entire valley over the calibration period is used.

This maximum planted area was disaggregated to the irrigation nodes based on the maximum observed planted area in that irrigation node up to the 1989/90 irrigation season, with a sanity check based on the maximum area that each could plant given their licence and on-farm storage volumes and approximate application rates.

C.5. MINIMUM AREA

The concept of a minimum planted area is based on the notion that, at some point of severe resource constraint, irrigators will 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.

For those valleys where extreme shortages of available resource have been observed over several seasons, the apparent risk taken by irrigators' has shown significant variation. It seems likely that, in the first season of extreme resource constraint, irrigators' will take a significantly higher risk than in subsequent seasons of drought.

Similarly to maximum areas, to represent such variability in the minimum areas planted by irrigators in drought conditions, an average minimum instead of absolute minimum observed area is used in IQQM.

This planted area was distributed to the irrigation nodes that have access to on-farm storages and was disaggregated based on the ratio of their licence volumes.

Where no season of appropriately low resource availability has been observed, it is assumed that the minimum area should at least be equivalent to the identified perennial cropping.

C.6. EFFECTS OF TEMPORARY TRADE

Currently IQQM is not capable of modelling the temporary trade activities of irrigators explicitly. However, 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. To ensure that irrigation groups within IQQM are not artificially constrained to plant less than their maximum area due to the lack of trade representation within IQQM, appropriate adjustments to irrigation group entitlements are made. These adjustments reflect the degree of temporary trade occurring.

Where there is significant under-utilisation and there have not been any observed years in the calibration period of significant resource constraint, the level of transfers that would appear to be necessary to support observed crop areas in certain irrigation groups may not have occurred. However, if the transfer market exists and is being used, it is logical to assume that "spare" water will be traded in resource constrained years in an attempt to maintain the observed crop areas where possible.

A consequence of manually adjusting entitlement levels between irrigation groups to represent temporary trade is that, when resources become sufficiently constrained, the irrigation group with a manually reduced entitlement will be artificially constrained, while the group with increased entitlement will be artificially high. The result will be that the planted areas and hence diversions will be skewed, and consequently distort the flow distribution. However, the effect on total diversions is expected to be minimal as long as *(a)* there are few periods of such extreme resource constraint, or *(b)* the degree of entitlement adjustment is small.

The definition of “spare” or unused water should be based on entitlement over and above that needed to meet the observed crop area requirements at that irrigation group under drought conditions. Summaries of temporary trade within the valley indicate that only a small percentage of the total valley entitlement was traded annually during the calibration period. This volume was considered too small to warrant adjustment of entitlements for the various irrigation nodes.

C.7. RANGE OF OBSERVED BEHAVIOUR / SENSITIVITY ANALYSES

In many cases there may not be sufficient observed behaviour across all levels of water availability to satisfactorily calibrate the resource availability – planted area relationship, especially for behaviour under various levels of resource constraint.

Where there is no observed behaviour under resource constrained conditions during the calibration period an assumed relationship needs to be adopted. This may be based on other similar areas where appropriate observed behaviour is available, or based on observed behaviour outside the calibration period. If there are no similar areas or periods outside the calibration period from which to base resource constrained behaviour, then an assumption of “risk” is required.

A sensitivity analysis of adopted resource availability – planted area relationships is an important indicator of the likely impact of incorrect assumptions being made, and for what purposes the final model scenario is considered valid. A number of relationships considered to represent the likely range of variability should be trialed to determine the sensitivity of the desired output from the model scenario. Use of the model scenario to provide long-term statistics may be relatively insensitive to the adopted relationship at the lower resource availability levels.

Whenever the observed behaviour is adopted from other areas or periods outside the calibration period, the assumptions regarding climatic, economic and social influences not modelled within IQQM remaining the same becomes less likely to be true. If the sensitivity analysis indicates that the desired output from the model scenario in question is sensitive to the adopted relationship at lower resource availabilities, then it may be necessary to investigate more closely whether the assumption that influences not modelled within IQQM (mentioned previously) are similar is appropriate.

Appendix D. Quality Assessment Guidelines

This Appendix describes the latest draft practice notes for assessing the quality of model calibration or validation – as outlined in Section 1.6.

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

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

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

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

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

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

There is a further variation of this indicator used to assess the apparent error associated with storage volume time series, call the *coefficient of mean absolute storage drawdown deviation* as described below:

```
CMASDD   =  ∑Absolute value(SMDS-OMDS) / (Max Observed Drawdown * No months)     %

Where    SMDS =  Simulated monthly change in storage volume
         OMDS =  Observed monthly change in storage volume
```

To define an overall model confidence, the quality of the observed data needs to be considered. However, as noted at the end of Chapter 1, objective means of determining measurement uncertainty and climatic representativeness are not readily available. In the interim period prior to such means being developed, these guidelines have incorporated the effects of these two sources of uncertainty by:

- Using record length as a surrogate for climatic representativeness;
- Formulating quality rating tolerance bands relevant to the known greater or lesser measurement uncertainty of the observed data. As an example planted area uncertainty's moderate confidence rating is for simulated areas within ±15% of observed, whereas to achieved the

same confidence rating in diversion replication a match to within ±10% must be achieved – indicating the greater inherent measurement uncertainty allowed for in the planted area data.

D.1. FLOW CALIBRATION QUALITY INDICATORS AND RATINGS

Set out below are the latest draft practice notes for assessing the quality of model calibration or validation achieved – as outlined at the end of Chapter 1.

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

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

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

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

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

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

There is a further variation of this indicator used to assess the apparent error associated with storage volume time series, call the *coefficient of mean absolute storage drawdown deviation* as described below:

```
CMASDD   =  ∑Absolute value(SMDS-OMDS) / (Max Observed Drawdown * No months)      %

Where    SMDS= Simulated monthly change in storage volume
         OMDS= Observed monthly change in storage volume
```

Table D.1: Comparing actual gauged with model simulated flows over a period

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

Notes:-

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

D.2. STORAGE CALIBRATION QUALITY INDICATORS AND RATINGS

Table D.2: Comparing actual gauged with model simulated storage over a period

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT (see note 2)*		*QUALITY RATING GUIDELINES (see note 1)*
		Definition	*Apparent Error (AE)*	
STORAGE VOLUME REPLICATION (time series of storage volumes)	Storage volume time series CMASDD	CMASDD – Coefficient of Mean Absolute Storage Drawdown Deviation	AE = CMASDD (see note 3)	Very High: AE within ±2% High: AE within ±5% Moderate: AE within ±8% Low: AE within ±10% Very Low: AE within ±15%

Notes:-
1. Where range specifications are not mutually exclusive, the range conforming to the maximum quality rating should be adopted
2. Unless explicitly stated, all indicator values should be calculated in absolute value terms
3. CMAAD = 100* ∑Absolute value(SMDS – OMDS) / (Observed maximum drawdown*Number of months)

D.3. DIVERSION CALIBRATION QUALITY INDICATORS AND RATINGS

Table D.3: Comparing actual gauged with model simulated diversions over a period

(applicable for ONA, OFA and TOTAL diversions)

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT (see note 2)*		*QUALITY RATING GUIDELINES (see note 1)*
		Definition	*Apparent Error (AE)*	
Whole of Valley , and irrigator groups	VOLUME RATIO "vr" based on Total period diversion Where "vr" = 100 * (Simulated / Observed) Expressed as a %	ONA total	AE = ("vr" – 100)	Very High: AE within ±2% High: AE within ±5% Moderate: AE within ±15% Low: AE within ±30% Very Low: AE within ±40%
		OFA total	AE = ("vr" – 100)	Very High: AE within ±3% High: AE within ±7% Moderate: AE within ±20% Low: AE within ±35% Very Low: AE within ±50%
		Total Diversions	AE = ("vr" – 100)	Very High: AE within ±2% High: AE within ±5% Moderate: AE within ±15% Low: AE within ±30% Very Low: AE within ±40%
	Annual diversion time series comparison (ONA, OFA and Total): CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD (see note 3)	Very High: AE within 10% High: AE within 15% Moderate: AE within 20% Low: AE within 25% Very Low: AE within 30%

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

D.4. PLANTED CROP AREA CALIBRATION QUALITY INDICATORS AND RATINGS

Table D.4: Comparing actual recorded with model simulated planted crop areas

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT (see note 2)*		*QUALITY RATING GUIDELINES (see note 1)*
		Definition	*Apparent Error (AE)*	
Whole of Valley, and irrigator groups	AREA RATIO Whole period total area ratio (ar): Where “ar” = 100 * (Simulated / Observed)	Overall % (ar)	AE = (“ar” – 100)	Very High: AE within ±3% High: AE within ±7% Moderate: AE within ±20% Low: AE within ±35% Very Low: AE within ±50%
	Annual cropped area time series comparison CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD (see note 3)	Very High: AE within 15% High: AE within 20% Moderate: AE within 25% Low: AE within 30% Very Low: AE within 35%

Notes:-

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

D.5. REPRESENTATIVENESS OF CALIBRATION PERIOD

As noted in Chapter 1, the observed data quality should ideally be based on a combination of measurement uncertainty of the data, and the representativeness of the calibration period. At this stage, however, only record length is readily available, as an indicator of climatic representativeness, as presented in Table D.5.

Table D.5: Climatic representativeness classification guideline

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

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

D.6. OVERALL MODEL QUALITY RATING

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

1) Total diversion for the valley (Volume ratio and CMAAD)

2) End of system flows (Volume ratio and CMAAD)
3) Combined storage behaviour (CMASDD)
4) Key gauge site (Mid range volume ratio and CMAAD)

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

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

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

The transformation is carried out as follows:

SI = (I-LL)*(SU-SL)/(UL-LL) + SL

Where SI = Standardised indicator

I = Indicator for selected criteria

UL = Upper limit of the confidence band that I lies between

LL = Lower limit of the confidence band that I lies between

SU = Standardised upper confidence limit of equivalent indicator confidence limit

SL = Standardised lower confidence limit of equivalent indicator confidence limit

To obtain an overall quality indicator (OI) each of the eight indicators are standardised and averaged (AI). That is, AI = ∑ SI,s / 8. This average quality indicator is then adjusted for climatic representativeness of the calibration period on the following basis:

$OI = AI * 3.0 * NY^{-0.65}$

Where OI = Overall quality indicator

AI = Average standardise quality indicator

NY = Number of years model is calibrated over

The adjustment for climatic representativeness 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. However, it should be noted that calibration period length is a surrogate for climatic representativeness, and that if this period does not contain dry and wet periods then this adjustment may not be appropriate.

The overall quality indicator gives an indication of what the model may be used for.

- **“OI” quality of high to very high**: can be used for detailed concept design new weirs or storage structures, or to design modifications to existing structures, or to determine CAP conformance for a particular year.
- **“OI” quality of low to moderate**: useful for comparing alternative improvement options or development scenario impacts, eg for Hydro-power feasibility studies, and for long term CAP determination.
- **“OI” quality of very low** indicates that the model requires further calibration before it can be relied upon.

Appendix E. MDBMC Cap Development Conditions and Management Rules

Table E.1: 1993/94 Infrastructure & Development Parameters

ITEMS	DESCRIPTION	COMMENTS
GENERAL		
Simulation Period	1 July 1898 to 30 June 2001	
CATCHMENT INFORMATION		
Storages modelled	Carcoar, Wyangala, Lake Cargelligo, Lake Brewster and Brewster Weir	
Storage Volumes *(ML)*	Dead Storage / Capacity	
Wyangala	1000 / 1217,000	
Carcoar	200 / 36,000	
Lake Cargelligo	17,000 / 60,000	
Lake Brewster	18,000 / 155,000	
Brewster Weir	0 / 5,500	
FLOW INFORMATION		
Storage Inflows *(GL/yr)*	Wyangala:784 GL Carcoar: 18 GL Lake Cargelligo: Filled using surplus flow and kept at 23 GL in dry year by ordering water from Wyangala Lake Brewster: Filled using surplus flows	Average over simulation period
Lateral inflows *(GL/yr)*	Lachlan River 530 GL(1) Belubula River 217 GL(1)	(1)Tributaries and ungauged residuals
IRRIGATION INFORMATION		
General Security (GS) licence volume *(GL)*	Lachlan 619 Belubula 24 Total 643	
High Security (HS) licence volume *(GL)*	Lachlan 23 Belubula 1 Total 24	
Maximum irrigable area *(Ha)*	Lachlan 78,710 Belubula 1,890 Total 80,600	
On-farm storage	Nil	

capacity *(GL)*		
Pump capacity *(ML/d)*	33 GL	
Active licence factor *(%)*	Lachlan: Fully developed [2] Belubula: 40% developed [3]	[2]Assumed that water trading will utilise all the sleeper licenses (re-distribution of licenses). [3]No re-distribution of licenses in Belubula.
Irrigators' carry over *(%)*	Nil	
On-farm storage operation	Flood plain harvesting Nil End-of-year diversions Nil	.
Average crop mix *(%)*	See Table 4.1	
OTHER EXTRACTIONS		
Town water supply *(ML/yr)*	Cowra 4,200 Forbes 4,100 Condobolin 1,200 Willandra 200 Hillston 200 Booligal 100 **TOTAL 10,000**	Modelled as fixed pattern of monthly usage each year
Stock & domestic *(ML/yr)*	Belubula 200 Booberoi-Cargelligo 1,500 Cargelligo-Brewster 960 Willandra-Hillston 2,670 Hillston-Booligal 4,000 **TOTAL 9,330**	Modelled as fixed pattern of monthly usage each year
Industrial / mining *(ML/yr)*	Not modelled	
Groundwater access *(ML/yr)*	Not modelled	
RESOURCE ASSESSMENT		
Storage Reserve *(GL)*	Wyangala 201 Carcoar 8	Max. @ start of water year
Transmission / operation loss *(GL)*	Wyangala 194 Carcoar 6 **TOTAL 200**	@ 100% allocation

Minimum storage inflows *(ML)*	Wyangala 38,400 Carcoar 1,600	Max. @ start of water year
Minimum tributary inflows *(ML)*	d/s Wyangala tribs. 12,750 d/s Carcoar tribs. 1,966	Max. @ start of water year
System development factor *(%)*	Lachlan River: Fully developed(4) Belubula River: 40% developed	(4)All sleepers traded only in Lachlan
Maximum allocation *(%)*	120	
RIVER AND STORAGE OPERATING RULES		
Transfer rules (Lake Cargelligo and Lake Brewster)	Drawdown Lake Brewster to 29 GL first and then send order through Brewster Weir	
Tributary recession factors *(%)*	Wyangala orders: Borrowa R 100 Belubula R 100 Back Ck 50 Carcoar orders: Combing Ck 30 Flyers Ck 30	
Over order allowances *(%)*	All reaches 0	
Off-allocation Cap *(GL/yr)*	Nil	
SURPLUS FLOW ACCESS		
Off-allocation thresholds	See Table B.6.	
RIVER FLOW REQUIREMENTS		
Minimum flow requirements *(ML/d)*	D/s Wyangala 70 Belubula @ Bangaroo 10 d/s Cargelligo 15 d/s Brewster Weir 20 Lachlan @ Booligal 160 Hillston Oct-Mar 200 Apr 400	
Wetlands		

Appendix F. Historical Water Diversions

The DLWC have used a number of database systems over the years to manage water diversion data and there are a number of sets of historical diversion data in existence for certain periods. When the Lachlan model was calibrated a review was undertaken and what was believed to be the final set of diversion data obtained. Since that time a number of data review processes have been undertaken to better identify the data. The following table details the water diversion data used in the model calibration and the latest available.

Table F.1: Annual Water Diversions

Year	Water Diversion data used in calibration (GL)	Latest Diversion details (GL)	Difference
1983/84	114.0	115.1	-1.1
1984/85	217.0	217.5	-0.5
1985/86	305.0	304.8	0.2
1986/87	294.0	294.2	-0.2
1987/88	345.0	345.6	-0.6
1988/89	205.0	205.5	-0.5
1989/90	328.0	327.1	0.9
1990/91	329.0	329.4	-0.4
1991/92	366.0	365.7	0.3
1992/93	258.0	258.7	-0.7
1993/94	282.0	283.0	-1.0
1994/95	432.0	433.6	-1.6
1995/96	396.0	384.3	11.7
1996/97	436.0	442.8	-6.8
1997/98	414.0	413.6	0.4
1998/99	282.0	277.9	4.1
1999/00	285.0	285.3	-0.3
Average	311.1	310.8	0.2

The model was calibrated over the 1992/93 to 1997/98 period and validated over the 1983/84 to 1997/98 period. The total volumetric error in modelled diversions over the calibration period was about 2%, and the total discrepancies indicated above are well within this volume. It is considered that the differences outlined in the above table would have little to no impact on the model calibration.