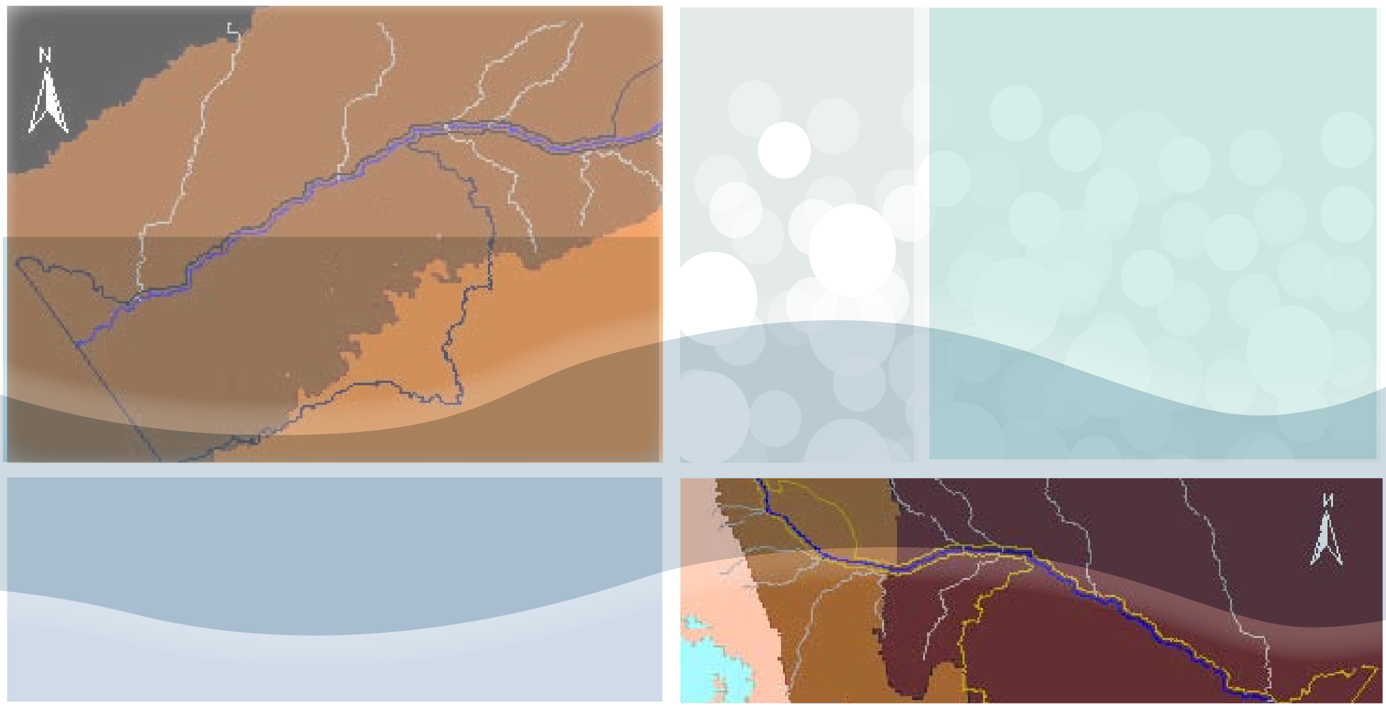
Instream salinity models of NSW tributaries in the Murray-Darling Basin

Volume 7 – Barwon-Darling River Salinity Integrated Quantity and Quality Model



NSW Government
Department of Water & Energy

Publisher

NSW Department of Water and Energy
Level 17, 227 Elizabeth Street
GPO Box 3889
Sydney NSW 2001

T 02 8281 7777 **F** 02 8281 7799

information@dwe.nsw.gov.au

www.dwe.nsw.gov.au

Instream salinity models of NSW tributaries in the Murray-Darling Basin Volume 7 – Barwon-Darling River Salinity Integrated Quantity and Quality Model

April 2008

ISBN (volume 2) 978 0 7347 5990 0

ISBN (set) 978 0 7347 5994 8

Volumes in this set:

In-stream Salinity Models of NSW Tributaries in the Murray Darling Basin

- Volume 1 – Border Rivers Salinity Integrated Quantity and Quality Model
- Volume 2 – Gwydir River Salinity Integrated Quantity and Quality Model
- Volume 3 – Namoi River Salinity Integrated Quantity and Quality Model
- Volume 4 – Macquarie River Salinity Integrated Quantity and Quality Model
- Volume 5 – Lachlan River Salinity Integrated Quantity and Quality Model
- Volume 6 – Murrumbidgee River Salinity Integrated Quantity and Quality Model
- Volume 7 – Barwon-Darling River System Salinity Integrated Quantity and Quality Model

Acknowledgements

Technical work and reporting by Harry He, Perlita Arranz, Juli Boddy, Raj Rajendran, Richard Cooke and Richard Beecham.

This publication may be cited as:

Department of Water and Energy, 2008. *Instream salinity models of NSW tributaries in the Murray-Darling Basin: Volume 7 – Barwon-Darling River Salinity Integrated Quantity and Quality Model*, NSW Government.

© State of New South Wales through the Department of Water and Energy, 2008

This work may be freely reproduced and distributed for most purposes, however some restrictions apply. Contact the Department of Water and Energy for copyright information.

Disclaimer: While every reasonable effort has been made to ensure that this document is correct at the time of publication, the State of New South Wales, its agents and employees, disclaim any and all liability to any person in respect of anything or the consequences of anything done or omitted to be done in reliance upon the whole or any part of this document.

DWE 07_089_7

Contents

Page

Figures

Page

Tables

Page

1. Introduction

1.1. PURPOSE OF REPORT

The purpose of this report is to document the results of work carried out to develop a Barwon Darling River Salt Transport Model. This model was developed to meet the needs of the Murray-Darling Basin Salinity Management Strategy (Basin Strategy – BSMS see Section 1.3.3.1) and the NSW Salinity Strategy (SSS). This report is intended primarily for an audience with a technical and/or policy background concerned with salinity management

The model substantially increases the salinity modelling capability by NSW for salinity management in the Murray-Darling Basin (MDB), and represents the best available interpretation of salinity processes in these NSW Rivers. The geographic scope of the work is extensive, covering an area of about 600,000 km^2. The model can assess in-stream effects of water sharing policies, as well as working jointly with the 2CSalt model to assess in-stream salinity and water availability effects of land use and management. These effects can be assessed at a daily time scale for a 25-year period at key locations within the Barwon Darling River Basin. The model can also link with other models to assess effects at key locations in the Darling River and/or Murray River.

1.1.1. Report structure

This modelling has taken place against a historical background of basinwide salinity management, which is discussed in Section 1.2. A number of basinwide and statewide natural resource management policies are relevant to salinity management and the need for this model. The modelling requirements are clearly set out in Schedule C of the Murray Darling Basin Agreement. The policies are discussed in Section 1.3, with a focus on Schedule C in Section 1.3.3. This model is one of a suite of models and decision support systems that have been developed for salinity management, and this is discussed in Section 1.4. The steps taken to develop this model are discussed in the final section of this chapter.

The processes affecting salinity behaviour in a catchment are influenced by many physical factors, and the most important of these are described in Chapter 1. Whereas the actual salinity behaviour is best described by data, and the data available to characterise this behaviour is described in Chapter 3. The salt transport model was developed using a daily water balance model as the platform. The Barwon Darling Integrated Quantity Quality Model (IQQM) has been used for water resource management for several years in the NSW, and was converted to the salt transport model in this project. The software used for the model was thoroughly tested and enhanced to eliminate any technical faults. The Barwon Darling IQQM and software testing is described in Chapter 0.

Estimating salt loads entering the river system is the key task to develop a model that will reliably estimate in-stream salinity behaviour so that it is suitable for the intended purpose. The results of existing and calibrated estimates are documented in Chapter 5. The calibrated model is intended to be used evaluate scenarios, the most important of which is a baseline condition (described in Section 1.3.3), as well as impacts of changing land use, management, and water sharing. The results for the baseline condition are reported and discussed in Chapter 6. The development of models for salinity management is a comparatively new field of work in the MDB, when compared to water balance modelling. The Schedule C foresees the need to improve estimates in light of both limitations of the current work, additional data, and improved technical capability of the scientific organisations. An assessment of the limitations of the model, and some recommendations for future improvement are discussed in Chapter 7.

1.1.2. Related reports

This report is one of seven similar reports for each of the major NSW tributaries of the MDB. The reports are:

- Volume 1 - Border Rivers (jointly with Queensland);
- Volume 2 - Gwydir River;
- Volume 3 - Namoi and Peel Rivers;
- Volume 4 - Macquarie, Castlereagh and Bogan Rivers;
- Volume 5 - Lachlan River;
- Volume 6 - Murrumbidgee River; and
- Volume 7 - Barwon-Darling River.

Each tributary report is complete and self-explanatory, describing what was done for each stage of model development. However, these descriptions have been kept brief to ensure the report content is more focused on information and results specific to that tributary. Note that this report primarily summarizes the modeling work undertaken prior to 2005.

1.2. HISTORICAL BACKGROUND TO WORK

Modelling in-stream salinity has a history extending to before the development of the Murray-Darling Basin Commission (MDBC) 1988 Salinity and Drainage Strategy, which focused on irrigation induced salinity. The complexity and scope of modelling of dryland salinisation processes has evolved in line with the needs of natural resource management. With the concerns about dryland salinity came additional water quality data to provide evidence of the salinity trends. The increased data led to broad policy and greater demands on models to provide useful results to guide the cost effective selection of salinity management options. The following sections give a brief history of the development of salinity policy and its implications on the development of salinity modelling.

1.2.1. 1988 Salinity and Drainage Strategy

The Murray Darling Basin Ministerial Council (MDBMC) adopted the Salinity and Drainage Strategy (SDS) in 1988. The objectives of the strategy revolved around:

- improving the water quality in the Murray River for the benefit of all users;
- controlling existing land degradation, prevent further degradation and where possible rehabilitate resources to ensure sustainable use; and
- conserving the natural environment.

The SDS set out specific salinity reduction targets against benchmark conditions. The strategy also defined the rights and responsibilities of the State and Commonwealth Governments. Implementation included applying the strategic direction and allocating salinity credits and construction of various projects (under cost sharing arrangements). The salinity assessment work required a combination of observed salinity data and in stream river modelling. Assessments of salinity impacts were at a local or semi-regional scale, eg. Beecham and Arranz (2001), and the results from these were assessed by the MDBC for salinity impact in the Murray River.

The 1999 SDS review identified major achievements of the SDS as: (i) reducing salt entering the Murray River by constructing salt interception scheme; and (ii) developing land, water and salt management plans to identify and manage the problems.

1.2.2. 1997 Salt trends

Concerns about the increase in the extent of dryland salinisation prompted an assessment of water quality data to look for evidence of a corresponding increase in in-stream salinities. The resultant Salt Trends study (Jolly et al., 1997) reported increasing trends in Electrical Conductivity (EC) over time in major and minor tributaries of the MDB.

The factors controlling salt mobilisation were identified and included a wide range of processes including climatic distribution, groundwater hydrology and chemistry, landuse, surface water hydrology and chemistry, geology, topography, soil characteristics and land degradation. The study recommended a broad range of activities be undertaken to better understand the dry land salinisation processes.

1.2.3. 1999 Salinity Audit

The awareness from studies such as Salt Trends highlighted that instream impacts of dryland salinisation were greater than first though prior to development of the SDS. This prompted further investigations to provide information on the possible future magnitude of increased instream salinity. To this end, the MDBC coordinated a Salinity Audit of the whole MDB (MDBC, 1999). The Salinity Audit was intended to establish trend in salt mobilisation in the landscape, and corresponding changes in in-stream salinities for all major tributaries, made on the basis that there were not going to be any changes in management.

The methods adopted by NSW (Beale et al., 1999) to produce these outputs linked statistical estimates of flow and salt load in tributaries of the MDB, with rates of groundwater rise in their catchments. The results of this study indicated that salinity levels in the NSW tributaries of the MDB would significantly increase over the next 20-100 years, with major associated economic and environmental costs.

The results of the Salinity Audit resulted in the MDBMC and NSW Government developing strategies to manage salinity. These are reported in Sections 1.3.3 and 1.3.6 respectively.

1.2.4. 2006 Salinity Audit

Additional biophysical data has recently been analysed which confirm the actual extent of salinity outbreaks and current status of in-stream salinity. However, these studies have also cast serious doubt on trends predicted using rising groundwater extrapolations (DECC 2006). A concerted effort to improve understanding of the extent of salinity, and its relationship with climatic regime and groundwater behaviour in the hydrological cycle in different contexts, has shown inconsistencies with the general regional rising water tables theory (Summerell et al. 2005).

In particular, the new work indicates that climate regime so dominates that it is difficult to detect the impacts of land-use or management interventions, and that response times between recharge and discharge, especially in the local-scale fractured rock aquifer systems that dominate in the tablelands and slopes of eastern NSW, are much shorter than previously thought. This leads to the conclusion that the impacts of clearing on groundwater levels have already been incurred, so no continuing effect can be attributed to this cause. Many (not all) of the NSW MDB subcatchments are in a state of 'dynamic equilibrium', and their groundwater levels fluctuate about a new average value in response to climate regime (long periods of above or below average rainfall) (DECC, 2007).

1.3. CURRENT POLICY FRAMEWORK

A range of natural resource polices provide reasons for developing the salt transport models. These include basinwide policies developed through the MDBC, and Statewide policies developed through the NSW Government. The interrelationship of the key policies to this work are shown in Figure 1.1.

1.3.1. MDBC Integrated Catchment Management

Integrated Catchment Management (ICM) is the process by which MDBC seeks to meet its charter to:

> "…promote and coordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray–Darling Basin." (MDBC, 2001)

The ICM process requires that stakeholders consider the effect on all people within the catchment of their decisions on how they use land, water and other environmental resources. The process uses management systems and strategies to meet targets for water sharing and water quality. Two strategies that fall under ICM are described in Section 1.3.2 and Section 1.3.3.

1.3.2. Murray-Darling Basin Ministerial Council Cap on water diversions

In 1997 the MDBMC implemented a cap on water diversions ("The Cap") in the MDB. The Cap was developed in response to continuing growth of water diversions and declining river health, and was the first step towards striking a balance between consumptive and instream users in the Basin. The Cap limits diversions to that which would have occurred under 1993/4 levels of:

- irrigation and infrastructure development;
- water sharing policy; and
- river operations and management.

1.3.3. Murray-Darling Basin Ministerial Council Basin Salinity Management Strategy

The MDBMC responded to the salinity problems predicted in the Salinity Audit with the Basin Salinity Management Strategy (BSMS). The objectives of the strategy are:

- maintain the water quality of the shared water resources of the Murray and Darling Rivers;
- control the rise in salt loads in all tributaries of the basin;
- control land degradation; and
- maximise net benefits from salinity control across the Basin.

These BSMS is implementing nine elements of strategic action, including:

- capacity building;
- identify values and assets at risk;
- setting salinity targets;
- managing trade-offs;
- salinity and catchment management plans,
- redesigning farming systems;
- targeting reforestation and vegetation management;
- constructing salt interception works; and
- ensuring Basin-wide accountability by monitoring, evaluating and reporting.

The last of these is particularly relevant to this work. The statutory requirements for the BSMS are specified in Schedule C of the Murray-Darling Basin Agreement, replacing those parts that previously referred to the 1988 SDS. The key parts of Schedule C that relate to the modelling work are discussed in the following subsection.

1.3.3.1. Schedule C of the Murray-Darling Basin Agreement

Clauses 5(2), 5(3), 37(1) and 36(1)(a) of Schedule C dictate that the MDBC and the Contracting States must prepare estimates of baseline conditions flow, salt load, and salinity for the benchmark period at the end-of-valley target site for each of the major tributaries by 31 March 2004. These estimates must be approved by a suitably qualified panel appointed by the MDBC.

The baseline conditions refers to the physical and management status of the catchment as of 1 January 2000, specifically:

- land use (level of development in landscape);
- water use (level of diversions from the rivers);
- land and water management policies and practices;
- river operation regimes;
- salt interception schemes;
- run-off generation and salt mobilisation; and
- groundwater status and condition.

The benchmark climatic period refers to the 1 May 1975-30 April 2000 climate sequence; ie., rainfall and potential evapotranspiration.

Part VIII of Schedule C refers specifically to models, and sets out the performance criteria for the models. The models must be able to:

(i) Simulate under Baseline Conditions, the daily salinity, salt load and flow regime at nominated sites for the Benchmark Climatic period.

(ii) Predict the effect of all accountable Actions and delayed salinity impacts on salinity, salt load and flow at each of these nominated sites for each of 2015, 2050, and 2100,

These model capabilities must be approved by a suitably qualified panel appointed by the MDBC. There is specific prevision that the models are reviewed by the end of 2004, and at seven-yearly intervals thereafter.

1.3.4. Catchment Action Plans

The NSW Government established the Catchment Management Boards Authorities in 2003, whose key roles include developing Catchment Action Plans (CAPs), and managing incentive programs to implement the plans. These are rolling three-year investment strategies and are updated annually.

The CAPs are based on defining investment priorities for natural resource management, and salinity is one aspect that is considered where appropriate. Models can play an important role in identifying where to target investment to achieve the best environmental benefit value for money which supports prioritisation. Models also have a crucial role in monitoring, evaluation and reporting, if only because they provide a means of separating the effects of the management signal from the dominant climate signal. The models bring consistency and rigour to analysis of alternate management options, and help comply with the Standard for Quality Natural Resource Management (NRC, 2005).

1.3.5. NSW Water Sharing Plans

The Water Management Act 2000 aims to provide better ways to equitably share and manage NSW's water resources. Water Sharing Plans are ten year plans that outline how water is to be shared between the environment and water users. These plans cover both surface water and groundwater and both inland and coastal areas and contain both rules for resource access and use.

1.3.6. NSW Salinity Strategy

In 2000, the NSW Government released the NSW Salinity Strategy. The Strategy brought together previously divided approaches into one strategy revolving around salinity targets. The salinity targets enable:

- Quantification of desirable salinity outcomes;
- Management of cumulative impacts of various actions at various sites
- Comparison of the environmental, economic and social benefits and costs for various actions; and
- Choice of the most cost effective action to treat the problem.

The salinity targets were developed and recommended through the Catchment Management Boards. To monitor the salinity targets and to assess the impacts of management options for land use changes on these salinity targets, numerical modelling tools to estimate salt load wash off and salt load transport became high priority. The modelling framework to meet these salinity strategies is described in Section 1.4.

1.3.7. NSW Environmental Services Scheme

In 2002, the NSW Government launched the Environmental Services Scheme (ESS) seeking expressions of interest from landholder groups. The aim was to identify the environmental benefits that could be achieved by changed land use activity and to have them valued by the community. This recognised that good farm management can slow the march of salinity, reduce acid sulfate soil and improve water quality. The scheme provides financial support for some of these activities, and is one of the actions under the NSW Salinity Strategy.

To judge the impacts of the proposed land use changes on end of valley and within valley salinity targets has again put pressure on the need for numerical models that can simulate salt wash off processes and salt transport processes.

1.3.8. CMA Incentive schemes

CMA incentive schemes are used as mechanisms for funding on ground works and measures. As with the ESS, the aim is to buy environmental outcomes rather than output. Models are critical to evaluating the expected outcomes from given outputs. Property Vegetation Plans (PVPs) are evaluated with a Decision Support Tool which uses two salinity models. There is provision for incentive PVPs as well as clearing PVPs and continuing use PVPs.

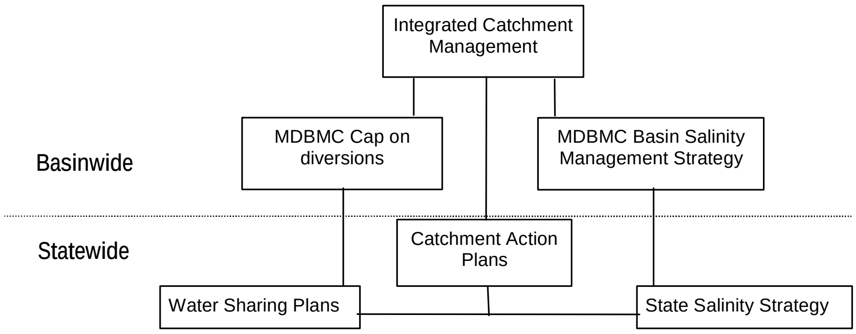


Figure 1.1. Relationship of Basinwide and Statewide policies and plans

1.4. DWE MODEL FRAMEWORK

NSW has developed a framework of models that link the surface water hydrology and salinity processes to support salinity management. A range of processes are represented in models that vary from the property scale to the basin scale. The scale of application of a model, in both spatial sense and temporal sense, influences the model structure and detail. Aspects of natural processes that are important at one scale may not matter at another.

Figure 1.2 shows the linkages between the surface water and salinity models, their application at different scales and the desired outcomes of within valley and end of valley salinity targets.

1.4.1. Objectives of modelling

The primary objective of the modelling is to support the implementation of the CAPs. This requires understanding and appropriate representation of the salt movement in and from the landscape to the streams, and in the streams to the end of valley target locations.

Property scale modelling is required to support decisions on land use change and property investments on-farm. This required modelling of the effect of land use on runoff, salt washoff, and recharge. Decisions at this scale can directly impact on the landholder's income.

Moving from the property scale to catchment and then to basin scale requires the dryland salinisation processes to be modelled together with wash off and groundwater interaction to estimate the water and salt flowing into the river system.

The objectives of the basin modelling are to be able to assess the end of valley salinity levels, and evaluating the performance of salinity management scenarios. To achieve this objective salt needs to be transported down the river, amalgamated with other catchment runoff and salt loads. It is also necessary to deal with such issues as dams and major irrigation developments (eg., Murrumbidgee Irrigation).

Model results for salinity need to be available in both concentrations and total salt loads to meet the needs of the policies. Results for impacts of land use changes on streamflow (runoff yields) are also necessary.

1.4.2. Modelling requirements

The modelling had the following requirements:

- Daily predictions
- Applicable across different scales - local (site, property, farm), landscape, sub-catchment, catchment and basin
- Applicable for all NSW catchments
- Model complexity consistent with available data
- Link to tools to evaluate economics, social impacts, environmental services, cumulative impacts
- Represent land use changes and consequent impacts
- must be able to model water management independently

1.4.3. Strengths and Limitations

The following points detail some of the strengths and weakness of this model framework:

- Only technology available consistent with salinity targets – These models are the best available at present to meet the needs of the policy. As time progresses it is expected advancements with these model will improve the model capabilities and output.
- Complements adaptive management approach in NSW
- State of the art modelling appropriate for the temporal and spatial scales required by State and National policy
- Integrates catchment and instream processes
- Model uncertainty
- Data gaps and data uncertainty
- Error propagation
- Spatial generalisation

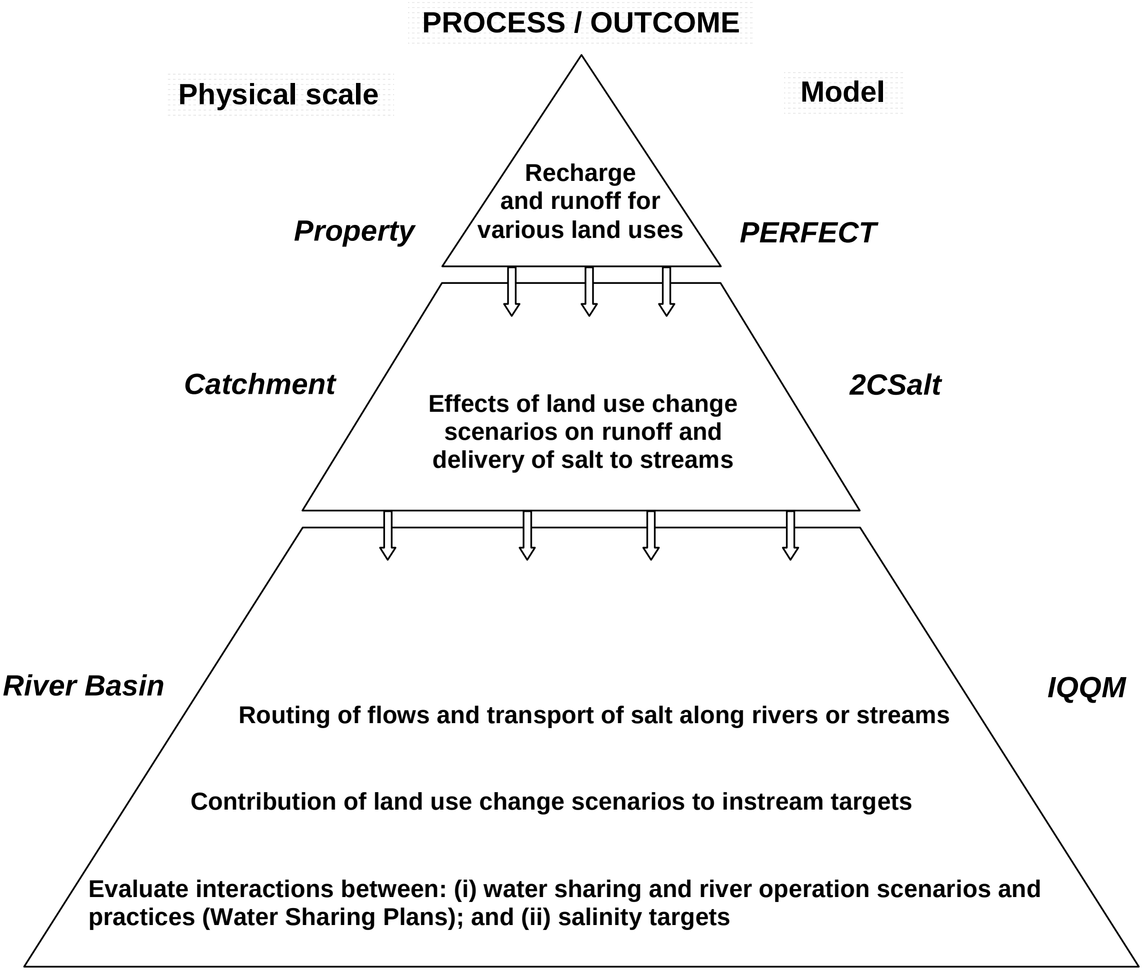


Figure 1.2. Applications and linkages of DECC and DWE models at different scales

1.5. STAGED MODEL DEVELOPMENT

The work reported here was developed in logical stages as shown in Figure 1.3. The tasks in Stage 1 were done in parallel. The initial estimate of salinity behaviour in the river system was done in Stage 2 using the work done for the Salinity Audit (Beale et al., 1999) as the starting point. The results from this task were evaluated in the second task of Stage 2. The first task in Stage 3 was done if the results from the model evaluation were not satisfactory. The final task in model development is running the scenarios. The tasks for all three stages are discussed in more detail in the following subsections.

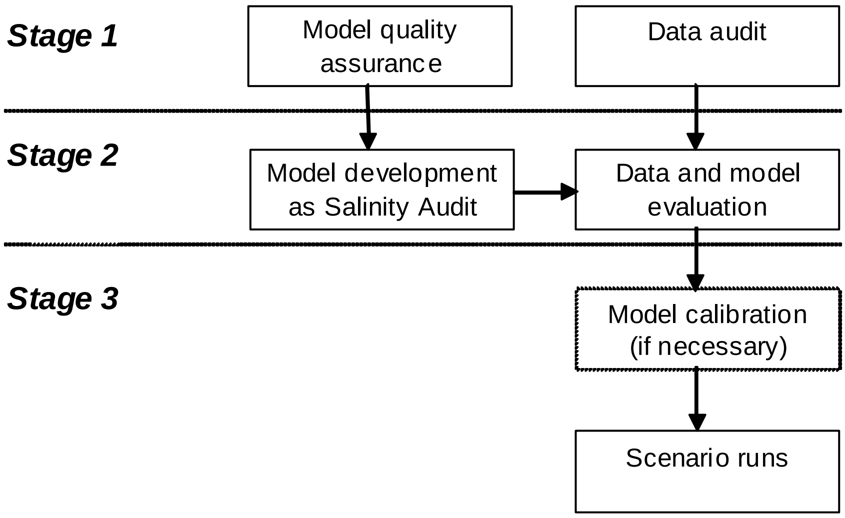


Figure 1.3. Stages of model development

1.5.1. Stage 1: Model QA and Data Audit

The existent IQQM that had been configured and calibrated for the Barwon Darling River system was the starting point for the in-stream salinity model. The software Fortran 90 source code that simulates the salt transport is relatively untested, and therefore there is the possibility that it contains errors. A set of Quality Assurance (QA) tests was done on the software and tributary model to eliminate any software related errors that could confound interpretation of the results.

Representative data is needed to develop and calibrate the model. Records of discrete and continuous Electrical Conductivity (EC) data are stored on DWE data bases. This data was extracted, and an audit of the spatial and temporal characteristics of this data was made. This data was also screened, and some important characteristics analysed. The representativeness of the data was assessed further in Stage 2.

1.5.2. Stage 2: Initial model development and data and model evaluation

This stage was subject to satisfactorily correcting software errors, and completing processing of salinity data. A 'first cut' estimate of salinity was made based on the work done for the Salinity Audit, and evaluated against the processed data. This stage tested the possibility that the prior work would produce satisfactory results when converted to a different modelling environment, and would have had the advantages of minimising to recalibrate the models, and also resulted in consistent outputs with those from the Salinity Audit. As these outputs were used to generate salt targets, this is a desirable outcome. For this reason the similarities and differences between the results are analysed in some depth in Appendix B.

The outputs required from the salt transport model are similar to those required for the Salinity Audit 'current' case as reported in Beale et al., 1999. There are two principal differences in the specifications for the output.

(i) The Baseline Conditions: water sharing policies used to estimate diversions and corresponding river flow were for the 1993/4 levels of development; whereas this work uses 1 January 2000 conditions.

(ii) Benchmark climatic period: was 1 January 1975-31 December 1995; whereas the current benchmark period is 1 May 1975-30 April 2000.

(iii) Time step: monthly were needed for the Salinity Audit, whereas daily are needed for the BSMS.

There are also important differences in the methods used:

(iv) Combining tributary flows and salt loads. The Salinity Audit was done using monthly flows processed in EXCEL spreadsheets, whereas this work uses the IQQM daily simulation model.

(v) Salt balances: The checks to ensure tributary salt loads were consistent with observed data in the mainstream was done using salt loads in the Salinity Audit, whereas this work will be using resultant concentrations.

The results were evaluated by first evaluating how representative the data was, and also by comparing model results with salinity observations at target locations to assess the model's performance. The model evaluation uses objective statistical methods, supported by interpretation and presentation of time series graphs. The statistical methods express measures of confidence in: (i) the ability of the data to represent the system behaviour; and (ii) with what levels of confidence do the model results reproduce the data. These statistical measures were developed to reflect judgements made from traditional visual interpretations of graphs of time series or exceedance plots of the results from simulations compared against observations. The rationale behind this approach is to have a consistent and rigorous way to assess and report results.

1.5.3. Stage 3: Model calibration and scenario modelling

Pending the results of the model evaluation, the inflows to the river system will be revised to better match distributions of salinities at the evaluation points.

The model will then be adjusted to represent various conditions of the river valley. The adjustments would be made to river management operations such as environmental flow rules, irrigation diversion rules. The first scenario will be the *Baseline Conditions* model to represent the flow and salt loads that represent catchment conditions as at 1 January 2000.

2. The Barwon-Darling River System

2.1. PHYSICAL FEATURES OF THE CATCHMENT

2.1.1. General

The Barwon-Darling River is one of the major rivers of the Murray-Darling Basin (Figure 2.1). The Barwon River is formed by the confluence of the Macintyre and Weir Rivers upstream of Mungindi and flows south-west for 600 km to Wilcannia. It then passes through the Menindee Lakes before flowing south to join the Murray River at Wentworth. Between Mungindi and Bourke, it receives water from several major river basins (four of which are covered in Volumes 3 to 6 of this report) but has virtually no catchment area of its own. The area drained by the Barwon-Darling River increases from 49,470 km^2 at Mungindi to 132,200 km^2 at Walgett, 386,000 km^2 at Bourke and 569,800 km^2 at Wilcannia. The area downstream of Wilcannia is not covered in this report as it is modelled by the MDBC as part of the Murray River System model.

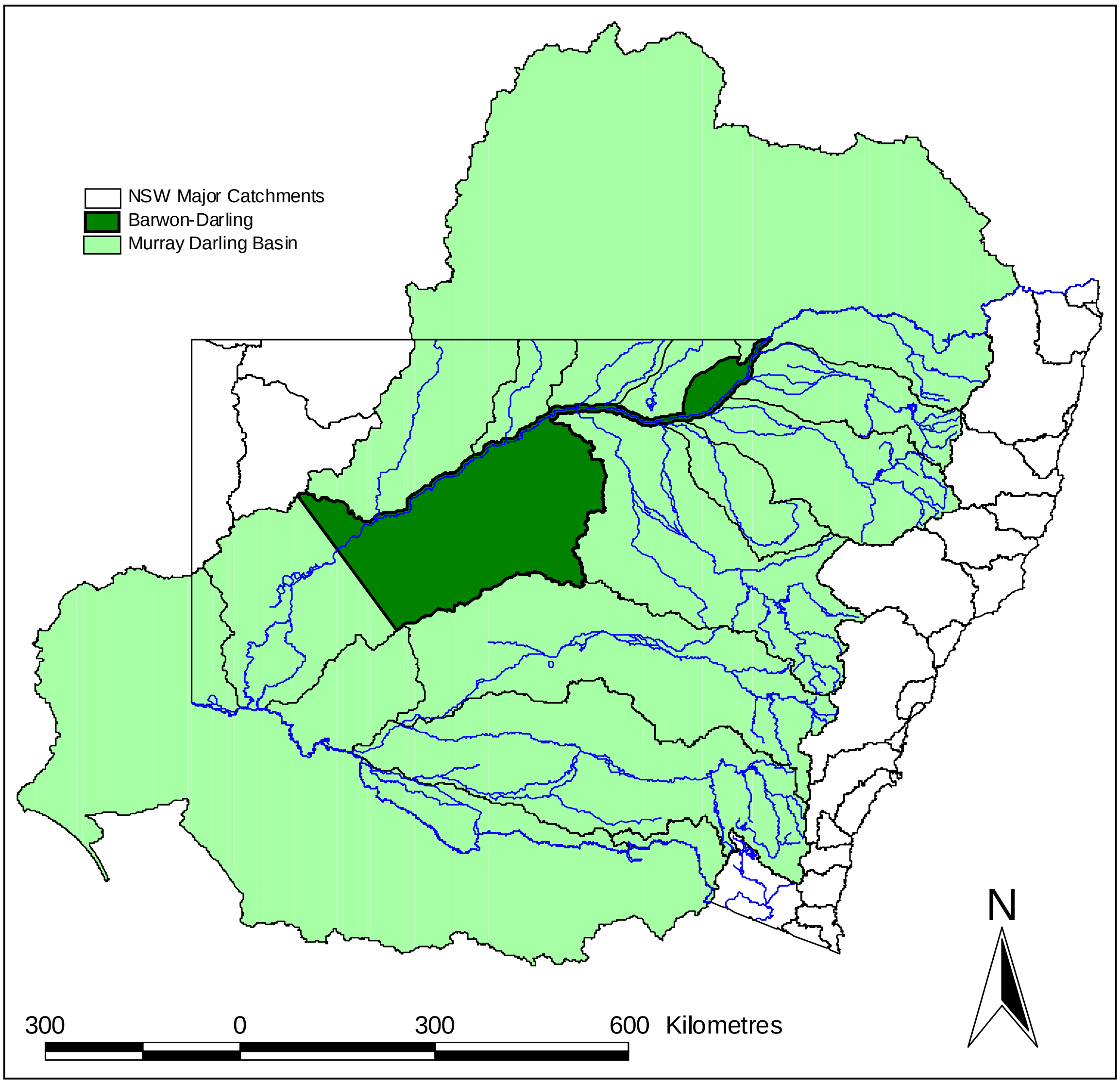


Figure 2.1. Relationship of Barwon-Darling River catchment to Murray-Darling Basin

There are no cities or large towns in the Barwon-Darling River; the largest towns are Cobar and Bourke with populations of about 4,500 and 3,000 people respectively. There are several smaller towns, such as Walgett, Brewarrina, Wilcannia, Collarenebri and Mungindi with populations of 500 to 2,000 people as well as a few settlements with less than 100 people (Figure 2.2).

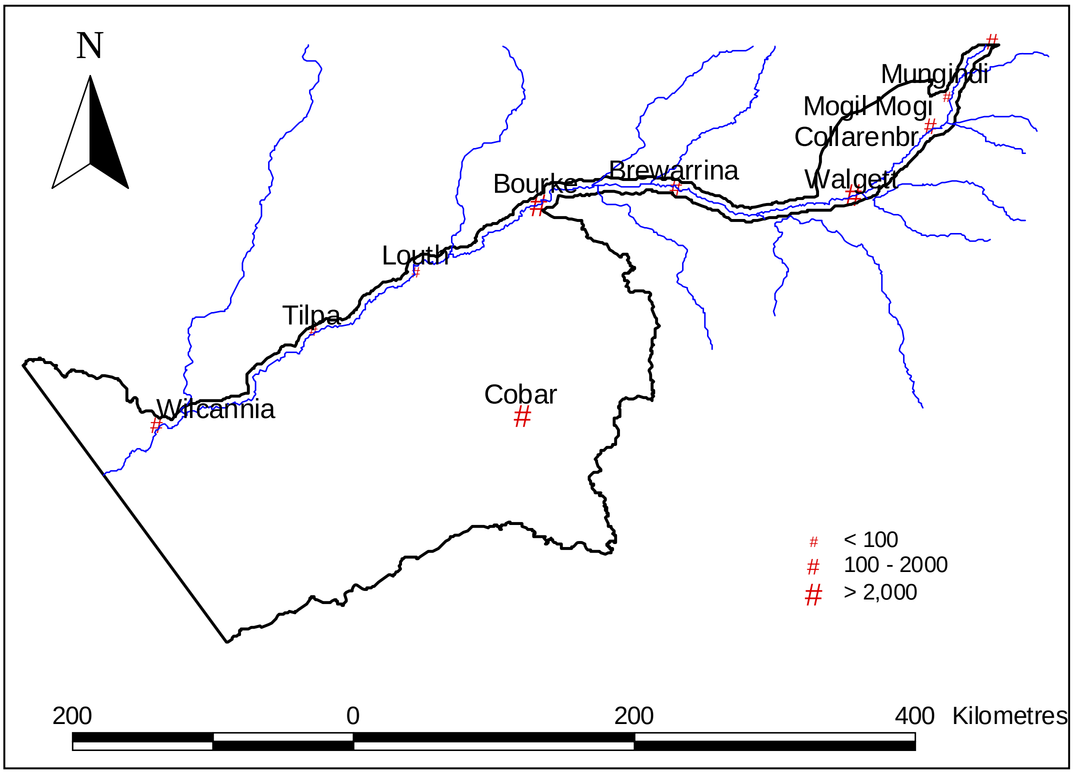


Figure 2.2. Cities and towns in Barwon-Darling River catchment

The Barwon-Darling River System can be considered as three regions or reaches, based on whether it is principally a source region/reach of streamflow, or whether it is a region/reach of extraction or loss:

(vi) Barwon River from Mungindi to Walgett (source region/reach)

(vii) Barwon-Darling River from Walgett to Bourke (source & extraction region/reach)

(viii) Darling River from Bourke to Wilcannia (loss region/reach)

2.1.2. Stream network

2.1.2.1. Barwon River from Mungindi to Walgett

The Barwon River is formed by the confluence of the Macintyre and Weir Rivers, about 25 km north-east of Mungindi. From Mungindi, it flows south-west through a broad floodplain for 150 km to Walgett. Tributaries include: the Moonie River from Queensland; the Boomi River and Gil Gil Creek from the Border Rivers catchment; the Gwydir and Mehi Rivers from the Gwydir catchment; and the Namoi River and Pian Creek from the Namoi catchment. The Barwon River also receives water from the effluent streams and extensive floodplain areas that characterise the lower reaches of these river valleys.

Only a small amount of irrigation, about 20% of the total for the system, occurs in this reach.

2.1.2.2. Barwon-Darling River from Walgett to Bourke

The Barwon River flows due west from Walgett to Bourke, a distance of about 200 km. It is at the junction with the Culgoa River, just upstream of Bourke, that the Barwon becomes the Darling River. Inflows in this reach include: the Castlereagh River, Marthaguy Creek, Macquarie River, Marra Creek and Bogan River from the Macquarie catchment; and the Narran Lake outflow, Bokhara River and Culgoa River from the Condamine-Balonne catchment. These catchments also have extensive floodplain areas in their lower reaches, which contribute large volumes of water to the Barwon-Darling River during floods.

Most of the irrigation diversions, nearly 65%, from the Barwon-Darling River occur in this reach.

2.1.2.3. Darling River from Bourke to Wilcannia

From Bourke, the Darling River flows south-west through a broad, flat floodplain for about 300 km to Wilcannia. The lower half of the river has several lagoons and interconnected shallow depressions that store large quantities of water during major floods (Rajendran and Sharma, 1995). Some of this water returns to the river but much is lost through evaporation and seepage. Although the River is joined by the Warrego and Paroo Rivers from the north and a sizeable residual catchment to the south-east, this reach receives virtually no inflows in this reach. As the area is dry and flat and the watercourses ill-defined and ephemeral. The area is so dry that Cobar, which lies 250 km to the south of Bourke and is the largest town in the catchment, obtains its water from the Macquarie River system.

A small amount of water is diverted for irrigation in this reach but a much greater quantity is lost through evaporation and seepage.

2.1.3. Hydrometeorology

2.1.3.1. Rainfall

Average annual rainfall in the Barwon-Darling River catchment ranges from about 500 mm in the east to 260 mm in the west (Figure 2.3). The catchment receives most of its rainfall in the warmer part of the year (Figure 2.4), peaking in the summer months of January and February. A residual mass curve of the rainfall from 1890 to present (Figure 2.5) shows that:

- the first half of the nineteenth century had extended periods of lower than average rainfall,
- the third quarter had fairly average rainfall with alternating periods of higher and lower than average rainfall, and
- the BSMS Benchmark Climatic period (ie the fourth quarter of the figure) has extended periods of higher than average rainfall as well as short periods of drought such as 1979-1980 and 1995-1996. Fuller details of the Benchmark Climatic period can be seen in the detailed annual total rainfall at Bourke (Figure 2.6).

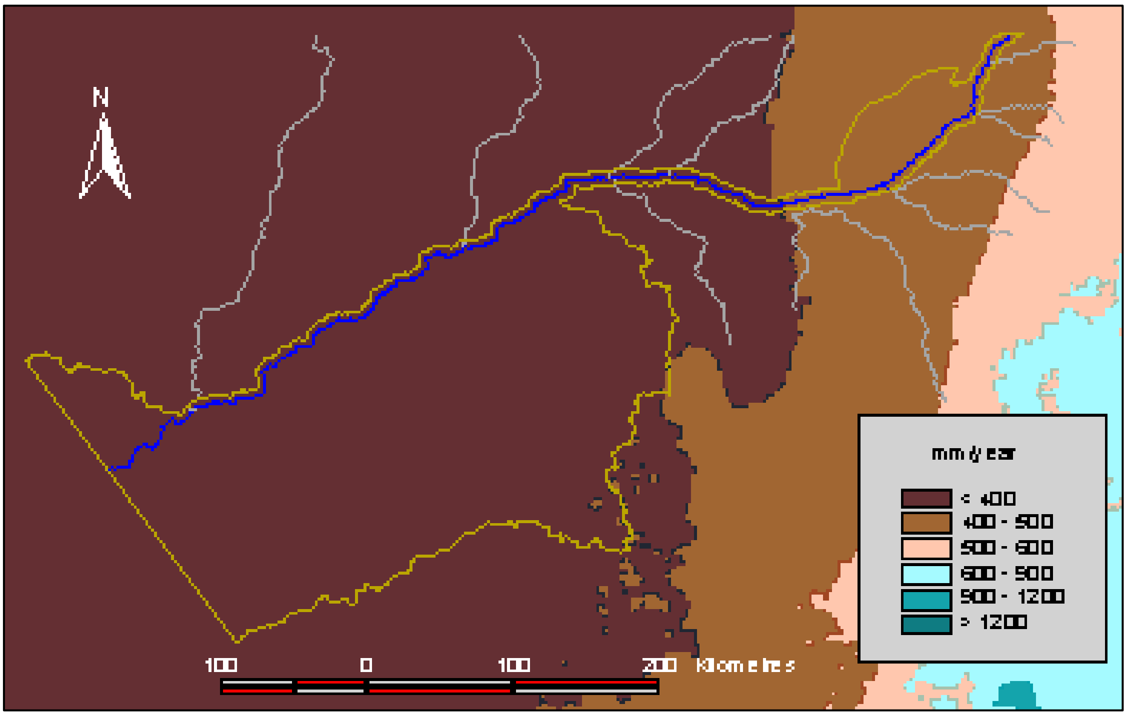


Figure 2.3. Average annual rainfall in Barwon-Darling River catchment

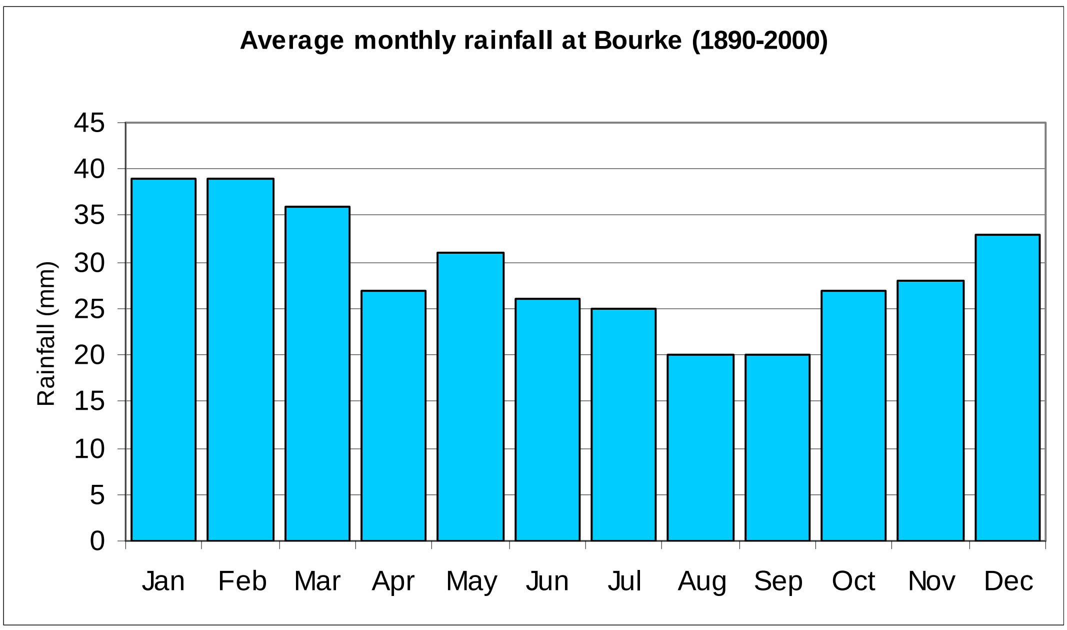


Figure 2.4. Average monthly rainfall at Bourke 1890-2000.

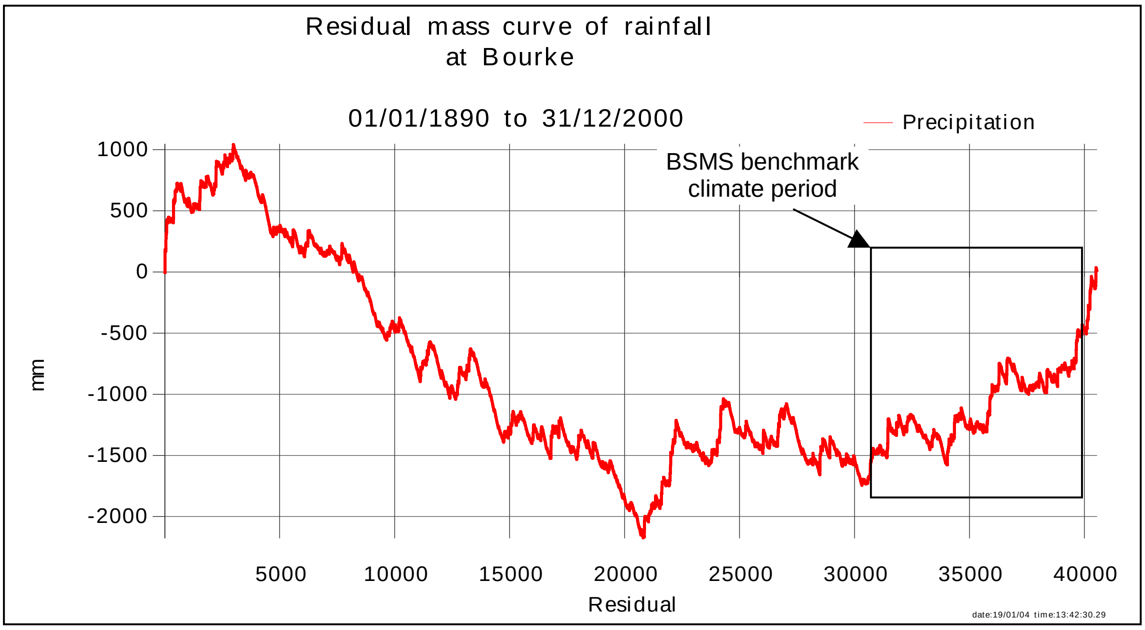


Figure 2.5. Residual mass curve of rainfall at Bourke

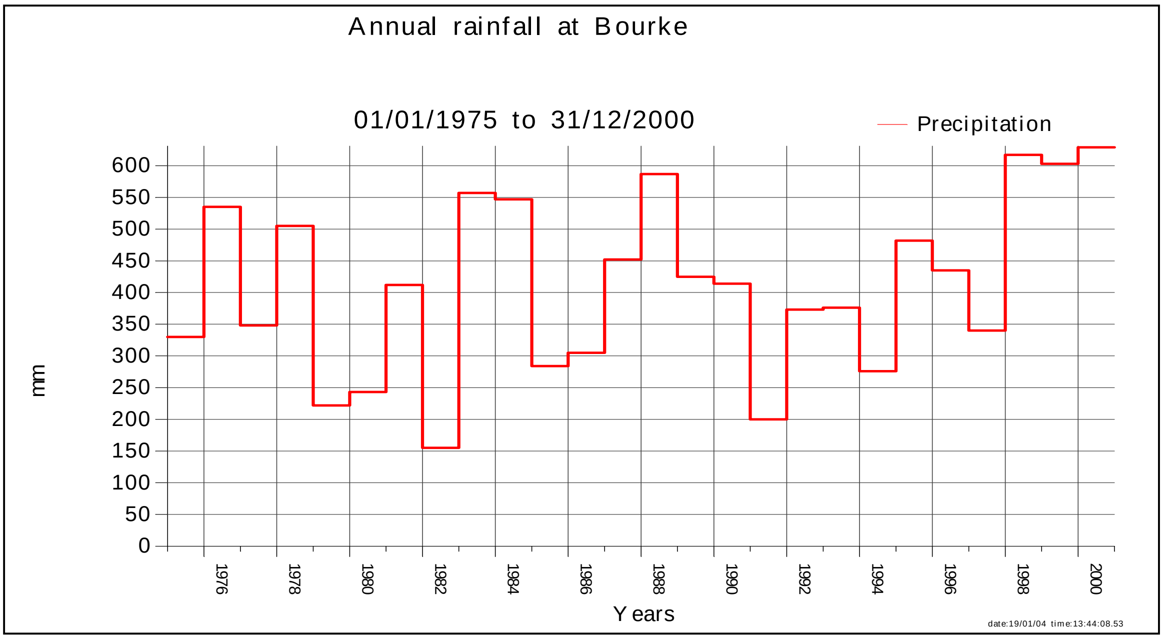


Figure 2.6. Annual rainfall at Bourke 1975-2000

2.1.3.2. Evaporation

Average Class A pan evaporation in the Barwon-Darling River catchment ranges from around 1800 mm/year in the south-east to well over 2000 mm/year in the north and west (Figure 2.7). Evaporation is also strongly seasonal, varying from 2.3 mm/d during July at Bourke, to 10.2 mm/d during January.

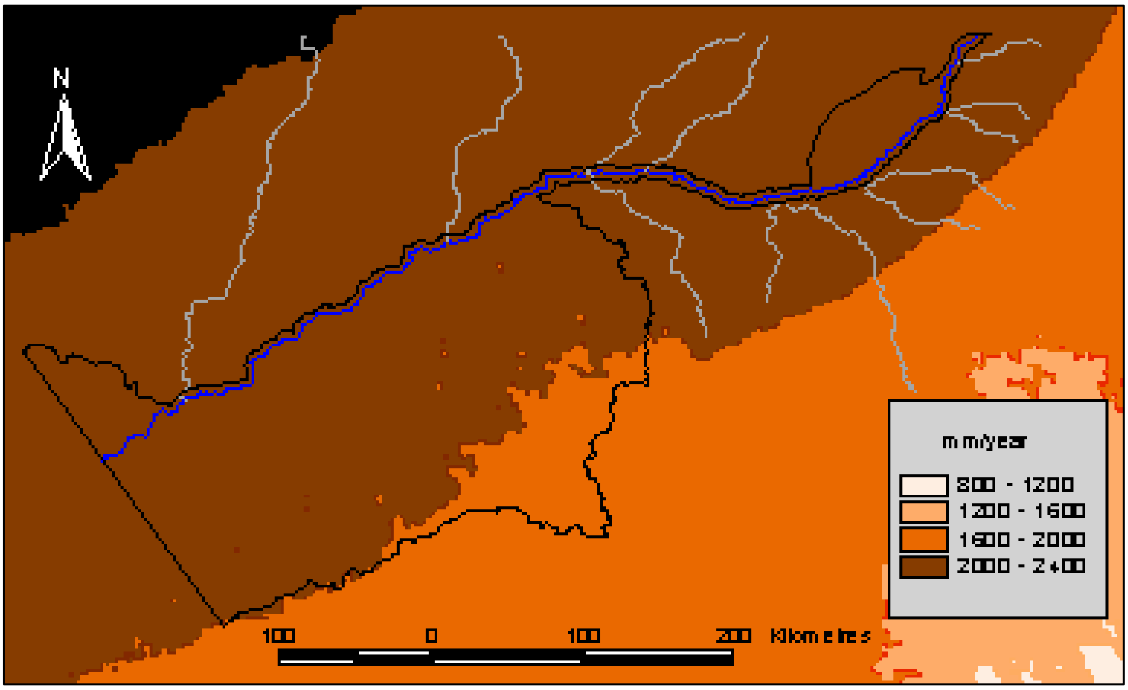


Figure 2.7. Average annual Class A Pan evaporation in Barwon-Darling River catchment (1973-1995)

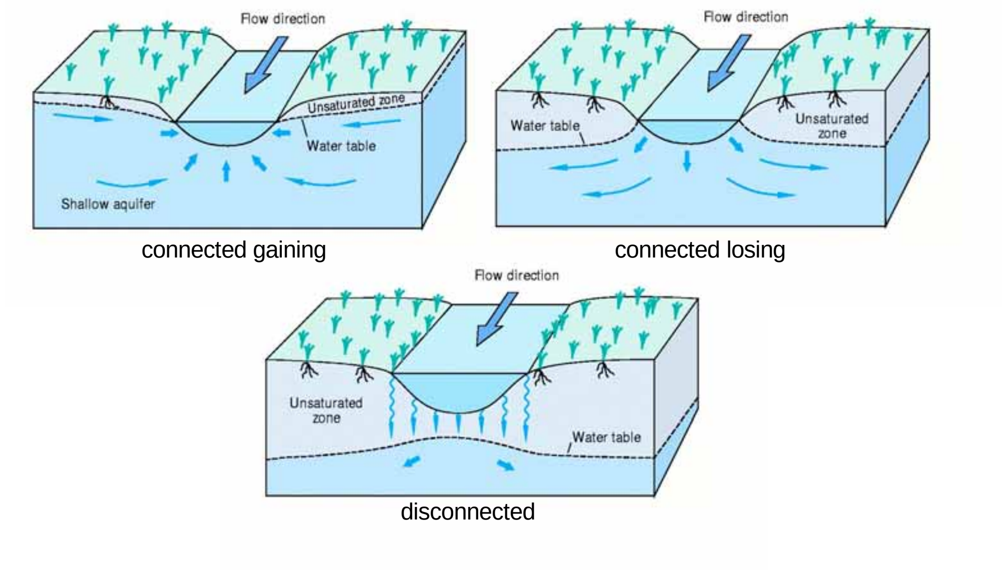
2.1.4. Groundwater interactions.

Groundwater interaction with river systems is discussed here as it may directly affect salt balance in some reaches of the Barwon-Darling River. Salt from groundwater can enter the river system by two pathways: (i) capillary rise from shallow water tables and mobilisation in surface runoff; or (ii) groundwater discharge directly into the river system. Similarly, salt can exit the river system when recharging groundwater occurs.

Movement of groundwater into and out of a river system may have a minimal effect on the overall water balance. However, groundwater is usually more saline, and small volumes of it may significantly increase river salt loads and salinity.

The way in which surface and groundwater systems interact depends on the depth of the watertable (Figure 2.8). Where the watertable is close to the base of the riverbed, the reach is hydraulically connected and will gain or lose water according to the relative hydraulic heads of the two systems. Disconnected reaches always lose water, with the rate of seepage limited by the hydraulic conductivity of the riverbed.

Figure 2.8. Types of river reach with respect to groundwater interaction



(*after Braaten and Gates, 2002*)

Generally, whether a river section is hydraulically connected has a geographic distribution (Figure 2.9). Most upland streams are hydraulically connected, receiving flow from fractured rock aquifers. In the foothills of the ranges, narrow floodplains overlying bedrock and relatively high rainfall produce shallow alluvial water tables and strong hydraulic connections between river and aquifer. The direction of flux can vary over time. Water lost from the river during a flood or period of high regulated flow will recharge the aquifer, which may then drain back to the river when the flow is lower.

Typically, arid conditions, wide alluvial plains and deep groundwater in the lower parts of the valley lead to long stretches of river which are hydraulically disconnected. According to Braaten and Gates (2002), the Barwon River upstream of Walgett and the Darling River below Bourke are both hydraulically disconnected. However, other studies have shown that the Darling River below Bourke is affected by saline inflows from the regional groundwater system, particularly during periods of low flow (Williams, 1993 and Woolley, 1997).

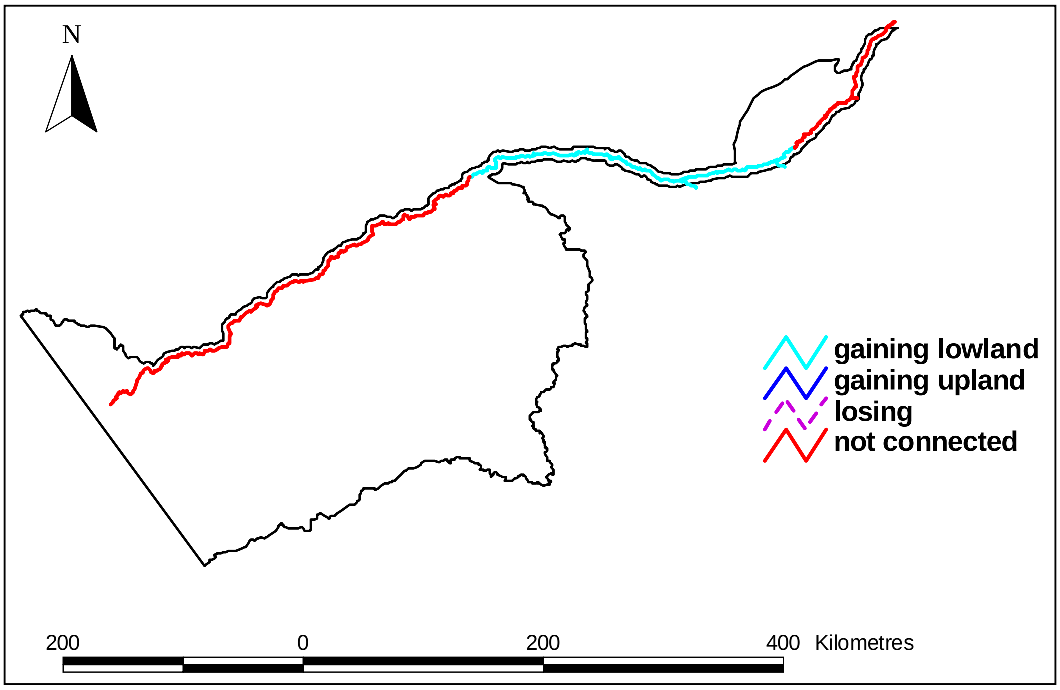


Figure 2.9. Hydraulic connection between rivers and groundwater *(after Braaten and Gates, 2002)*

2.1.5. Land use

Land use in the Barwon-Darling River catchment is dominated by grazing (Figure 2.10). The small area remaining is used mostly for forestry or nature conservation / minimal use with a tiny area of irrigated crops along the Barwon River between Walgett and Bourke.

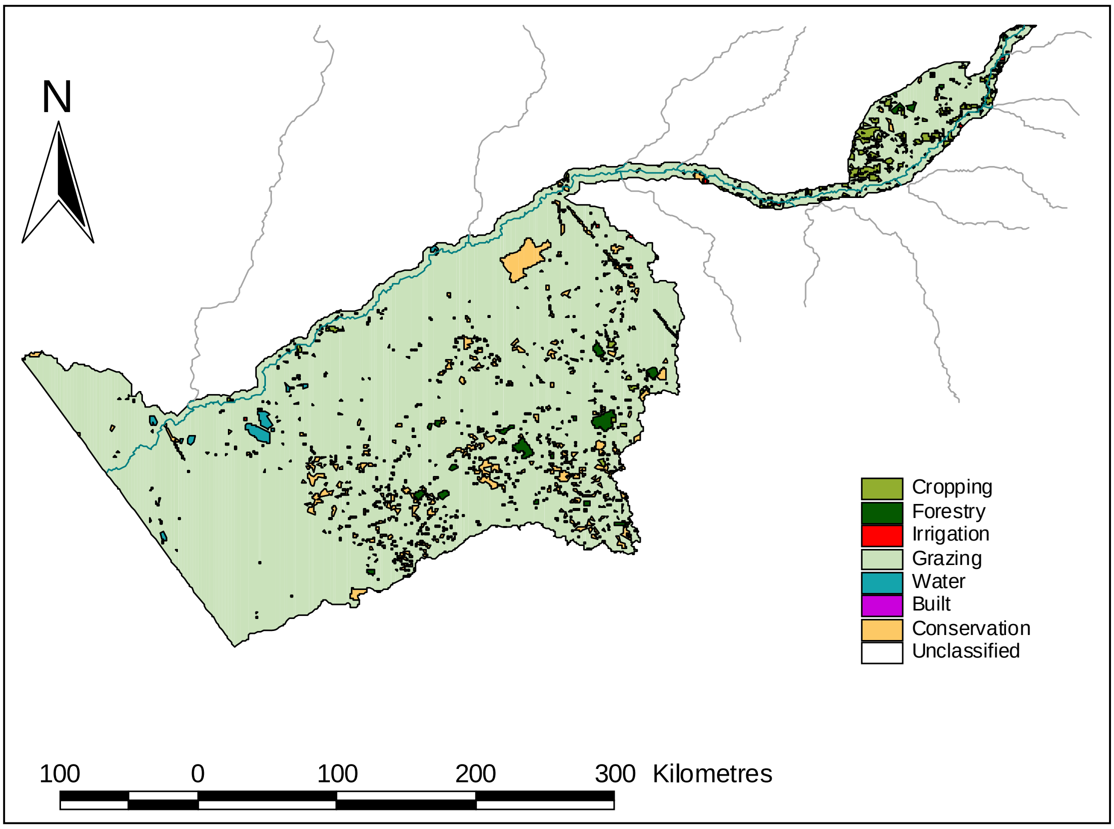


Figure 2.10. Landuse in Barwon-Darling River catchment

2.2. WATER RESOURCE MANAGEMENT

Although many of the contributing river valleys are regulated, the Barwon-Darling River is an unregulated system with no major storages. Weirs along the river provide sufficient depth for water to be pumped out for irrigation and town water supplies but they are not large enough to play any regulatory role.

As the Barwon-Darling River is unregulated, irrigation development is heavily dependent on large, privately-owned, on-farm storages. Irrigation licences specify an annual volume and the river flow thresholds above which water can be accessed for irrigation of crops and/or filling on-farm storages.

2.3. SALINITY IN CATCHMENT

Salinity is a threat in the Barwon-Darling River System. However, all known dryland salinity areas occur in the catchments of the contributing river basins (see Volumes 3 to 6 of this report) rather than in the small catchment areas directly associated with the Barwon-Darling River.

Salt loads from the NSW contributing river basins of the Barwon-Darling Basin were estimated as part of the Salinity Audit (Beale et al., 1999) and are shown in Table 2.1.

Table 2.1 Salt loads from NSW tributary valleys in the Barwon-Darling Basin (figures quoted are from the NSW Salinity Audit for the most downstream Balance Point in each valley)

Tributary Valley	Station Number	Station Name	Catchment Area	Mean flow	Mean salt load	Mean salt load
			km^2	GL/year	T/year	$T/year/km^2$
Border Rivers	416002	Barwon River @ Mungindi	22,600	1,017.0	142,100	6.3
Gwydir	418001	Gwydir River @ Pallamallawa	12,300	725.7	149,400	12.1
Namoi	419012	Namoi River @ Boggabri	22,600	768.4	178,600	7.9
Castlereagh	420005	Castlereagh River @ Coonamble	8,400	105.5	19,500	2.3
Macquarie	421006	Macquarie River @ Narromine	26,160	1,279.2	234,000	8.9
Bogan	421023	Bogan River @ Gongolgon	27,970	223.8	34000	1.2

3. Salinity Data

3.1. AVAILABLE DATA

All the salinity data used in this catchment were extracted from DWE databases. These data, which are collected at streamflow recording stations, are tabulated in Appendix A. The distribution and relative length of the data records are shown in Figure 3.1 for discrete EC data stations and in Figure 3.2 for continuous EC data stations. The end-of-system stations on rivers that contribute flow to the Barwon-Darling are also shown where EC data is available.

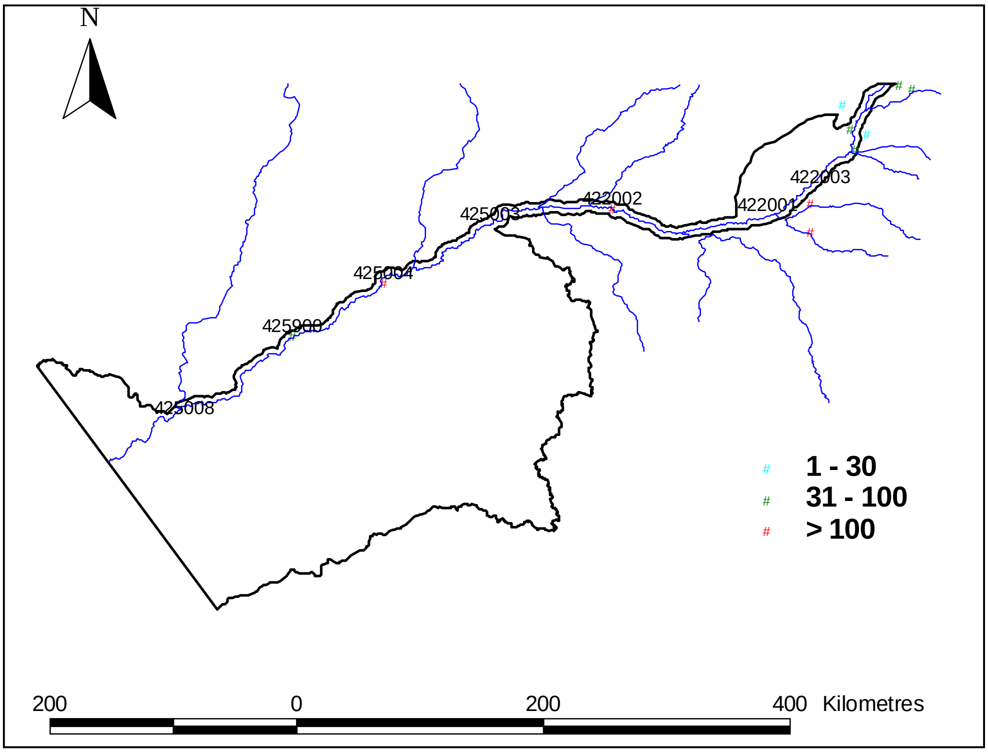


Figure 3.1. Location and record length size for discrete EC data stations.

The legends used in Figure 3.1 and Figure 3.2 are indicative of the usefulness of the data for modelling purposes. A discrete data set with < 30 data points is of little value, from 30-100 of some value, and above 100 is starting to provide a good estimate of salinity behaviour. The class intervals for the continuous data sets are also indicative, for the same purpose. These classes are based on experience, and a more rigorous approach to determine how well these data sets describe the salinity regime is discussed in Volume 2, Chapter 5.

A feature of the discrete data sets is that of the 22 data sets reported in Appendix A, 4 have less than 30 data points, and 12 have more than 100 data points. The larger data sets appear to give a good coverage along the length of the Barwon-Darling River. Some of the major tributaries, such as the Namoi and Macquarie Rivers, also have large data sets whilst the less significant tributaries tend to have small data sets.

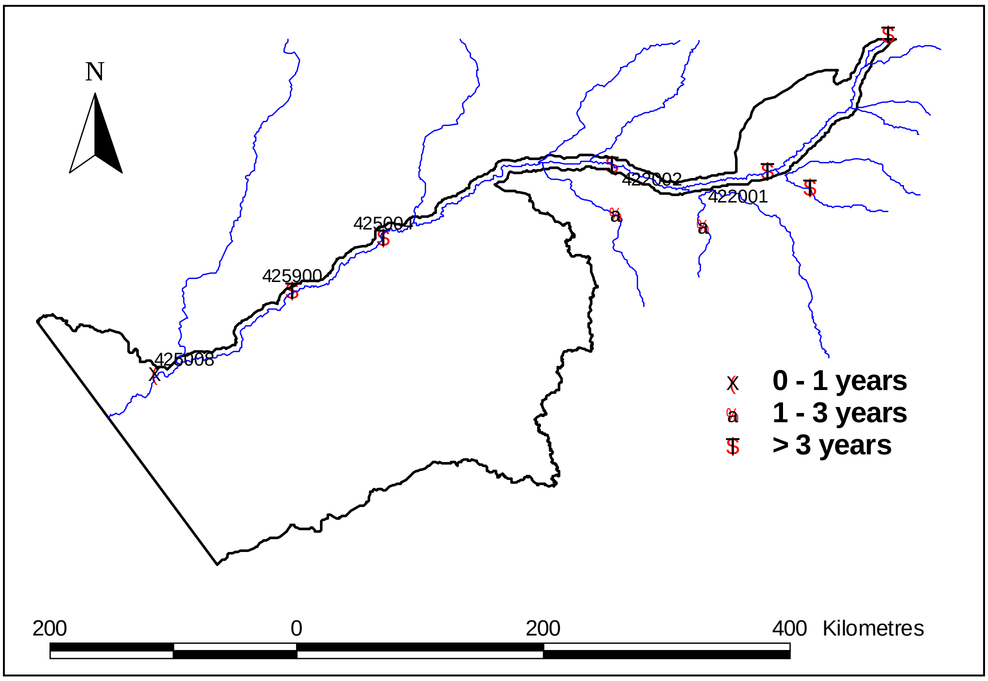


Figure 3.2. Location and record length for continuous EC data stations.

The Barwon-Darling River has a reasonable coverage of continuous stations compared with most other NSW MDB valleys, although there is little continuous data at the end-of-system gauge at Wilcannia. The four other main river gauges all have more than three years of data, as do the end-of-system gauges for the Border Rivers and Namoi Valleys.

3.2. DATA USED FOR INFLOW ESTIMATES AND MODEL EVALUATION

The stations that can potentially be used for the salinity models are those located at either inflow points, or at gauging stations used to evaluate results of the quantity model. All twenty-two stations with discrete EC data and nine stations with continuous EC data can potentially be used for these purposes.

There are fourteen stations with discrete EC data at inflow points, four of which also have continuous EC data (Table 3.1). Discrete data from these stations was to estimate salt load inflows to the Barwon-Darling River model. A further eight stations with discrete EC data are located at points that could be used to evaluate model results (Table 3.2). Five of these stations also have continuous EC data (Table 3.3). These data sets were screened to remove outliers and observations on days with no flow records.

3.2.1. Exploratory analysis of data

A simple representation of the data was prepared to get some insight into the contributions of inflows to salinity and the variations in salinity along the mainstream. This analysis was based on looking at the patterns of the median salinity and median flow, as reported in Table 3.4.

A plot of the median salinity against median flow of inflow points (Figure 3.3) shows that the Barwon, Namoi and Macquarie Rivers contribute the largest quantities of salt to the Barwon-Darling River system. The Barwon River (416001) catchment contributes large amounts of moderately saline water whilst the Namoi River (419026) and Macquarie River (421012) catchments contribute moderate amounts of high salinity water. The highest median salinity occurs in Pian Creek (419049) but the median flow is quite low at this station. The Warrego River (423001) and Moonie River (417001) contribute the least flow and salt to the Barwon-Darling River system.

The longitudinal overview of median salinities (Figure 3.4) shows that median salinities in the Barwon-Darling River tend to increase downstream. The discrete data shows a decrease in the median salinity between Tilpa (425900) and Wilcannia (425008) whilst the continuous data shows an increase. A decrease could be explained by the presence of lakes in this reach. However, the two data sets are not directly comparable and both have limitations: the discrete data covers a long period but may miss much of the variability whilst the continuous data covers only the most recent years. If salinity is increasing over time, this would explain why the median salinities of the continuous data sets are higher than those of the discrete data sets.

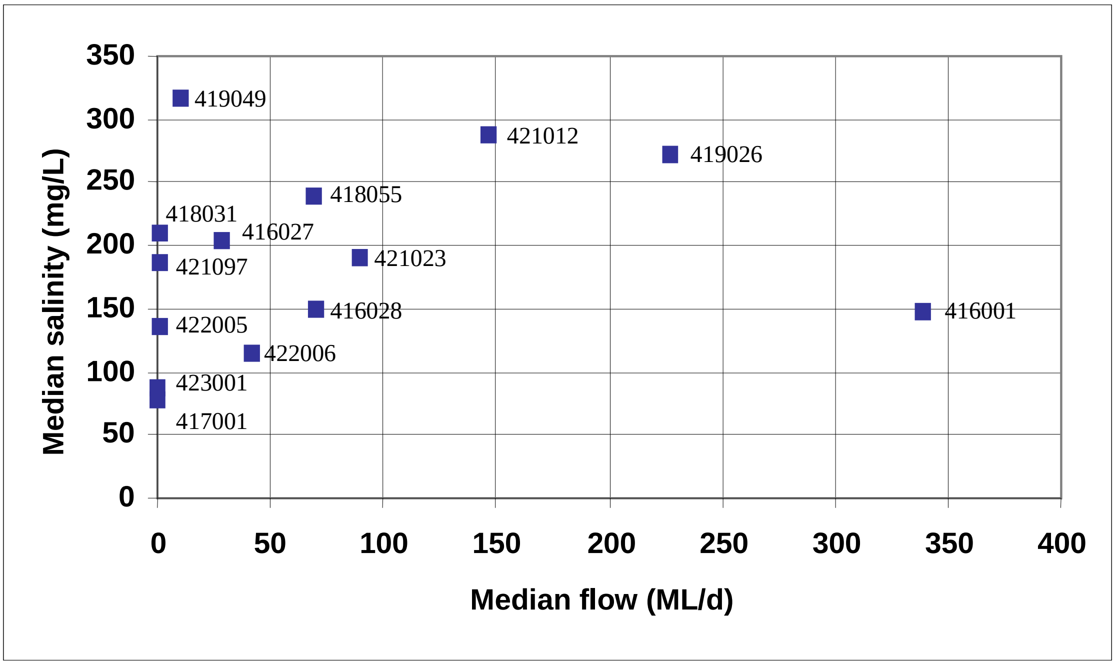


Figure 3.3. Median salinity versus median flow for inflow sites with discrete EC data

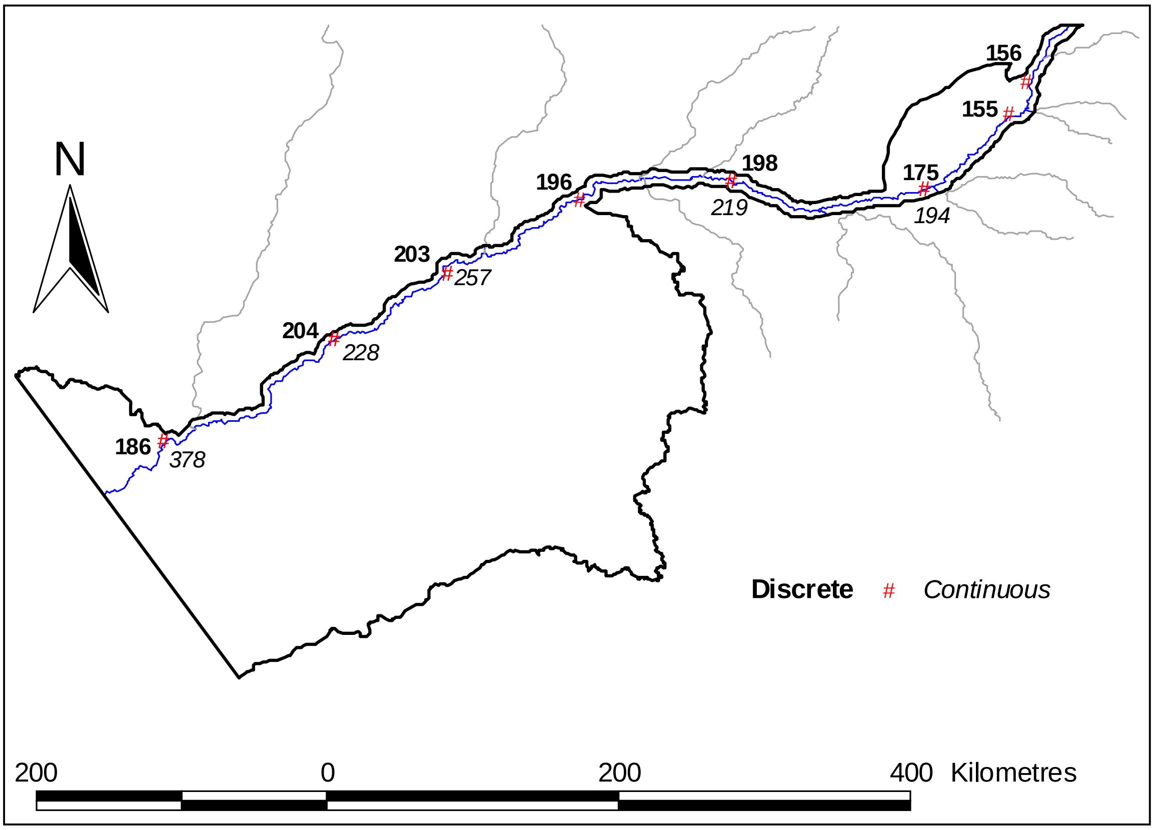


Figure 3.4. Median salinity along main stream

Table 3.1. Stations at inflow points with discrete and continuous EC data, with results of preliminary screening

Station Number	Station Name	Data use	Data points removed			Final data days
			<15 μS/cm	*zero or missing flow*	*outliers*	
416001	Barwon River @ Mungindi	Inflow	9	73	1	536
416001	*Barwon River @ Mungindi*	*Inflow*	0	0	2	*2,182*
416027	Gil Gil Creek @ Weemelah	Inflow	0	3	1	73
416028	Boomi River @ Neeworra	Inflow	0	2	0	69
417001	Moonie River @ Gundablouie	Inflow	0	2	0	24
418031	Gwydir River @ Collymongle	Inflow	0	1	0	19
418055	Mehi River near Collarenebri	Inflow	0	9	0	94
419026	Namoi River @ Goangra	Inflow	0	7	0	198
419026	*Namoi River @ Goangra*	*Inflow*	0	0	0	*2,391*
419049	Pian Creek @ Waminda	Inflow	0	27	0	120
421012	Macquarie River @ Carinda	Inflow	0	2	0	242
421012	*Macquarie River @ Carinda*	*Inflow*	0	0	0	*745*
421023	Bogan River @ Gongolgon	Inflow	0	3	0	162
421023	*Bogan River @ Gongolgon*	*Inflow*	0	0	0	*398*
421097	Marra Creek @ Carinda Rd	Inflow	0	0	0	30
422005	Bokhara River @ Bokhara	Inflow	0	2	0	47
422006	Culgoa River @ D/S Collerina	Inflow	0	0	0	138
423001	Warrego River @ Fords Br	Inflow	0	3	0	21

Note: Stations in italic font are continuous, all others are discrete

Table 3.2. Stations at evaluation points with discrete EC data, with results of preliminary screening

Station Number	Station Name	Data use	Data points removed			Final data days
			<15 μS/cm	*zero or missing flow*	*outliers*	
422001	Barwon River @ Walgett	Evaluation	*0*	*33*	*0*	484
422002	*Barwon River @ Brewarrina*	*Evaluation*	*0*	*0*	*0*	*209*
422003	*Barwon River @ Collarenebri*	*Evaluation*	*0*	*38*	*0*	*340*
422004	*Barwon River @ Mogil Mogil*	*Evaluation*	*0*	*0*	*0*	*93*
425003	Darling River @ Bourke	Evaluation	*1*	*34*	*0*	1,597
425004	*Darling River @ Louth*	*Evaluation*	*0*	*14*	*0*	*179*
425900	*Darling River @ Tilpa*	*Evaluation*	*0*	*0*	*0*	*57*
425008	Darling River @ Wilcannia (main channel)	Evaluation	*1*	*32*	*0*	1,204

Note: Stations in italic font are not reliable at high flows and are are used only for checking salinity results. At all other stations, flow, salinity and salt load results are evaluated against observed data.

Table 3.3. Stations at evaluation points with continuous EC data, with results of preliminary screening

Station number	Station name	Data use	Data days		Comments for data errors	Final data days
			Missing flow	*Data errors*		
422001	Barwon River @ Walgett	Evaluation	*920*	*0*		1,463
422002	*Barwon River @ Brewarrina*	*Evaluation*	*0*	*45*	*Instrument malfunction*	*2,169*
425004	*Darling River @ Louth*	*Evaluation*	*0*	*5*	*Zero values*	*1,399*
425900	*Darling River @ Tilpa*	*Evaluation*	*0*	*0*		*1,268*
425008	Darling River @ Wilcannia (main channel)	Evaluation	*9*	*9*	Sensor at water surface	66

Note: Stations in italic font are not reliable at high flows and are are used only for checking salinity results. At all other stations, flow, salinity and salt load results are evaluated against observed data.

Table 3.4. Cumulative distribution statistics of screened EC data sets

Station Number	Station name	Data type	Data use	Salinity statistics kg/ML C_{25}	C_{50}	C_{75}	Q_{50} ML/d
416001	Barwon River @ Mungindi	Discrete	Inflow	179	147	119	339
416001	Barwon River @ Mungindi	Continuous	Inflow	184	153	124	
416027	Gil Gil Creek @ Weemelah	Discrete	Inflow	300	205	142	28
416028	Boomi River @ Neeworra	Discrete	Inflow	199	150	112	70
417001	Moonie River @ Gundablouie	Discrete	Inflow	96	77	56	0
418031	Gwydir River @ Collymongle	Discrete	Inflow	265	210	181	1
418055	Mehi River near Collarenebri	Discrete	Inflow	316	240	182	69
419026	Namoi River @ Goangra	Discrete	Inflow	336	273	212	227
419026	Namoi River @ Goangra	Continuous	Inflow	326	260	206	
419049	Pian Creek River @ Waminda	Discrete	Inflow	389	316	263	10
421012	Macquarie River @ Carinda	Discrete	Inflow	327	287	253	147
421012	Macquarie River @ Carinda	Continuous	Inflow	351	275	238	
421023	Bogan River @ Gongolgon	Discrete	Inflow	248	191	143	90
421023	Bogan River @ Gongolgon	Continuous	Inflow	398	320	273	
421097	Marra Creek @ Carinda Rd	Discrete	Inflow	218	187	172	1
422001	Barwon River @ Walgett	Discrete	Evaluation	239	175	135	850
422001	Barwon River @ Walgett	Continuous	Evaluation	240	194	149	
422002	*Barwon River @ Brewarrina*	*Discrete*	*Evaluation*	*264*	*198*	*136*	*820*
422002	*Barwon River @ Brewarrina*	*Continuous*	*Evaluation*	*318*	*219*	*143*	
422003	*Barwon River @ Collarenebri*	*Discrete*	*Evaluation*	*188*	*155*	*126*	*356*
422004	*Barwon River @ Mogil Mogil*	*Discrete*	*Evaluation*	*203*	*156*	*121*	*263*
422005	Bokhara River @ Bokhara	Discrete	Inflow	192	137	96	1
422006	Culgoa River @ D/S Collerina	Discrete	Inflow	150	115	87	42
423001	Warrego River @ Fords Br	Discrete	Inflow	112	87	60	0
425003	Darling River @ Bourke	Discrete	Evaluation	269	196	149	1,904
425004	*Darling River @ Louth*	*Discrete*	*Evaluation*	*307*	*203*	*155*	*1,920*
425004	*Darling River @ Louth*	*Continuous*	*Evaluation*	*458*	*257*	*190*	
425008	Darling River @ Wilcannia (main channel)	Discrete	Evaluation	273	186	144	1,523
425008	Darling River @ Wilcannia (main channel)	Continuous	Evaluation	484	378	326	
425900	*Darling River @ Tilpa*	*Discrete*	*Evaluation*	*377*	*204*	*155*	*611*
425900	*Darling River @ Tilpa*	*Continuous*	*Evaluation*	*337*	*228*	*138*	

Note: Stations in italic font are not reliable at high flows and are are used only for checking salinity results. At all other stations, flow, salinity and salt load results are evaluated against observed data.

4. The Barwon-Darling River IQQM

4.1. QUANTITY MODEL

The Barwon-Darling River IQQM extends from Mungindi on the NSW-Queensland border down to Wilcannia. The model was initially developed and calibrated as three separate reach models: Mungindi to Walgett; Walgett to Bourke; and Bourke to Wilcannia. Calibration was carried out over the period 1987-1989, then the combined model was validated during 1991/92.

As the Barwon-Darling River is an unregulated system, the model is relatively simple compared with the other NSW valley IQQMs. It has no storages, and therefore no ordering routines, and only a comparatively small range of node types and sub-types. These represent the natural system configuration and the variety of human-influenced processes associated with the Barwon-Darling River. A full description of the features and calibration of the Border Rivers IQQM is presented in Rajendran and Sharma (1995).

The initial calibration identified a consistent problem in modelling flood events due to underestimation of tributary inflows. The most downstream gauges on the tributaries, which are used as inflows to the Barwon-Darling IQQM, are unreliable during periods of overbank flow due to the size of the floodplain and the merging of water from different sources. This problem has been addressed by incorporating a ‘floodplain reach’ into each of the contributing valley IQQMs. These reaches run in parallel with the existing valley models, picking up what used to be losses and non-returning effluents, and have no effect individual valley model results. Their sole purpose is to model the processes occurring in the floodplain areas at the end of the valleys and to deliver these ungauged flows to the Barwon-Darling model.

The model has also been refined to enable it to simulate emerging water management modelling needs. Further refinements were anticipated during the course of this project to improve its capability to reliably model salt transport. The overall structure of the Barwon-Darling River IQQM is shown in Figure 4.1.

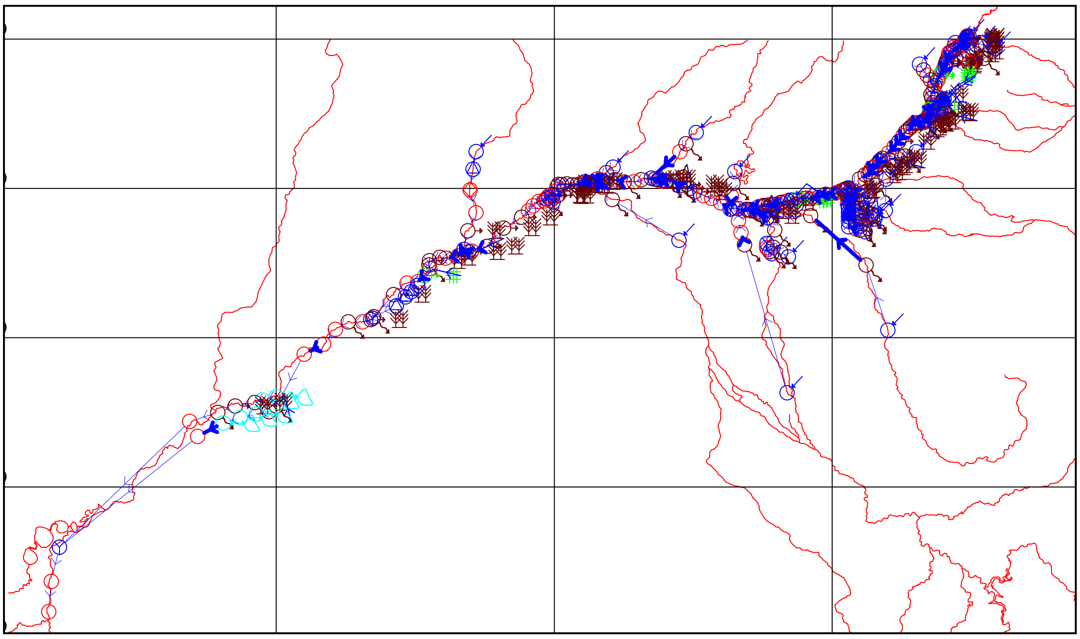


Figure 4.1. Schematic of Barwon-Darling River System IQQM.

This figure can only present an overview of the Barwon-Darling River IQQM. This limitation has been addressed by presenting the major types of nodes as separate figures, showing the geographic location and relative magnitude, where possible, of:

- inflows and losses (Figure 4.2); and
- irrigation extractions (Figure 4.3).

These features are discussed in Sections 4.1.1 and 4.1.2.

4.1.1. Inflows and Losses

The Barwon-Darling River IQQM uses a total of 28 inflow nodes to represent gauged inflows from contributing basins (14), floodplain inflows from contributing basins (6), other ungauged or residual inflows (8) and natural processes in the system. The model includes 20 effluent nodes used to represent transmission losses (15) and effluents (5). There are also eight gauge nodes along the main stream: three of which were used for flow calibration and five for review only as they are unreliable at high flows. The magnitude and distribution of the inflow and effluent nodes is shown in Figure 4.2. These inflow nodes match the catchments described in Section 5.1.2.

Most of the inflow to the Barwon-Darling IQQM, about 2,764 GL/year (64% of total), enters the system upstream of Walgett. Almost 80% of this inflow is gauged. It comes from: the Barwon River, Boomi River and Gil Gil Creek in the Border Rivers Valley; the Moonie River in Queensland; the Gwydir and Mehi Rivers in the Gwydir Valley; and the Namoi River and Pian Creek in the Namoi Valley. A further 1,459 GL/year (34% of total) of inflows enter the river between Walgett and Bourke. About 60% of this inflow is gauged and comes from: the Castlereagh River, Marthaguy Creek, Macquarie River, Marra Creek and Bogan River in the Macquarie-Castlereagh-Bogan Valley; and the Bokhara and Culgoa Rivers in the Condamine-Balonne Valley. Inflows between Bourke and Wilcannia average only 110 GL/year (2% of total). About 72% of this inflow is gauged and comes from the Warrego and Paroo Rivers.

Ungauged inflows in the Barwon-Darling Rivers IQQM consist predominantly of floodplain flows, which overtop or bypass the most downstream gauges on the tributaries. There are also a small number of 'residual catchment' inflows, which include any groundwater inflows as they were calibrated to improve the flow match at reliable mainstream gauges.

There are fifteen nodes in the model that represent instream losses and which where derived in the process of flow calibration. These nodes are located either on the tributaries before they join the main stream or immediately upstream of calibration nodes. Loss nodes in the Barwon-Darling River IQQM are spread fairly evenly throughout the system: upstream of Bourke they are generally associated with the tributary inflows; further downstream in the Darling River they represent the high instream losses.

There are also five loss nodes used to represent system effluents, four of which return to the system upstream of the model end-of-system gauge at Wilcannia (425008). Those effluents which return include: flows which bypass the Mogil Mogil gauge (422004); Grawan Creek which bypasses Collarenebri; flows which break-out of the Barwon River and return via the Macquarie River; and Cato Creek which bypasses Brewarrina. The fifth effluent node represents Talyawalka Creek which leaves the Darling River upstream of Wilcannia but does not return until after the Menindee Lakes, which is downstream of the end of the model.

Inputs to the model are observed data. Where the data has gaps and/or needs to be extended, appropriate hydrologic and statistical techniques have been developed to fit with data limitations and model needs. Details of the streamflow and climatic data are available in the valley Cap calibration report. For climatic and streamflow variables the following approach was used:

- Rainfall – observed data was gap filled and/or extended by statistical correlation with surrounding long term rainfall sites.
- Evaporation – observed data was gap filled and/or extended by generated data that was derived by statistically relating total evaporation and number of rain days for each month.
- Streamflow – observed data was gap filled and/or extended by generated data from a calibrated Sacramento rainfall runoff model. Ungauged catchment inflows are generally estimated by correlation with surrounding gauging stations and mass balance on the main river.
- Dam inflow – may be either observed data generated by mass balance approach at the dam or upstream flows routed to the dam. As outlined above streamflow data has been gap filled and/or extended by Sacramento rainfall runoff model.

4.1.2. Irrigations extractions

As with other unregulated river systems, irrigators along the Barwon-Darling Rivers extract water under an annual entitlement system. The total annual entitlement volume is about 520 GL, of which over 85% is controlled by large scale irrigators. The dominant crop type for these irrigators is cotton (about 24,000 ha). The distribution of water usage for irrigation is shown in Figure 4.3.

4.1.2.1. Surplus or Flood water usage

When the Barwon-Darling River floods, water that is not debited against a licence holder's entitlement, can also be extracted. This water either flows directly into the on-farm storage or into the supply channel that runs across the floodplain. Water extracted is typically stored in on-farm storages (almost 300 GL capacity) for later use. Annual usage of this source of water is estimated at around 18 GL/year but is obviously highly variable dependent on the occurrence of large floods.

4.1.3. Peer Review

There has been no formal peer reviews of the quantity component of Barwon Darling Rivers IQQM. Consultation with Barwon-Darling Rivers irrigators has been undertaken to ensure model input parameters are indicative of on-farm management practices.

The quality component of IQQM was developed from the US EPA model QUAL2E. Several conference papers have been presented and reviewed outlining the IQQM quality modelling and focused on salinity. Additional discussions have occurred with the MDBC outlining the Department's salt routing procedure.

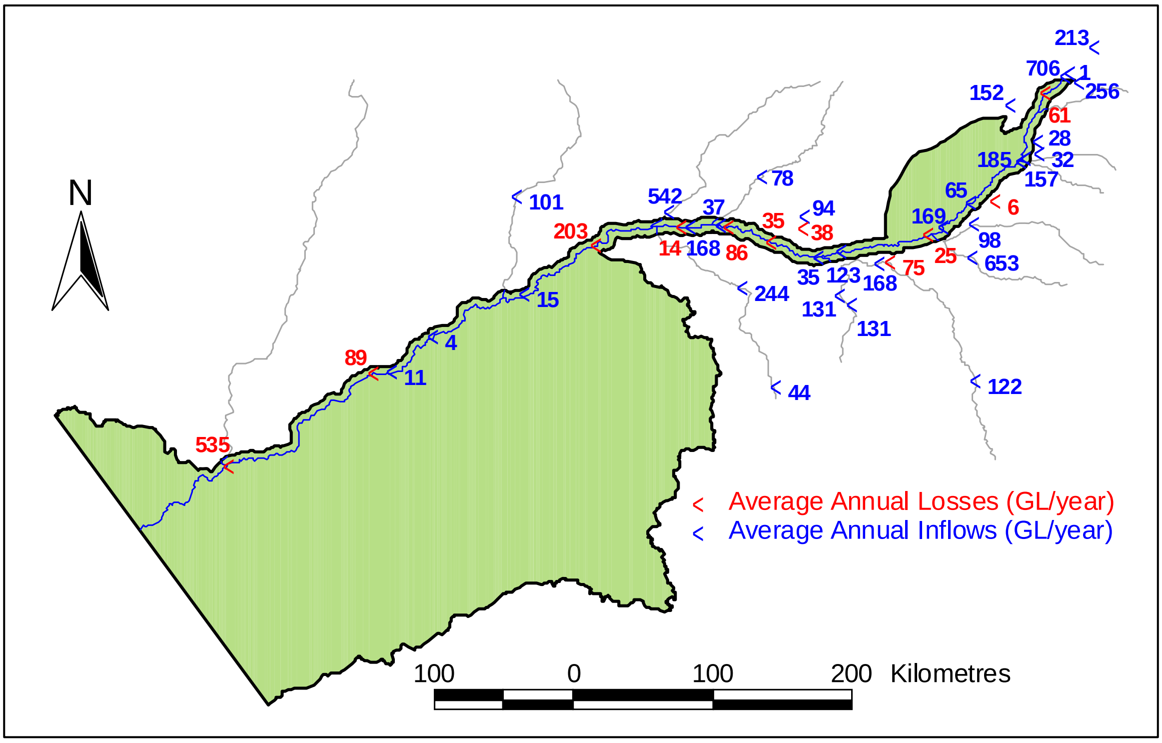


Figure 4.2. Distribution of modelled annual average (1975-2000) inflows and losses in Barwon-Darling River System.

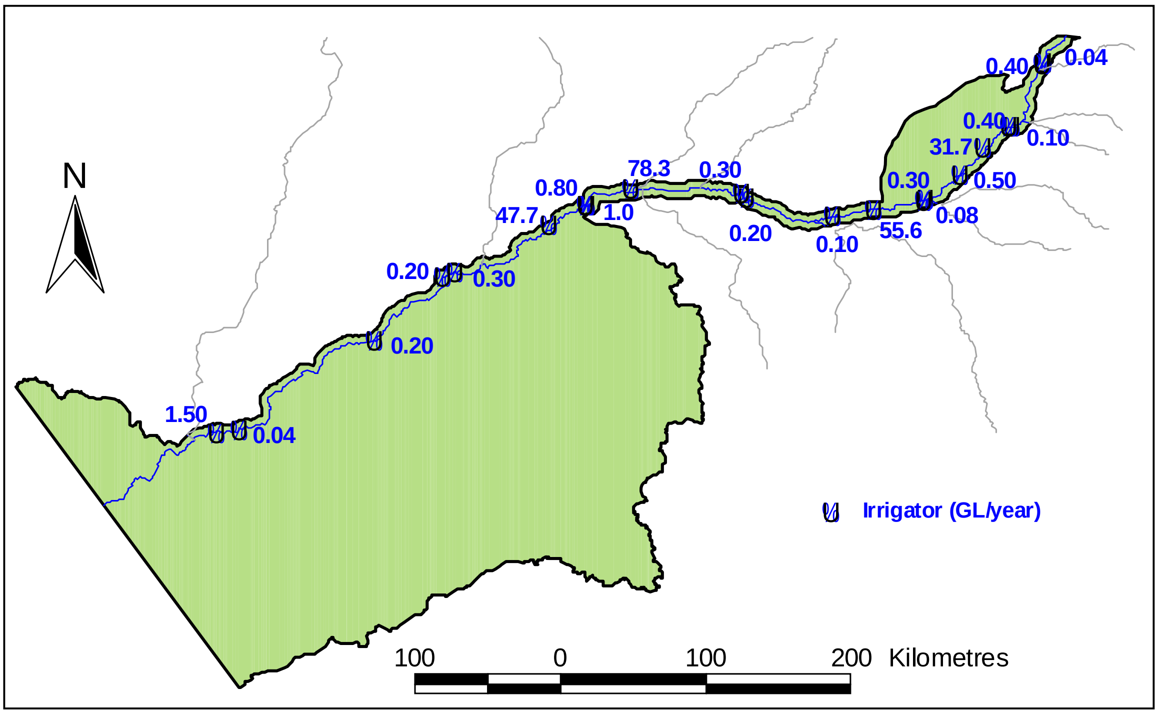


Figure 4.3. Modelled average annual irrigation diversions (GL/year; 1975-2000) for the Barwon-Darling River System.

4.2. QUALITY ASSURANCE OF QUALITY MODEL

4.2.1. QA Test 1: Update base quantity model

The results of the mass balance check for the major water balance components of the base quantity model over the simulation period 1975-2000 (see Volume 2, Section 3.1.1) are shown in Table 4.1. The total error over the period of simulation is 19 ML, out of a total inflow of $151*10^6$ ML, or 0.00001%. The magnitude of these results is typical of the order of magnitude that would be expected from rounding errors in the calculations, and we can conclude that there are effectively no flow mass balance errors in the IQQM software.

Table 4.1. Flow mass balance report for Barwon-Darling River IQQM, 1993/4 Cap Scenario for 1975-2000.

Water balance component	Sum over simulation period (ML)
Inflows	151,055,875
Losses	142,986,593
Extractions	7,692,092
On-farm Storage change	-377,170
Error	19

4.2.2. QA Test 2: Initialise salinity module with zero salt load

The purpose of this test was to ensure that introducing salt modelling to the system either:

i. did not change the magnitude of the quantity mass balance components from that of QA Test 1; or
ii. that there were no sources or sinks of salt are introduced by software bugs.

The results for the quantity mass balance comparison reported in Table 4.2 show no changes for the water balance components of the order of 0.0000007 - 0.000013%. The differences in flow volumes is due to the introduction of surface area in reaches with routing parameters for salt movement and is also typical of the order of magnitude that would be expected from rounding errors. The salt mass balance report is shown in Table 4.3, where it can be seen there are no numerical sources or sinks of salt introduced by the software.

The concentrations statistics at the end-of-system ($\mu \pm \sigma$) are 0.0 ± 0.0 mg/L, supporting the conclusion that no sources or sinks were introduced by the software.

Table 4.2. Flow mass balance comparison report for Barwon-Darling River IQQM after including salt modelling

Water balance component	QA Test 1 Sum over simulation period (ML)	QA Test 2 Sum over simulation period (ML)
Inflows	151,055,875	151,055,876
Losses	142,986,593	142,986,595
Extractions	7,692,092	7,692,093
On-farm Storage change	-377,170	-377,170
Error	19	19

Table 4.3. Salt mass balance report for Barwon-Darling River IQQM, 1993/4 Cap Scenario with zero salt inflows

Water balance component	QA Test 2 Sum over simulation period (Tonnes)
Inflows	0
Losses	0
Extractions	0
Storage change	0
Error	0

4.2.3. QA Test 3: Constant flow and concentration

The purpose of QA Test 3 was to test the stability of the model under constant flow conditions, and to further test that there are no numerical sources or sinks of salt introduced by the software. This was done by setting the flow and concentrations to constant values, and rainfall and evaporation to zero.

The result aimed for and achieved at the end of system was ($\mu \pm \sigma$) 200.0 ± 0.0 mg/L.

4.2.4. QA Test 4: Variable flow and constant concentration

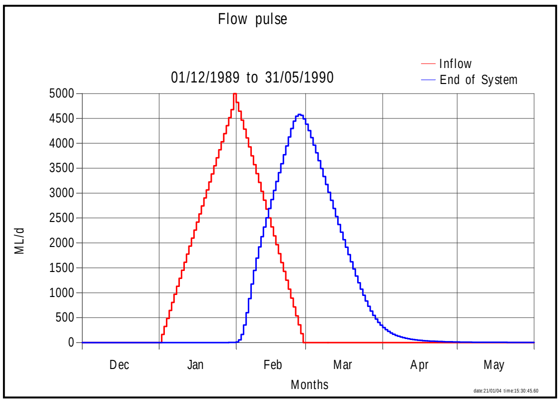
The purpose of QA Test 4 was to test the stability of the model under variable flow conditions, and to further test that there are no numerical sources or sinks in the model. The full set of inflows from QA Test 1 were used with a constant salinity concentration of 200 mg/L at all inflow nodes, and rainfall and evaporation set to zero.

The result aimed for and achieved at the end of system was ($\mu \pm \sigma$) 200.0 ± 0.0 mg/L.

4.2.5. QA Test 5: Flow pulse with constant concentration

The purpose of QA Test 5 was to verify that salt load was routed through the system consistently with flow. This was done by having a synthetic flow hydrograph at the top of the system as described in Volume 2, Section 3.1.5, with constant salinity concentration of 200 mg/L. All other inflow nodes had zero flow and concentration, and all storages, diversions, and effluents were modified to have no effect on water balance.

The results are shown at Figure 4.4. The effects of routing are clearly shown in these results with a lag and attenuation of the hydrograph. The patterns of the flow and salt load match exactly; showing that salt load is routed through the system consistently with the flow. The concentration aimed for at the end of system was ($\mu \pm \sigma$) 200.0 ± 0.0 mg/L. This result was achieved.

(a)


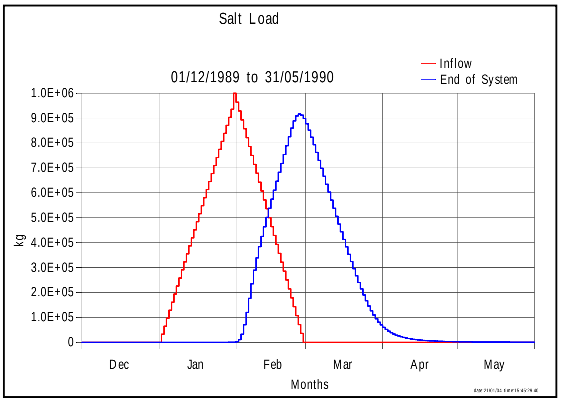
(b)


Figure 4.4. (a) Inflows and resultant EOS flows; (b) Salt load inflows and EOS salt loads

4.2.6. QA Test 6: Salt pulse with constant flow

The purpose of QA Test 6 was to further verify that salt was routed through the system consistently with flow. This was done by having a constant flow at the top of system with a concentration time series at this inflow point. These concentrations were varied linearly from 0 to 500 mg/L over a period of one month, and then decreased back to 0 mg/L over a period of one month. All other time series inflows and concentrations were set to zero. All storages, diversions and effluent nodes were modified to have no effect on water balance.

The results are shown at Figure 4.5. The effects of routing are clearly shown in these results with a lag and attenuation of the salt load hydrograph. The patterns of salt load and concentration are an exact match, confirming that salt load is routed through the system consistently with the flow.

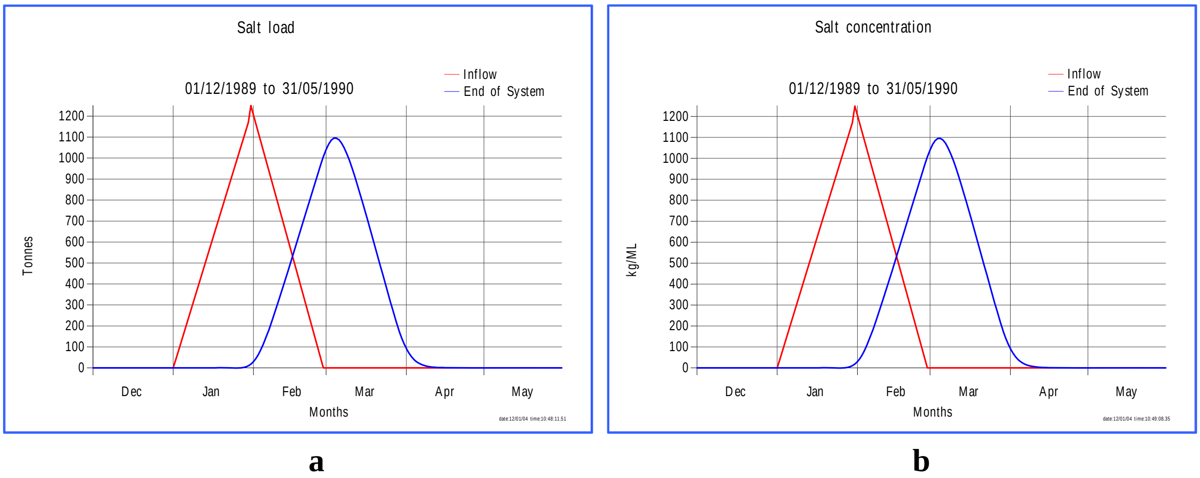


Figure 4.5. (a) Salt load inflows and EOS salt loads; (b) Inflow concentration and EOS concentration

4.3. QUALITY ASSURANCE CONCLUSIONS

The software passed the QA tests sufficiently well to justify developing the quality model for salt transport under BSMS baseline conditions. Some model limitations that account for salinity fluctuations in QA Test 3 were worked around by post-processing the salinity data for the model evaluation work.

5. Salt inflow estimates and evaluation

5.1. INITIAL ESTIMATES

The NSW Salinity Audit did not cover the Barwon-Darling River so there were no flow-salt load relationships to use as initial estimates of salt inputs to the Barwon-Darling IQQM. As there is little or no continuous salinity data available for most of the model inflow points (Table 3.1), the discrete salinity data was used to derive flow-salinity tables using the method described in Section 5.1.1. The flow-salinity table method was developed for use with unregulated inflows from small catchments in the valley models. Although it is not ideally applicable to the Barwon-Darling River inflows, which drain relatively large catchments and usually contain a mixture of regulated and unregulated flows, it was used in the absence of any viable alternative.

The flow and salinity results from the ‘first cut’ model are evaluated against in-stream salinity data to try to identify areas affected by groundwater interaction or other processes which are not modelled. If necessary, additional salt inputs are added and calibrated to improve the match with the concentration data.

5.1.1. Method used to derive flow-salinity tables

The flow-salinity table method assumes that flow is inversely related to concentration (Equation 5.1). The relationship is defined using corresponding pairs of data [(Q_1,C_1), (Q_2,C_2), …(Q_n,C_n)]. These points are taken from corresponding exceedance and non-exceedance ordinates on the ranked plots of data, to form a table of relationships (Figure 5.1).

$$C \propto \frac{1}{Q} \qquad (5.1)$$

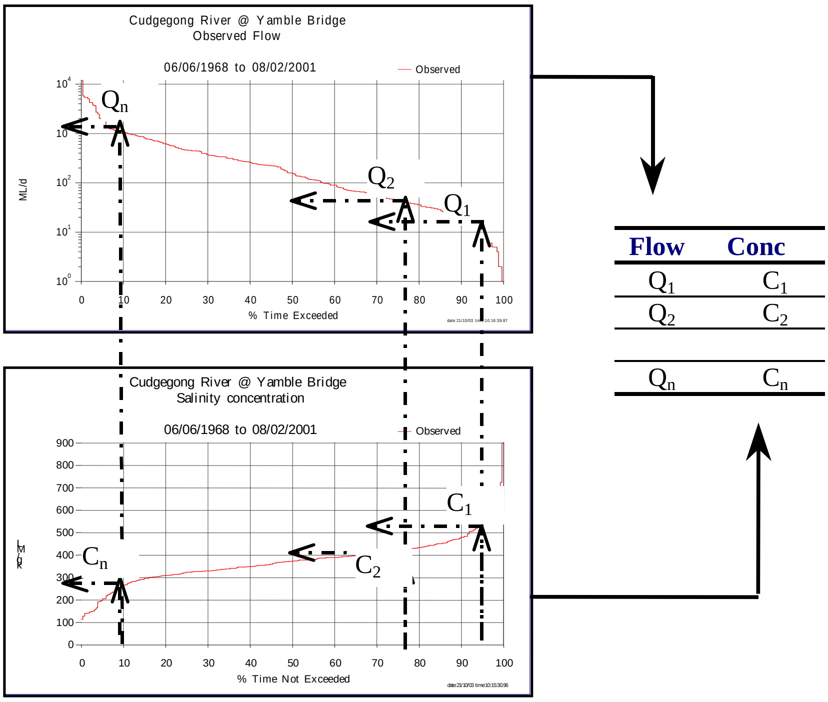


Figure 5.1. Derivation of flow-salinity table from exceedance curves

5.1.2. Initial estimates of salinity inputs

The flow and salinity inputs for the 'first cut' model are listed in Table 5.1. The flow-salinity tables used for each inflow node are shown in Appendix B Table B.8. and Table B.8.2.

Table 5.1. Flow and salt inputs for Barwon-Darling IQQM

IQQM inflow node no.	Type of input	Description	Flow input	Salt input
		Barwon River from Mungindi to Walgett		
001	Gauged	416001 Barwon River @ Mungindi	Observed	Flow-salinity table
018	Gauged	416028 Boomi River @ Neeworra	Observed	Flow-salinity table
146	Floodplain	Border Rivers floodplain (includes Little Weir River)	Simulated (Border Rivers baseline)	Flow-salinity table (Boomi R. salinities)
024	Gauged	416027 Gil Gil Creek @ Weemelah	Observed	Flow-salinity table
028	Gauged	417001 Moonie River @ Gundablouie	Observed	Flow-salinity table
360	Floodplain	Moonie River floodplain	Simulated (Moonie R baseline)	Flow-salinity table (Moonie R. salinities)
038	Gauged	418031 Gwydir River @ Collymongle	Observed	Flow-salinity table
343	Gauged	418055 Mehi River near Collarenebri	Observed	Flow-salinity table
351	Floodplain	Gwydir River floodplain	Simulated (Gwydir R. baseline)	Flow-salinity table (Mehi R. salinities)

IQQM inflow node no.	Type of input	Description	Flow input	Salt input
303	Residual	Residual catchment: Mungindi-Walgett	Calibrated residual(1)	Constant 150 mg/L
067	Gauged	419026 Namoi River @ Goangra	Observed	Flow-salinity table
068	Gauged	419049 Pian Creek @ Waminda	Observed	Flow-salinity table
076	Floodplain	Namoi River floodplain	Simulated (Namoi R. baseline)	Flow-salinity table (Pian Ck. salinities)
Barwon-Darling River from Walgett to Bourke				
370	Residual	Residual catchment: Walgett-Brewarrina (right hand side)	Calibrated residual(1)	Flow-salinity table (Bokhara R. salinities)
085	Gauged	421012 Macquarie River @ Carinda	Observed	Flow-salinity table
089	Gauged	421011 Marthaguy Creek @ Carinda	Observed	Flow-salinity table (Macquarie R. salinities)
094	Gauged	420005 Castlereagh River @ Coonamble	Observed	Flow-salinity table (Macquarie R. salinities)
371	Residual	Residual catchment: Walgett-Brewarrina (left hand side)	Calibrated residual(1)	Flow-salinity table (Macquarie R. salinities)
372	Floodplain	Macquarie River floodplain (first half)	Simulated (Macquarie R. baseline)	Flow-salinity table (Macquarie R. salinities)
373	Floodplain	Condamine-Balonne floodplain (first 30%)	not yet modelled	not yet modelled
104	Gauged	421097 Marra Creek @ Carinda Road	Observed	Flow-salinity table (Macquarie R. salinities)
182	Ungauged	Narran Lake overflow	Simulated (Narran Lake model)	Flow-salinity table (Bokhara R. salinities)
121	Gauged	422005 Bokhara River @ Bokhara	Observed	Flow-salinity table
382	Residual	Residual catchment: Brewarrina-Bourke (left hand side)	Calibrated residual(1)	Flow-salinity table (Bogan R. salinities)
383	Floodplain	Macquarie River floodplain (second half)	Simulated (Macquarie R. baseline)	Flow-salinity table (Bogan R. salinities)
384	Residual	Residual catchment: Brewarrina-Bourke (right hand side)	Calibrated residual(1)	Flow-salinity table (Culgoa R. salinities)
385	Floodplain	Condamine-Balonne floodplain (remaining 70%)	not yet modelled	not yet modelled

IQQM inflow node no.	Type of input	Description	Flow input	Salt input
127	Gauged	422006 Culgoa River d/s Collerina	Observed	Flow-salinity table
131	Gauged	421023 Bogan River @ Gongolgon	Observed	Flow-salinity table
Darling River from Bourke to Wilcannia				
401	Floodplain	Warrego River floodplain	not modelled	not modelled
402	Residual	Residual catchment: Bourke-Louth	Calibrated residual(1)	Constant 215 mg/L
361	Gauged	423001 Warrego River @ Fords Bridge (main channel)	Observed	Constant 90 mg/L
403	Residual	Residual catchment: Louth-Tilpa	Calibrated residual(1)	Constant 260 mg/L
404	Residual	Residual catchment: Tilpa-Wilcannia	Calibrated residual(1)	Constant 260 mg/L
405	Gauged	424001 Paroo River @ Wanaaring	not modelled	not modelled
406	Floodplain	Paroo River floodplain	not modelled	not modelled

(1) *From original flow model calibration*

There are also some unmodelled inflows that could potentially cause problems with the salinity and salt load results. The Condamine-Balonne floodplain has not yet been modelled, as the relevant Queensland models were not received in time to complete the necessary work. The Paroo River and the Paroo and Warrego floodplains are not modelled as they rarely contribute much flow to the Barwon-Darling River.

5.2. EVALUATION METHOD

5.2.1. Model configuration

The quantity model had to be reconfigured so that model results could be reliably compared against observed data, because the water quality is dependent on water quantity. This is demonstrated by considering Figure 5.2, and Equation 5.2. If either of the two simulated flows that mix are in error, the estimate of simulated concentration at the gauge location (C_{obs}) will be incorrect.

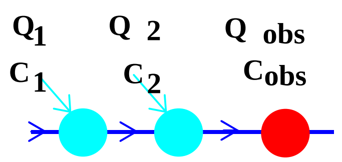


Figure 5.2. Calculating resultant concentration from two tributaries

$$C_{obs} = \frac{Q_1 \times C_1 + Q_2 \times C_2}{Q_1 + Q_2} \qquad (5.2)$$

Where: C_{obs} = Observed concentration at gauge location (mg/L)

C_1 = Concentration of water from tributary 1 (mg/L)

C_2 = Concentration of water from tributary 2 (mg/L)

Q_1 = Flow from tributary 1 (ML/d)

Q_2 = Flow from tributary 2 (ML/d)

The Barwon-Darling System IQQM provides good estimates of inflows except during periods of high flow when water spreads out across the floodplain and is impossible to gauge reliably. To address this problem, the model has a second set of inflow nodes, based on the simulated floodplain flows from the valley baseline models. The addition of these floodplain inflows achieves a much better match at the reliable gauges on the Barwon-Darling River during high flow events (He, 2004).

Within the main river, flows are affected by irrigation diversions. No single configuration of the model estimates these consistently over the period when salinity data was collected because of changes in levels of irrigation development. Simulated diversions in the Barwon-Darling IQQM used to evaluate results are based on 1993/4 levels of development, and any errors in estimating diversions would contribute to errors in the estimated of simulated flow compared with observed. However, these errors should not significantly effect simulated concentrations, because most of the inflows have already entered the major rivers (Figure 4.2) upstream of most of the diversions (Figure 4.3).

5.2.2. Selection of evaluation sites

Eight locations have data that could be used for model evaluation (Table 3.2). Five of these locations also have continuous data (Table 3.3). At this stage, performance measures have only been developed for discrete data as the continuous data sets are too short and methods have not yet been derived to account for serial correlation within the data sets.

The BSMS Target site is at the end of the system:

(i) Station 425002: Darling River @ Wilcannia (total flow).

N.B. The total flow at Wilcannia consists of the main channel flow in the Darling River at Wilcannia (425008) plus the flow in Talyawalka Creek (425018), an effluent which leaves the Darling River approximately 50 km upstream of Wilcannia. Only flow data is collected in Talyawalka Creek.

The additional sites evaluated were the major mass balance points (ie. those gauges that are reliably over the full flow range):

(ii) Station 422001: Barwon River @ Walgett;

(iii) Station 425003: Darling River @ Bourke; and

(iv) Station 425008: Darling River @ Wilcannia (main channel).

The other sites are unreliable during high flows and were used only to check salinity results:

(v) Station 422004: Barwon River @ Mogil Mogil;

(vi) Station 422003: Barwon River @ Collarenebri;

(vii) Station 422002: Barwon River @ Brewarrina;

(viii) Station 425004: Darling River @ Louth;

(ix) Station 425900: Darling River @ Tilpa.

These sites are shown in Figure 5.3, and the results presented in the following section.

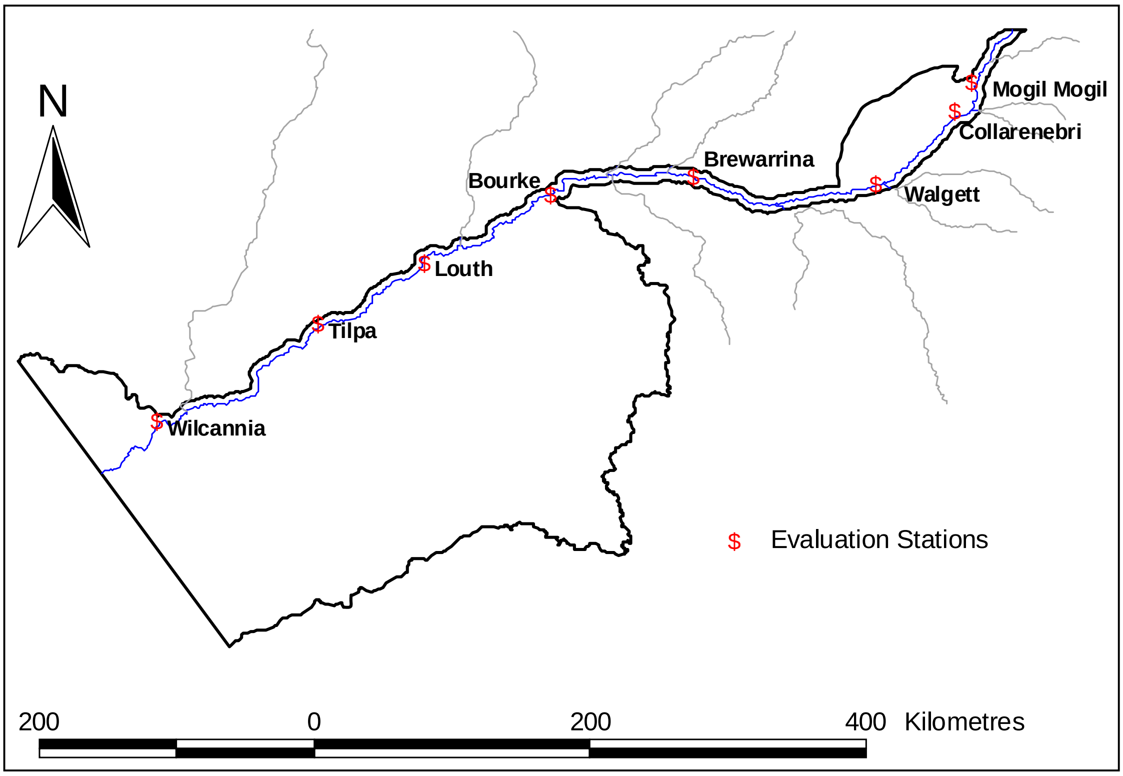


Figure 5.3. Location of evaluation sites.

5.2.3. Data quality performance measures

A component of evaluating model results is to understand how representative the observed data is of the hydrologic conditions in the catchment. EC observations at any location vary considerably depending on which of the following may apply: total flow; proportion of base flow compared with surface flow; where in catchment flow originated; stream-aquifer interactions; degree of regulation; antecedent conditions; season variability; and any underlying trends.

How good a data set is depends on how reasonably it samples all of the above. Because they cannot all be individually quantified, performance measures for the entire quality data include:

(i) how many data points there are;

(ii) what period the data represents;

(iii) what is the seasonal distribution of the data; and

(iv) how the data is distributed within the flow ranges.

The flow ranges referred to in this table are based on observed flow as follows:

- High flows exceeded between 0-20% of the time
- Medium flows exceeded between 20-80% of the time
- Low flows exceeded between 80-100% of the time

These percentiles were selected to approximate the corresponding BSMS reporting intervals for the salinity non-exceedance graphs. The same flow ranges were used as reporting groups for performance measure (iv), which compares the flow variability for that flow range with the flow variability within that range for days with EC data.

A good result for performance measures (i)-(iii) is a uniform distribution across the flow ranges and across all months, as well as the more data the better. A good result for performance measure (iv) is a close approximation of the observed flow statistics, ie; the observations sample the flow variability.

Time series graphs, of the full set of screened salinity data (Table 3.1) and observed flows, at evaluation locations are shown at the end of this chapter (Figure 5.11 to Figure 5.13). Performance measures (i), (ii), and (iii) are reported in Table 5.2. Performance measure (iv) from above is reported in Table 5.3.

5.2.4. Model result performance measures

Performance measures for comparing simulated and observed results for in-stream locations are reported within the three flow ranges defined in Section 5.2.2, as well as for the total flow range. For observed and simulated flow and concentration, the following are reported in tabular format:

- (i) mean;
- (ii) standard deviation;
- (iii) maximum; and
- (iv) minimum.

In addition, the following are reported for concentration:

- (v) mean error (Equation 5.3), which measures the average difference between simulated and observed; and
- (vi) coefficient of determination (Equation 5.4), which measures the ratio of explained variation to total variation.

Where S_t and O_t are simulated and observed measures at time *t*. These performance measures are dimensionless to allow for comparison between results at different sites. A perfect result for performance measures (v) is zero, and for (vi) is one.

$$E = \frac{\left| \sum_i S_i - \sum_i O_i \right|}{\sum_i O_i} \qquad (5.3)$$

$$R^2 = \frac{\sum_i (S_i - \overline{O})^2}{\sum_i (O_i - \overline{O})^2} \qquad (5.4)$$

Lastly, mean simulated loads are also compared for each flow range. An example with these results is shown in Table 5.4.

5.3. EVALUATION OF INITIAL ESTIMATES

The model has been evaluated at three sites along the main stream of the Barwon-Darling River System. The basis for selecting these sites is discussed in Section 5.2.2. Time series plots comparing observed and simulated salinity are located at the end of this chapter (Figure 5.11 to Figure 5.13), and discussion of these results with performance measures are presented in Sections 5.3.1 to 5.3.3.

5.3.1. Station 422001: Barwon River @ Walgett

Data has been collected fairly consistently at this gauging station. Samples have been collected every 1-2 months, over the evaluation period (1/5/1975 to 30/4/2000), except for a gap during 1991/92 and more frequent sampling during 1981, 1993 and 1996-97 (Figure 5.11). The salinity ranges from about 50 to 525 mg/L, with a median salinity of 170 mg/L.

The data is representative for all the flow ranges and months (Table 5.2). None of the flow ranges is over- or under-represented compared with the exceedance probability range. Table 5.3 shows that sampling in the medium flow range tends to be biased towards the lower flows whilst in the high flow range, data was collected during all but the highest flow events. In the low flow range, the data has similar statistical characteristics to those of the complete low flow record.

The results show that the model slightly overestimates flows, particularly in the upper medium to high range, at Walgett (Figure 5.4a). The lowest 15% of salinities are overestimated whilst the highest 30% are underestimated, the latter by as much as 50 mg/L (Figure 5.4b). However, salt loads are consistently overestimated (Table 5.4), primarily due to the problems in matching the flows.

Table 5.2. Distribution of flow with discrete EC across flow ranges and months for Station 422001: Barwon River @ Walgett

Flow range	Period	Number Points	Number of months with data											
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Low	1975-2000	75	6	4	3	5	3	1	4	2	2	2	4	4
Medium		240	10	12	8	8	10	10	6	5	11	10	9	13
High		71	3	4	4	1	4	5	2	3	2	1	2	4
All		386	14	16	13	12	15	14	12	9	13	11	12	15

Table 5.3. Comparison of statistics within flow ranges of all observed flows versus observed flows on days with discrete EC data during evaluation period for Station 422001: Barwon River @ Walgett

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	89	74	0	212
	With EC obs	96	62	1	210
Medium	*All*	1,480	1,514	213	6,693
	With EC obs	1,258	1,286	215	6,662
High	*All*	27,597	40,472	6,705	446,239
	With EC obs	21,392	20,223	6,849	124,281
ALL	*All*	6,421	20,997	0	446,239
	With EC obs	4,735	11,759	1	124,281

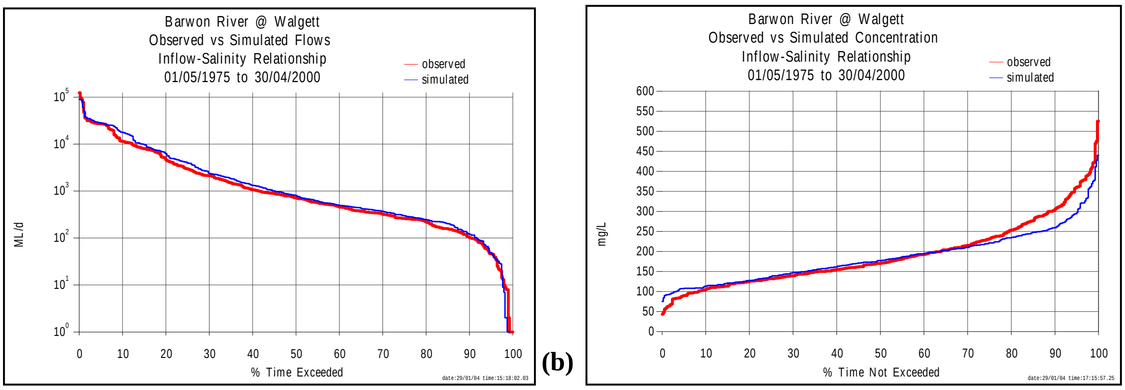


Figure 5.4. Station 422001: Barwon River @ Walgett; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity

Table 5.4. Comparison of statistics within flow ranges of: (i) observed versus simulated flow; (ii) observed discrete versus simulated salinity; and (iii) observed versus simulated load for Station 422001: Barwon River @ Walgett

Flow range	Data set	Distributions								C_o versus C_s		Mean load (t/d)
		Flow (ML/d)				Salinity (mg/L)				Mean error (mg/L)	R^2	
		Mean	S.D	Min	Max	Mean	S.D	Min	Max			
Low	Observed	102	59	8	210	259	93	94	525			25
	Simulated	231	469	2	3,865	266	65	132	440	68	0.20	48
Medium	Observed	1,258	1,286	215	6,662	191	70	43	475			210
	Simulated	1,501	1,707	121	9,581	181	41	75	290	46	0.25	222
High	Observed	21,391	20,223	6,849	124,281	120	32	56	193			2,612
	Simulated	23,394	17,513	6,230	89,988	120	22	84	174	22	0.18	2,743
All	Observed	4,797	11,824	8	124,281	190	82	43	525			624
	Simulated	5,348	11,549	2	89,988	185	63	75	440	46	0.43	660

5.3.2. Station 425003: Darling River @ Bourke

At the gauging station at Bourke, data has been collected at least every 1-2 months over the evaluation period, with the exception being gaps in 1975/76 and 1991/92. Also sampling was more frequent between 1981 and 1991 (Figure 5.12). The salinity ranges from about 50-660 mg/L, with one observation of 817 mg/L. This is unlikely to be an error as it occurs at the end of a long period of little or no flow and similar salinities were observed downstream at Wilcannia shortly afterwards. The median salinity is 195 mg/L. The increase in salinity between Walgett and Bourke is mainly due to high salinity inflows from the Macquarie River Valley.

The data is representative of all the flow ranges and months (Table 5.5). The high flow range (flows greater than 11,107 ML/d) is slightly over-represented (26% of data points) compared with the exceedance probability range (20% of the time). Consequently, both the low (less than 425 ML/d) and medium flow ranges are slightly under-represented (containing 17% and 57% of the data points respectively). In the medium and low flow ranges, the data has similar statistical characteristics to those of the complete flow record in those ranges Table 5.6. In the high flow range, data was collected during all but the very highest flow events.

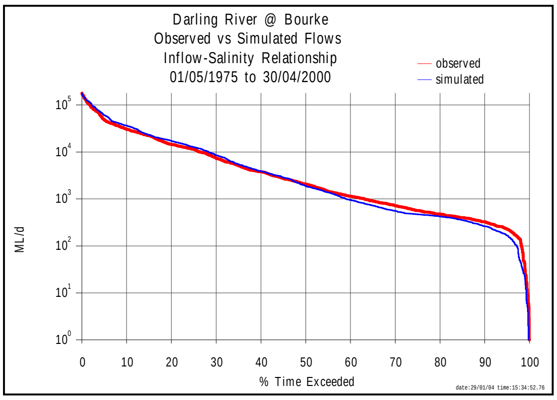
The simulated flow matches the observed flow distribution well (Figure 5.5a). However, salinity is significantly underestimated except for the lowest 10% of values (Figure 5.5b and Figure 5.16). Consequently, salt loads are also greatly underestimated, especially in the low and medium flow ranges (Table 5.7).

Table 5.5. Distribution of flow with discrete EC across flow ranges and months for Station 425003: Darling River @ Bourke

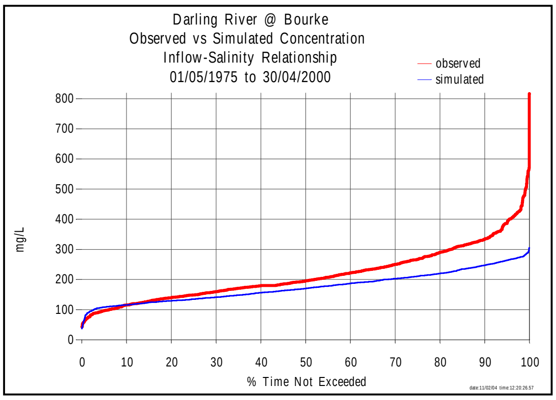
Flow range	Period	Number Points	Number of months with data											
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Low	1975-2000	261	9	10	5	7	7	4	6	6	5	3	3	4
Medium		873	18	17	16	16	11	16	12	12	12	16	15	14
High		395	4	5	8	7	7	8	6	9	6	5	3	5
All		1,529	20	19	21	22	19	22	20	22	20	18	18	17

Table 5.6. Comparison of statistics within flow ranges of all observed flows versus observed flows on days with discrete EC data during evaluation period for Station 425003: Darling River @ Bourke

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	204	147	0	425
	With EC obs	277	111	1	425
Medium	*All*	2,668	2,586	426	11,107
	With EC obs	2,748	2,645	426	11,095
High	*All*	43,080	53,200	11,108	529,589
	With EC obs	39,548	34,692	11,124	168,391
ALL	*All*	10,250	28,974	0	529,589
	With EC obs	11,833	24,142	1	168,391



(a)



(b)

Figure 5.5. Station 425003: Darling River @ Bourke; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity

Table 5.7. Comparison of statistics within flow ranges of: (i) observed versus simulated flow; (ii) observed discrete versus simulated salinity; and (iii) observed versus simulated load for Station 425003: Darling River @ Bourke

Flow range	Data set	Distributions								C_o versus C_s		Mean load (t/d)
		Flow (ML/d)				Salinity (mg/L)						
		Mean	*S.D*	*Min*	*Max*	*Mean*	*S.D*	*Min*	*Max*	*Mean error (mg/L)*	R^2	
Low	*Observed*	278	110	1	425	293	86	101	564			81
	Simulated	275	184	1	1,212	239	36	106	305	73	0.05	61
Medium	*Observed*	2,748	2,645	426	11,095	225	85	43	817			547
	Simulated	2,835	3,291	166	22,786	178	38	42	275	63	0.19	429
High	*Observed*	39,547	34,691	11,124	168,391	142	40	43	268			5,121
	Simulated	41,134	34,651	7,650	177,166	128	21	37	178	25	0.56	4,998
All	*Observed*	11,841	24,148	1	168,391	215	91	43	817			1,650
	Simulated	12,300	24,635	1	177,166	175	49	37	305	55	0.40	1,548

5.3.3. Station 425008: Darling River @ Wilcannia (main channel)

The gauging station on the Darling River @ Wilcannia (main channel) has had data collected every 1-2 weeks from over much of the evaluation period. The exceptions to this occurring during 1975-80, 1985-87 and 1990 periods when relatively few samples were taken (Figure 5.13). The salinity ranges from 54 to 960 mg/L, with a median salinity of 184 mg/L.

The data is representative of all the flow ranges and months (Table 5.8). The high flow range is over-represented (32% of data points) compared with the exceedance probability range (20% of the time). Consequently, both the medium (325-11,355 ML/d) and low flow ranges are slightly under-represented (containing 52% and 16% of the data points respectively). As at Walgett and Bourke, Table 5.9 indicates that data was not collected during very high flow events, although the problem is much less pronounced here. Apart from this, the data in all the flow ranges has similar statistical characteristics to those of the complete flow record.

The results show that the highest 3%, lower 50% and particularly the lowest 15% of flows tend to be overestimated, whilst the remaining flows are slightly underestimated (Figure 5.6a). However, salinity is underestimated for more than 80% of the time (Figure 5.6b). The median simulated salinity is about 20 mg/L lower than the observed, the 80th percentile about 80 mg/L lower, and the maximum 675 mg/L lower. Salt loads, like salinities, are also underestimated for all but the lowest flow range (Table 5.10).

Table 5.8. Distribution of flow with discrete EC across flow ranges and months for Station 425008: Darling River @ Wilcannia (main channel)

Flow range	Period	Number Points	Number of months with data											
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Low	1975-2000	**167**	4	6	6	4	4	3	3	3	5	5	8	4
Medium		**537**	14	15	11	15	11	11	10	10	12	12	12	13
High		**332**	1	2	4	7	7	6	6	7	5	4	3	2
All		**1,036**	17	18	18	19	16	18	16	16	19	19	20	16

Table 5.9. Comparison of statistics within flow ranges of all observed flows versus observed flows on days with discrete EC data during evaluation period for Station 425008: Darling River @ Wilcannia (main channel)

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	132	107	0	325
	With EC obs	130	98	0	324
Medium	*All*	2,526	2,650	326	11,495
	With EC obs	2,684	2,763	326	11,355
High	*All*	24,922	10,547	11,498	68,488
	With EC obs	24,098	8,773	11,506	45,400
ALL	*All*	6,524	10,578	0	68,488
	With EC obs	9,135	11,622	0	45,400

(a) (b)

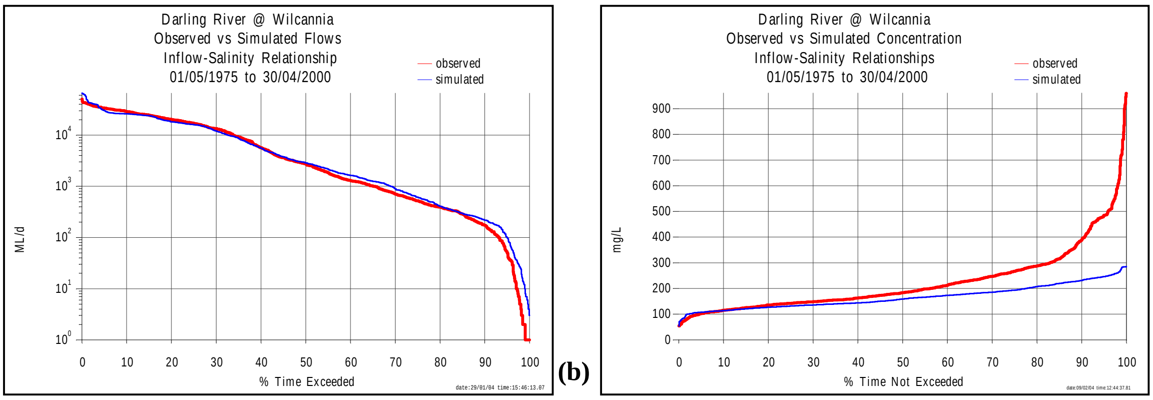


Figure 5.6. Station 425008: Darling River @ Wilcannia (main channel); (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity

Table 5.10. Comparison of statistics within flow ranges of: (i) observed versus simulated flow; (ii) observed discrete versus simulated salinity; and (iii) observed versus simulated load for Station 425008: Darling River @ Wilcannia (main channel)

Flow range	**Data set**	**Distributions**								**C_o versus C_s**		**Mean load (t/d)**
		Flow (ML/d)				**Salinity (mg/L)**				*Mean error (mg/L)*	R^2	
		Mean	*S.D*	*Min*	*Max*	*Mean*	*S.D*	*Min*	*Max*			
Low	*Observed*	130	98	0	324	369	168	70	960	168	0.07	45
	Simulated	273	313	3	1,899	220	38	136	285			56
Medium	*Observed*	2,671	2,757	326	11,355	230	108	72	809	76	0.07	542
	Simulated	2,839	2,977	104	22,545	173	35	72	264			446
High	*Observed*	24,098	8,773	11,506	45,400	141	34	54	310	24	0.28	3,390
	Simulated	23,598	10,793	8,089	66,136	126	18	54	167			2,945
All	*Observed*	9,141	11,632	0	45,400	224	129	54	960	74	0.22	1,376
	Simulated	9,090	11,932	3	66,136	166	44	54	285			1,185

5.3.4. Station 425002: Darling River @ Wilcannia (total flow)

As explained in Section 5.2.2, Station 425002 represents the sum of the flows at two gauging stations: Darling River @ Wilcannia (main channel) (425008) and Talyawalka Creek @ Barrier Highway (425018). Talyawalka Creek, as an effluent of the Darling River, has no salinity data of its own and the salinity of the total flow at Wilcannia is assumed to be the same as that measured in the main channel.

The results show that all but the very highest flows tend to be slightly overestimated (Figure 5.7a). As in the main channel results, the model greatly underestimates salinity except for the lowest 10% of values (Figure 5.7b). Salt loads are also underestimated for all but the lowest flow range (Table 5.11).

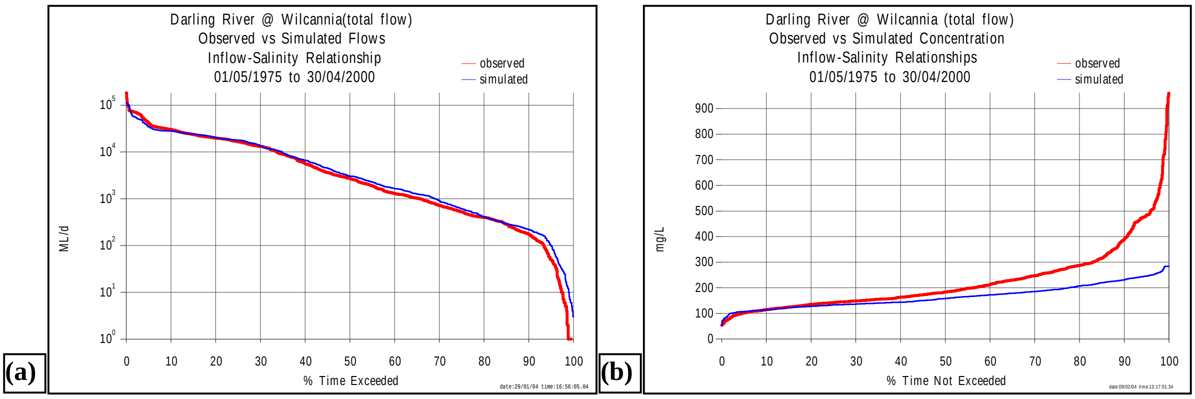


Figure 5.7. Station 425002: Darling River @ Wilcannia (total flow); (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity

Table 5.11. Comparison of statistics within flow ranges of: (i) observed versus simulated flow; (ii) observed discrete versus simulated salinity; and (iii) observed versus simulated load for Station 425002: Darling River @ Wilcannia (total flow)

Flow range	Data set	Distributions								C_o versus C_s		Mean load (t/d)
		Flow (ML/d)				Salinity (mg/L)				*Mean error (mg/L)*	R^2	
		Mean	*S.D*	*Min*	*Max*	*Mean*	*S.D*	*Min*	*Max*			
Low	*Observed*	144	108	0	339	364	165	70	960			49
	Simulated	280	306	3	1,899	219	37	136	284	163	0.06	57
Medium	*Observed*	2,949	3,046	343	12,394	227	107	72	809			587
	Simulated	3,420	3,574	105	18,404	171	35	72	263	75	0.08	532
High	*Observed*	30,094	20,719	12,452	184,043	141	33	54	230			4,248
	Simulated	27,960	17,034	8,516	113,277	127	18	54	164	23	0.35	3,503
All	*Observed*	10,925	17,492	0	184,043	224	129	54	960			1,635
	Simulated	10,525	15,361	3	113,277	166	44	54	284	74	0.23	1,376

5.3.5. Discussion of results from simulation with initial salinity estimates

At Walgett, salt loads are consistently overestimated due to problems in matching the flows and, in low flow range, by significant underestimation of salinities. In general, the simulated salinity distribution and average daily salt loads are within 10% of the observed values. The match between the simulated and observed flow distributions is better at Bourke and Wilcannia than at Walgett. However, the moderate and high salinities and hence the salt loads are consistently underestimated by 10 to 20% or more.

There are three possible reasons for the underestimation of salinity in the reaches of the Barwon-Darling River IQQM:

(i) the flow-salinity tables used at gauged inflow points don't reproduce the variability seen in the observed data;

(ii) assuming the same salinity for a floodplain inflow as for a nearby gauge is a practical solution to the lack of data but cannot take into account any salt picked up from the surface of the floodplain; and

(iii) interaction between the river and the groundwater table could add salt to the river but these processes are not considered in the model.

Without a reasonable period of continuous salinity data, at least for the major gauged inflows, there is not much that can be done to improve on the results obtained using these initial estimates flow-salinity tables. Nor is there any point in calibrating these inputs as they will be replaced with simulated inputs in the Barwon-Darling baseline model. (Eg: The flow-salinity table at Mungindi (416001), one of the largest inflows, produced quite poor results compared to observed continuous salinities but even significant adjustments had little effect on the results at Bourke.)

The floodplain salinities will also be replaced with simulated inputs in the baseline model, so they too are effectively 'outside' the Barwon-Darling IQQM with respect to salinity calibration.

Previous studies indicate that surface-groundwater interaction occurs along the Barwon River between Walgett and Bourke (Braaten and Gates, 2002) and the Darling River below Bourke (Williams, 1993 and Woolley, 1997). The movement of saline groundwater into the river would cause an increase in river salinity, even if there were no net observable flow of water into the river. Groundwater salinities over 20,000 mg/L have been observed downstream of Bourke. To simulate the salinity increase caused by surface-groundwater interaction, pairs of inflow and loss nodes could be added and calibrated, without upsetting the flow balance of the model.

5.4. SALINITY MODEL CALIBRATION

5.4.1. Method

The previous evaluation of modelled and observed salinities demonstrated that in two of the three major reaches, Walgett to Bourke and Bourke to Wilcannia, a significant net contribution of salt occurred. It was concluded that most of this salt came from high saline groundwater, either as direct inflow or as salt washoff from the banks. The aim of this calibration was to match the statistical characteristics of the observed data along the mainstream (ie Walgett, Bourke and Wilcannia).

The groundwater salt inputs were calibrated using the following procedure:

(i) A component of the river flow is estimated from the simulated flow at the calibration point using the baseflow separation tool in IQQM. This baseflow tool uses a Recursive Digital Filter (Nathan and McMahon, 1990) with filter parameter value equal to 0.995.

(ii) Two nodes are added to the model; one to add the new 'groundwater inflow' and one to remove it, thus preserving the flow balance of the calibrated flow model.

(iii) An estimated flow-salinity table is applied to the groundwater inflow and the model is run.

(iv) The flow-salinity table is revised systematically until a good match is achieved for the 20th, 50th and 80th percentiles of the salinity exceedance curve at the calibration point.

5.4.2. Station 422001: Barwon River @ Walgett

Evaluation of the model at Walgett shows that flow and salt load are overestimated despite the highest salinities being underestimated. Therefore, adding salt to match the high salinities would only make the salt load results worse. As the simulated salinities and salt loads are generally already within 10% of the observed values, no calibration was done in this reach.

5.4.3. Station 425003: Darling River @ Bourke

The model evaluation showed that salinity was significantly underestimated for all but the lowest 10% of values, see Figure 5.5, leading to a similar underestimation of salt loads.

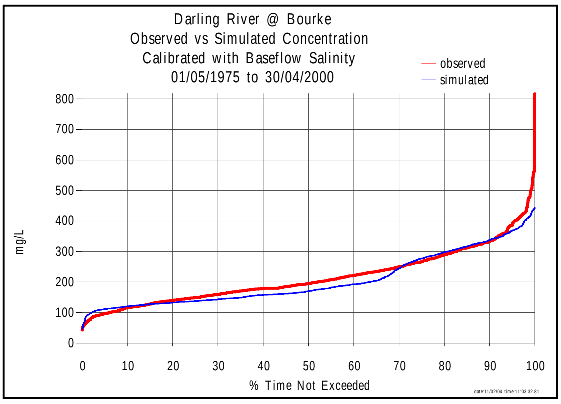
The groundwater salinity procedure, as described above, was applied and the flow-salinity table that was systematically adjusted to achieve the best possible salinity duration curve match at Bourke is shown in Table 5.12.

The calibration greatly improved both the salinity and salt load results (Figure 5.8a, Figure 5.8b and Table 5.13).

Table 5.12. Calibrated flow versus salinity relationship for groundwater inflow node between Station 422001: Barwon River @ Walgett and Station 425003: Darling River @ Bourke

Flow (ML/d)	Concentration (mg/L)
0	460
140	440
383	420
541	340
770	200
1,103	185
1,348	180
1,886	140
2,475	130
2,938	130
3,364	120
4,606	111
5,465	50
1e37	50

(a)



(b)

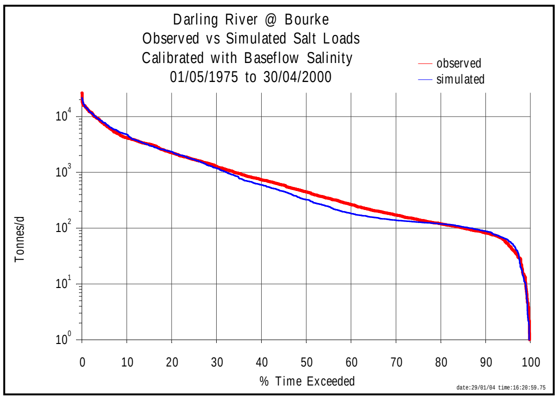


Figure 5.8. Calibrated model results for Station 425003: Darling River @ Bourke; (a) Non-exceedance curve for observed versus simulated salinity, (b) Exceedance curve for observed versus simulated salt load.

Table 5.13. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 425003: Darling River @ Bourke

Flow range	Data set	Distributions				C_o versus C_s		Mean load (t/d)
		Salinity (mg/L)				*Avg. error (mg/L)*	R^2	
		Mean	*S.D*	*Min*	*Max*			
Low	*Observed*	293	86	101	564			81
	Simulated	340	53	144	443	87	0.02	84
Medium	*Observed*	225	85	43	817			547
	Simulated	198	61	52	373	65	0.14	437
High	*Observed*	142	40	43	268			5,121
	Simulated	128	20	46	171	25	0.57	5,008
All	*Observed*	215	91	43	817			1,650
	Simulated	204	86	46	443	58	0.34	1,559

5.4.4. Station 425008: Darling River @ Wilcannia (main channel)

The results of the model evaluation at Wilcannia are similar to those at Bourke: salinities and salt loads are greatly underestimated for all but the lowest 10% of values.

The groundwater salinity procedure was applied at two locations to calibrate salinity between Bourke and Wilcannia. The first location, just upstream of Louth, uses the simulated baseflow at the Louth gauge (425004). The second location was just before the Talyawalka Creek effluent and uses the simulated baseflow at the Wilcannia main channel gauge (425008). The two flow-salinity tables were calibrated to match the salinity duration curves at Louth and Wilcannia respectively (Table 5.14). Results are presented only for Wilcannia as Louth is not a model evaluation site.

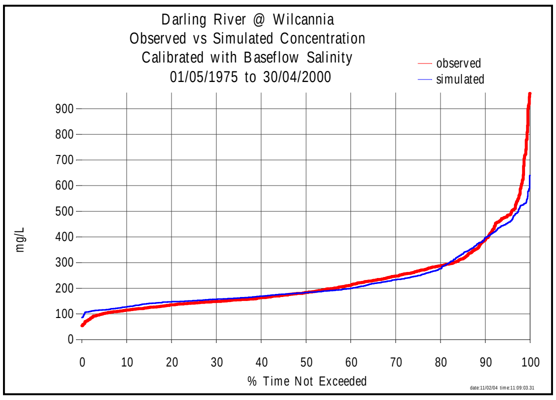
The calibration significantly improved the salinity results, especially for the moderate to high values (Figure 5.9). Although the changes also caused an overestimation of the lower salinities, the error is of a similar magnitude to the previous underestimation, and does not adversely affect the salt load results. The salt loads are still too low in the medium and high flow ranges and too high in the low flow range. Apart from the latter, the results are much better than those produced by the initial model (Table 5.15).

Table 5.14. Calibrated flow versus salinity relationships for groundwater inflow nodes between Station 425003: Darling River @ Bourke and Station 425008: Darling River @ Wilcannia (main channel)

Groundwater inflow node upstream of Louth	
Flow (ML/d)	**Concentration (mg/L)**
0	1100
200	680
350	600
430	275
500	240
590	230
800	220
1,000	200
2,000	200
3,000	200
5,000	140
10,000	30
1e37	10

Groundwater inflow node upstream of Wilcannia	
Flow (ML/d)	**Concentration (mg/L)**
0	1,200
18	800
25	700
50	500
100	490
200	470
250	380
300	340
350	320
500	280
750	260
1,000	200
2,000	190
5,000	180
10,000	175
20,000	170
30,000	100
1e37	50

(a)



(b)

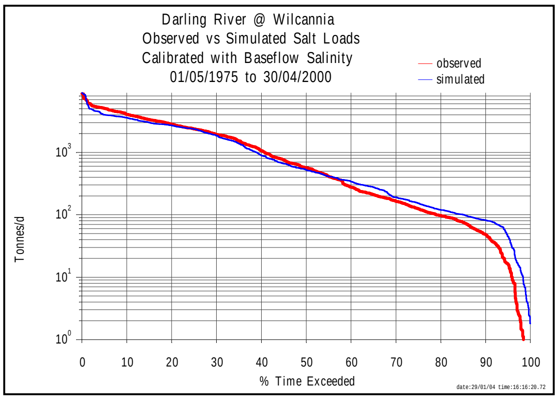


Figure 5.9. Calibrated model results for Station 425008: Darling River @ Wilcannia (main channel); (a) Non-exceedance curve for observed versus simulated salinity, (b) Exceedance curve for observed versus simulated salt load

Table 5.15. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 425008: Darling River @ Wilcannia (main channel)

Flow range	Data set	Distributions				C_o versus C_s		Mean load (t/d)
		Salinity (mg/L)				*Mean error (mg/L)*	R^2	
		Mean	*S.D*	*Min*	*Max*			
Low	*Observed*	369	168	70	960			45
	Simulated	403	94	193	640	156	0.02	87
Medium	*Observed*	230	108	72	809			543
	Simulated	214	58	112	485	76	0.07	509
High	*Observed*	141	34	54	310			3,390
	Simulated	140	19	86	171	22	0.27	3,203
All	*Observed*	224	129	54	960			1,375
	Simulated	221	104	86	640	71	0.28	1,304

5.4.5. Station 425002: Darling River @ Wilcannia (total flow)

The calibration produced a similar improvement in the salinity and salt load results for the Wilcannia total flow as it did for the main channel (Figure 5.10 and Table 5.16).

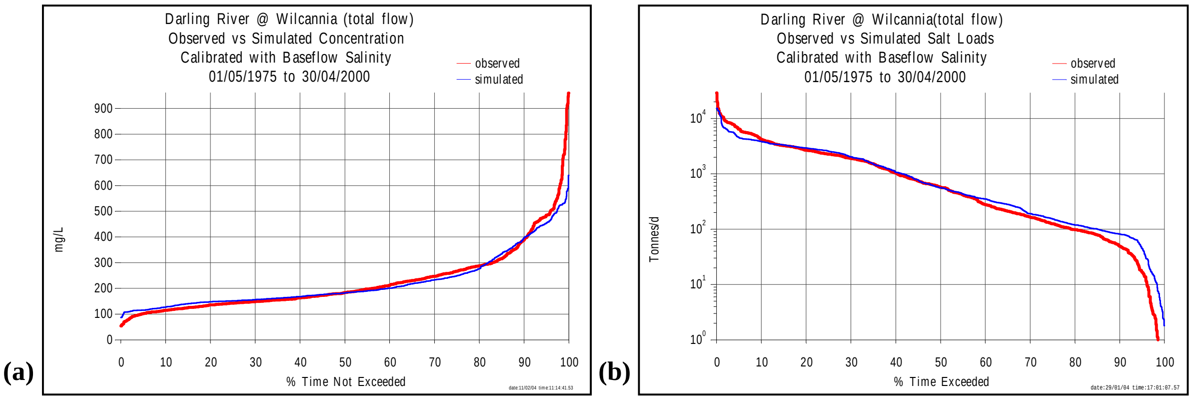


Figure 5.10. Calibrated model results for Station 425002: Darling River @ Wilcannia (total flow); (a) Non-exceedance curve for observed versus simulated salinity, (b) Exceedance curve for observed versus simulated salt load.

Table 5.16. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 425002: Darling River @ Wilcannia (total flow)

Flow range	Data set	Distributions				C_o versus C_s		Mean load (t/d)
		Salinity (mg/L)				*Mean error (mg/L)*	R^2	
		Mean	*S.D*	*Min*	*Max*			
Low	*Observed*	364	165	70	960			49
	Simulated	397	95	193	640	150	0.01	88
Medium	*Observed*	227	107	72	809			587
	Simulated	210	56	112	485	75	0.07	600
High	*Observed*	141	33	54	230			4,248
	Simulated	139	19	87	172	21	0.30	3,783
All	*Observed*	224	129	54	960			1,635
	Simulated	221	104	87	640	71	0.28	1,503

5.4.6. Discussion of results from calibration

The addition of extra salt via 'groundwater inflow' nodes in the Walgett to Bourke and Bourke to Wilcannia reaches produces a major improvement in the salinity and salt load results. Table 5.17 shows that the simulated salinity is now within 10% of the observed values, except during the low and medium flow periods at Bourke where it is within 10 to 20% of the observed values. The salt load results have also improved, although not to the same extent as the salinity results. Although there are still problems in the medium salt load range at Bourke and the low salt load range at Wilcannia, the overall load results are all within 10% of the observed values. Some of the difficulties in matching the salt loads (actually 'assumed' values, see Section 5.3.4) for Wilcannia total flow are due to known problems in modelling the flow division between the Darling River main channel and the Talyawalka Creek effluent.

Table 5.17. Summary of comparisons of simulated versus observed salt loads: calibrated model

Target Site		concentration match				salt load match			
Number	Name	*Low*	*Medium*	*High*	*All*	*Low*	*Medium*	*High*	*All*
		Legend: 1 < ±10%; 2 < ±20%; 3= > ±20%							
422001	Barwon River @ Walgett	1	1	1	1	3	1	1	1
425003	Darling River @ Bourke	2	2	1	1	1	3	1	1
425008	Darling River @ Wilcannia (main channel)	1	1	1	1	3	1	1	1
425002	Darling River @ Wilcannia (total flow)	1	1	1	1	3	1	2	1

5.5. VALIDATION OF RESULTS

So far, the model has only been evaluated using discrete salinity data. In this section, the continuous salinity data is used to assess the calibrated model in two different ways:

(i) The model results are compared with continuous salinity data where it is available at main river gauges (Table 3.3).

(ii) The flow-salinity table inputs in the model were replaced, where possible, with continuous salinity data (Table 3.1) and the results again compared with continuous salinity data where available at main river gauges.

The second method involved splitting the model into two at Walgett. The upstream model used continuous salinity inputs for the Barwon River @ at Mungindi (416001) and the Namoi River @ Goangra (419026). The downstream model used continuous flow and salinity data for the Barwon River @ Walgett (422001), thereby removing the effects of any accumulated flow and salinity errors upstream. The period of continuous data at these three stations restricted this run to the period 01/01/1996-30/06/1999.

The results and shown in Figure 5.22 to 5.29 and are discussed in Sections 5.5.1 to 5.4.5. A full statistical assessment is not possible at this stage, because: (i) methods have not been developed yet; (ii) the continuous data record is short and is not representative of the benchmark climate period; and (iii) there are discrepancies between discrete and continuous data. Nevertheless, the data is useful to assess that the model is representing the salinity behaviour correctly.

5.5.1. Station 422001: Barwon River @ Walgett

The model matches the general pattern of salinity behaviour at Walgett fairly well (Figure 5.22). The underestimated salinities in 1996 are due to poor modelling of the recessions following two large flow events. Similar problems with the simulated salinity occur during the second half of 1998 and throughout 1999 when flows are consistently overestimated. However, the salinity miss-match in the first half of 1998 is primarily caused by problems with the flow-salinity input relationships.

The Barwon River @ Mungindi (416001) and the Namoi River @ Goangra (419026) each contribute about 25% of the flow volume at Walgett. Replacing the flow-salinity tables at these inflows with observed salinity data generally did little to improve the salinity results at Walgett (Figure 5.23), thus confirming that most of the salinity modelling problems in this reach arise from flow modelling problems. However, the significant improvement seen in the first half of 1998, illustrates the consequence of using flow-salinity tables when they are not really applicable for all occasions. It follows that the model could be improved with better estimates of salinity behaviour for the Mehi River, Gil Gil Creek, Pian Creek and floodplain inflows.

5.5.2. Station 422002: Barwon River @ Brewarrina

The salinity behaviour at Brewarrina is similar to that at Walgett, both sites having a mean and median salinity of about 200 mg/L. Much of the time, salinity is slightly lower at Brewarrina but the peaks tend to be higher, often by 50 mg/L or more.

The calibrated model matches the observed salinity reasonably well although the flow and salinity problems seen at Walgett have been carried through (Figure 5.24). Replacing the flow and salinity inputs at Walgett with observed data removes these accumulated errors (Figure 5.25) but salinity is still overestimated, usually during recessions as flows are underestimated. The model still greatly underestimates the high salinities in early 1999.

5.5.3. Station 425004: Darling River @ Louth

There is not much flow data at Louth and the salinity data is patchy and possibly unreliable. There is little overlap with the discrete salinity data set, but the salinity data both at adjacent sites suggests that the very high salinities in 1998-99 are probably an inaccurate overestimate.

If the suspect data in 1998-99 is ignored, both the calibrated model and the model with observed inputs at Walgett roughly follow the observed salinity behaviour at Louth (Figure 5.26 and Figure 5.27). The observed and simulated means are reasonably close (293 mg/L versus 266 mg/L and 283 mg/L respectively) but the results are less conclusive than at Walgett and Brewarrina due to the limited data.

5.5.4. Station 425900: Darling River @ Tilpa

The continuous salinity data at Tilpa appears to be more reliable than that at Louth: the corresponding discrete data points follow the same pattern as the continuous data; and similar peaks and troughs are visible in the data at Wilcannia.

Both the calibrated model and the model with observed inputs at Walgett simulate the general pattern of salinity behaviour at Tilpa fairly well (Figure 5.28 and Figure 5.29). The most obvious discrepancy is the continued underestimation of the high salinities in early 1999.

5.6. MODEL SUITABILITY FOR PURPOSE

Each salt transport model has two key purposes under the BSMS. The first is to produce time series of flows, salinities, and salt loads for the Baseline Condition and the Benchmark Climate period. The second is to estimate the in-stream flow and salinity effects of land-based salinity management actions, such as landuse change and crop management. Finally, to estimate in-stream flow and salinity effects of changes to water sharing and utilisation, such as that of the Water Sharing Plans or other water management scenarios.

5.6.1. Baseline

The Barwon-Darling Rivers IQQM is a robust and reliable water balance model of the Barwon and Darling Rivers. Some issues have arisen in the course of the development of the salt transport model about the method used to estimate and calibrate flows from some tributary catchments. These methods developed a model that was fit for the purpose of water sharing, but create difficulties in calibrating the salt balance. There were mostly limitations in the methods used to estimate salinity from both ungauged and floodplain catchments. These issues were not a limitation for the previous water sharing work, but may effect reliability of results for the salt balance at sites in this system.

The results of the comparison for salinity and salt loads from the tables in Section 5.4 (model calibration) are summarised in Table 5.17. The quality of the results has been coded according to how close the simulated results match the mean observed concentrations or salt loads in the respective flow ranges.

At three of the four evaluation sties, the simulated concentrations are within ±10% of the mean observed concentrations, both overall and within each flow range. At Bourke, the low and medium flow ranges results are within ±20% of observed concentrations.

The total simulated salt loads were within ±10% of the observed salt loads at all four sites. The results within each flow range were more variable. In the low flow range, simulated loads were within ±10% of observed loads at Bourke but results were poor (>±20%) at the other sites. The opposite occurred in the medium flow range where only Bourke had poor results. In the high flow range, simulated loads were within ±10% of observed loads at all sites except Wilcannia (total flow) where loads where within ±10-20%. Most of the errors are due to difficulties in replicating the flow peaks and recessions accurately and problems in estimating inflow salinities without continuous salinity data.

In summary, the model appears to simulate the salinity behaviour in the river system reasonably well. Overall, the best that could be interpreted from these model results is that the model is able to simulate salt loads and concentrations within the ±10% range. The model is capable of simulating salt loads in the main river channel at Wilcannia, within the medium and high flow ranges. However there is more uncertainty within the low flow range. When floodplain flows at Wilcannia (ie total flows) are considered, the accuracy of the model is less clear. This lack of clarity is due to the unmeasured state of salinities on the floodplain (ie Talyawalka Creek) making it necessary to assume that they are exactly the same as the main channel.

5.6.2. Land use management scenarios

The CATSALT model is designed to simulate the changes to flow and salt loads resulting from changes to land use and cover in a catchment. The resultant time series would then be substituted for the time series used for the Baseline Conditions, and routed through the river system. This would produce a different distribution of flow, salinity, and salt load compared with the Baseline Condition.

5.6.3. Water management scenarios

The impacts of various management scenarios on salinity concentrations can be simulated with a reserved degree of confidence that must take into consideration the confidence limits of the model.

5.6.4. Additional plots

5.6.4.1. Observed flow and concentration

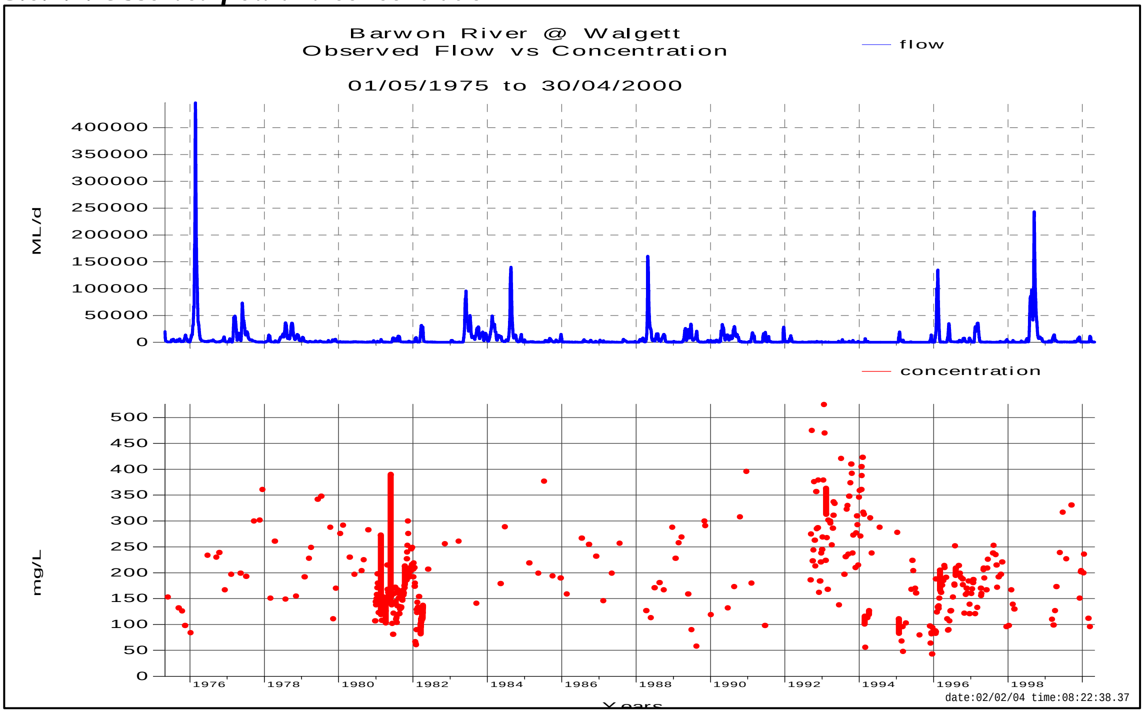


Figure 5.11. Station 422001: Barwon River @ Walgett, observed flow and concentration (discrete data)

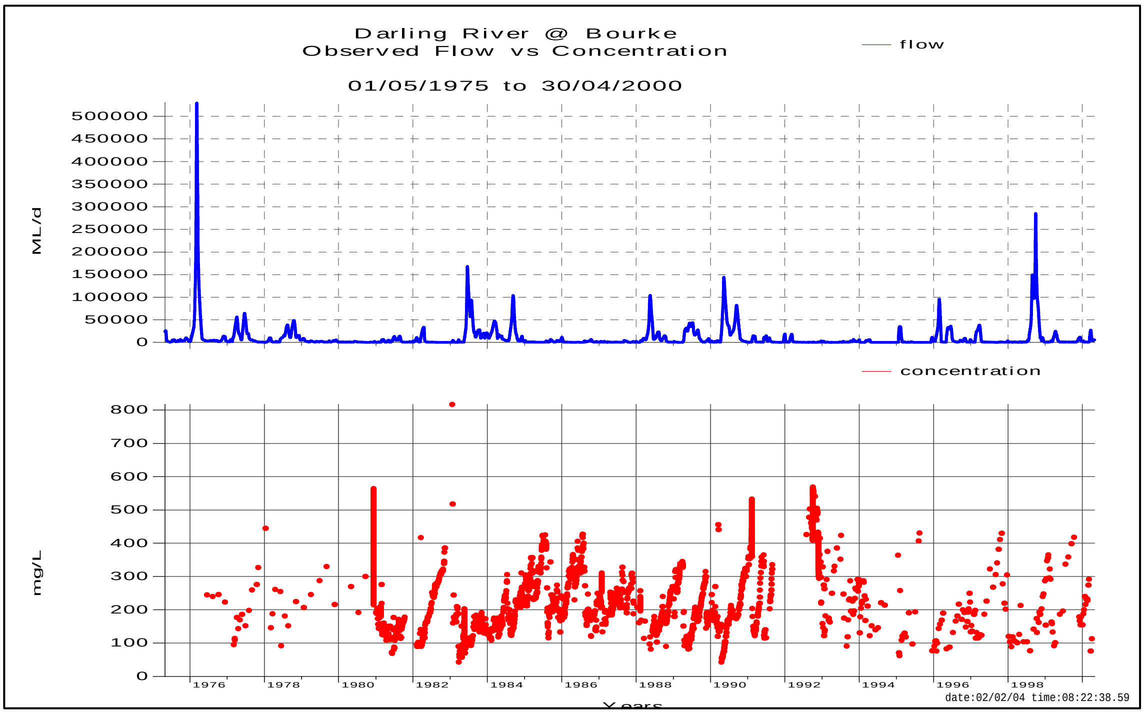


Figure 5.12. Station 425003: Darling River @ Bourke, observed flow and concentration (discrete data)

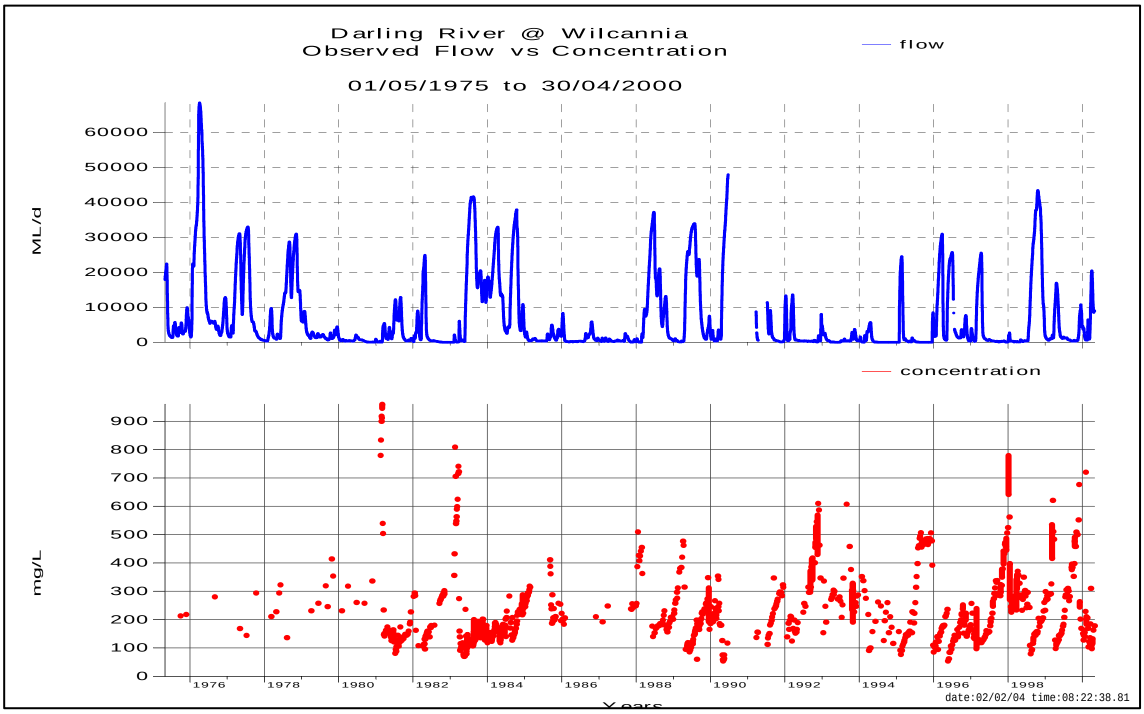


Figure 5.13. Station 425008: Darling River @ Wilcannia (main channel) flow and concentration data (discrete data)

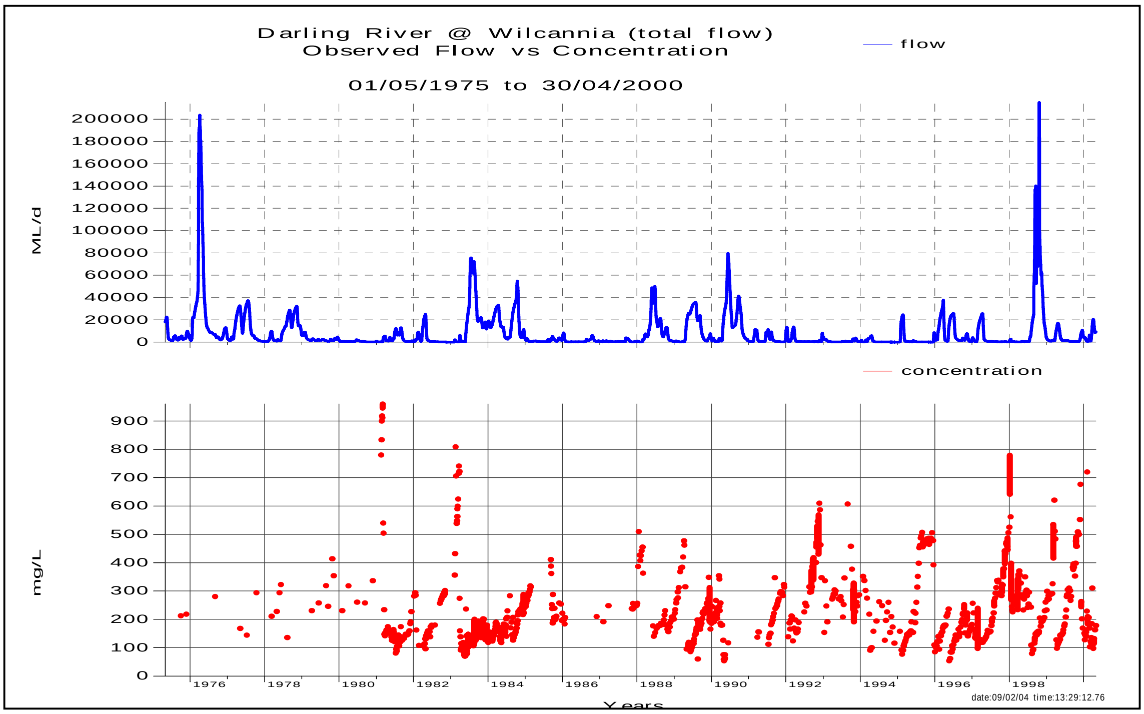


Figure 5.14. Station 425002: Darling River @ Wilcannia (total flow) flow and concentration data (discrete data at 425008)

5.6.4.2. Evaluation of initial model

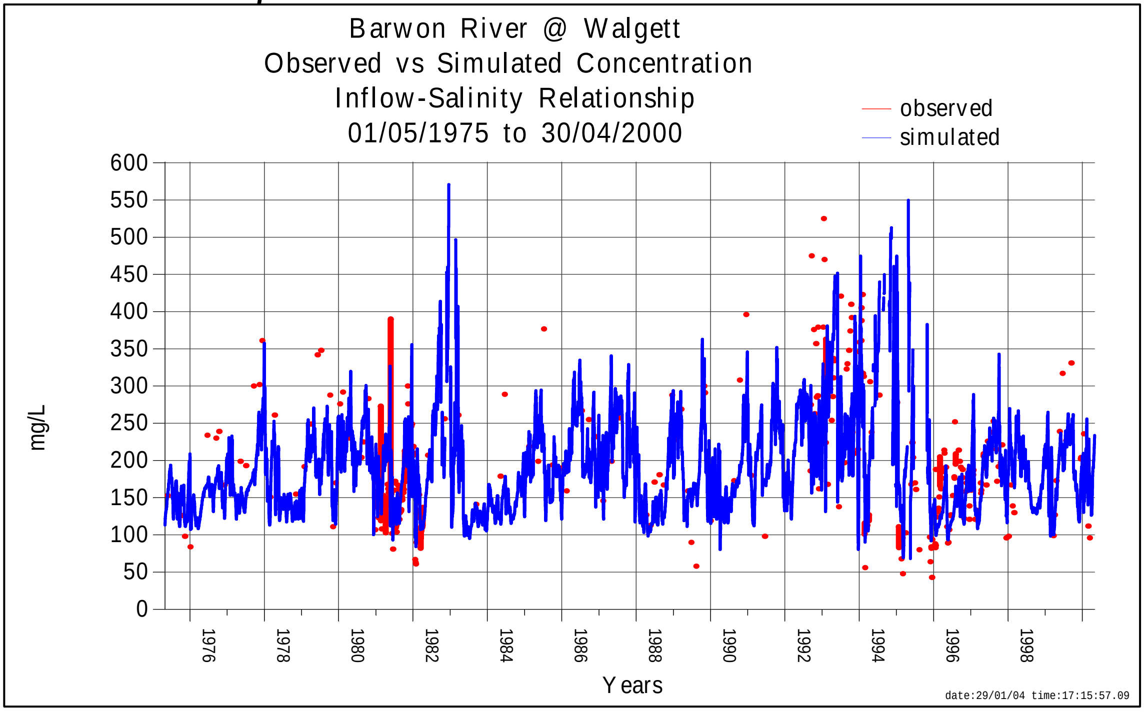


Figure 5.15. Simulated versus observed salinities (discrete data) at Station 422001: Barwon River @ Walgett, using flow-salinity tables for all inputs.

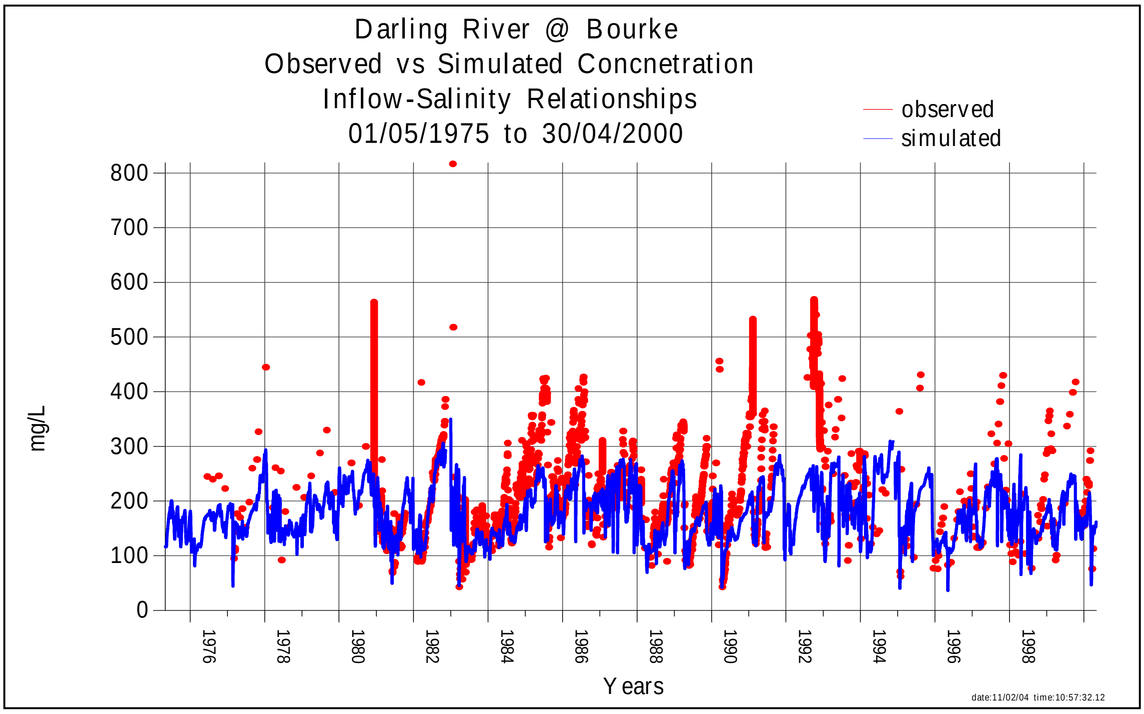


Figure 5.16. Simulated versus observed salinities (discrete data) at Station 425003: Darling River @ Bourke, using flow-salinity tables for all inputs

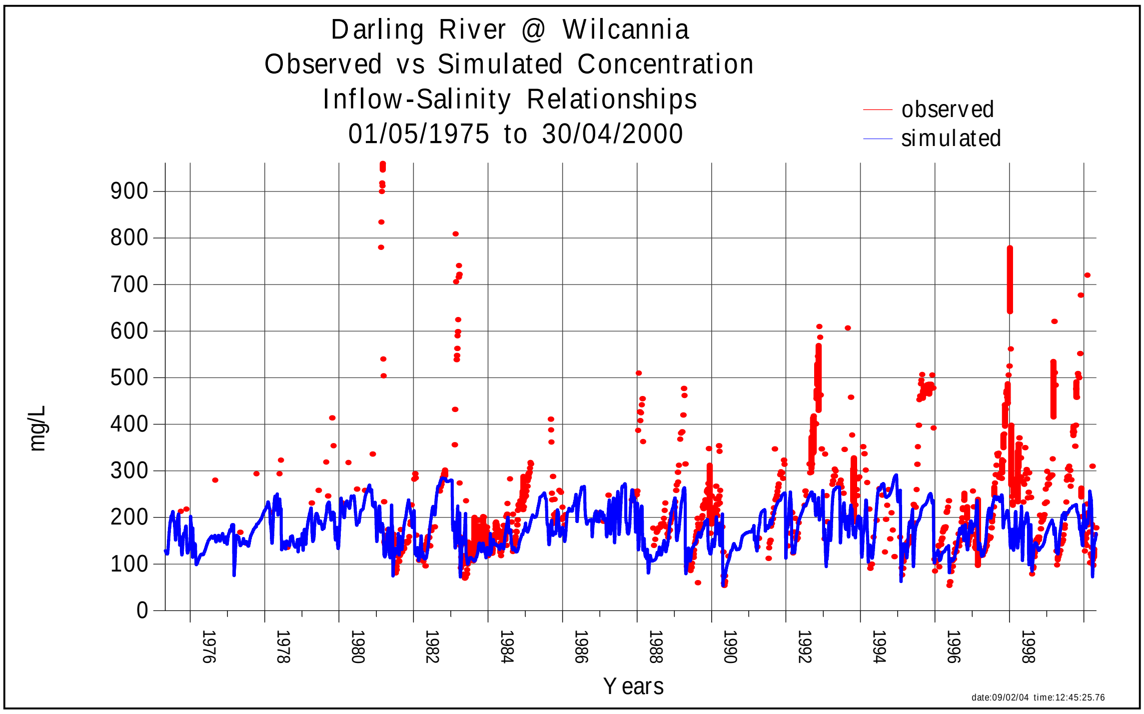


Figure 5.17. Simulated versus observed salinities (discrete data) at Station 425008: Darling River @ Wilcannia (main channel), using flow-salinity tables for all inputs.

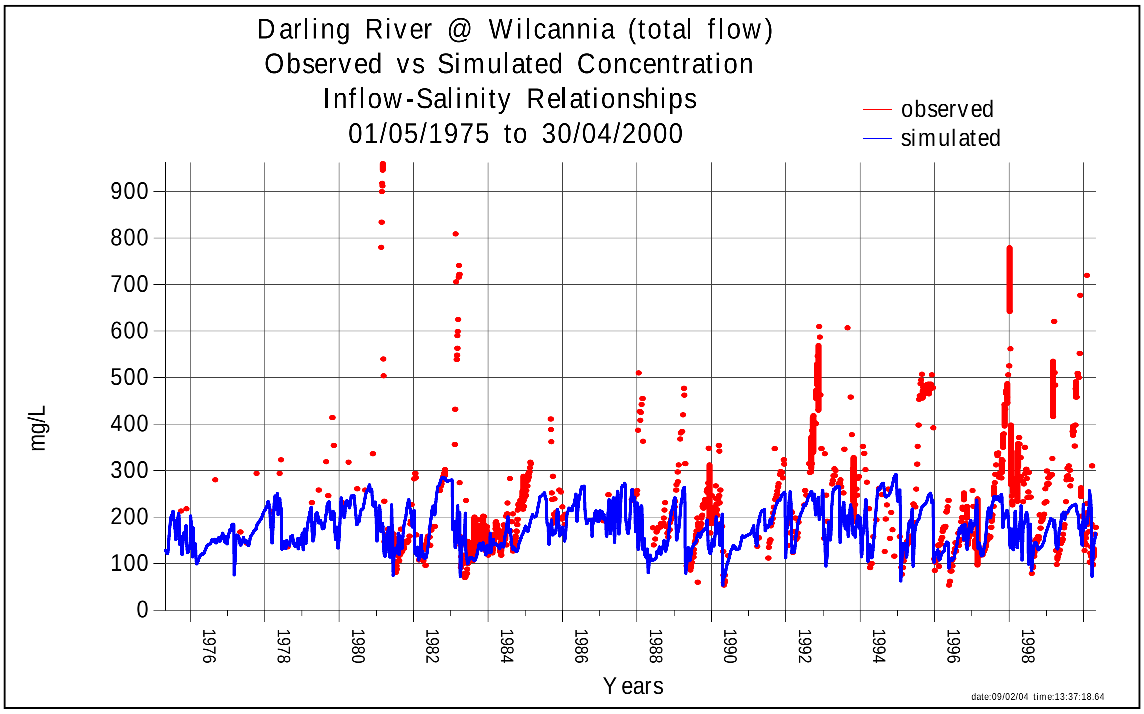


Figure 5.18. Simulated versus observed salinities (discrete data) at Station 425002: Darling River @ Wilcannia (total flow), using flow-salinity tables for all inputs.

5.6.4.3. Calibrated model results

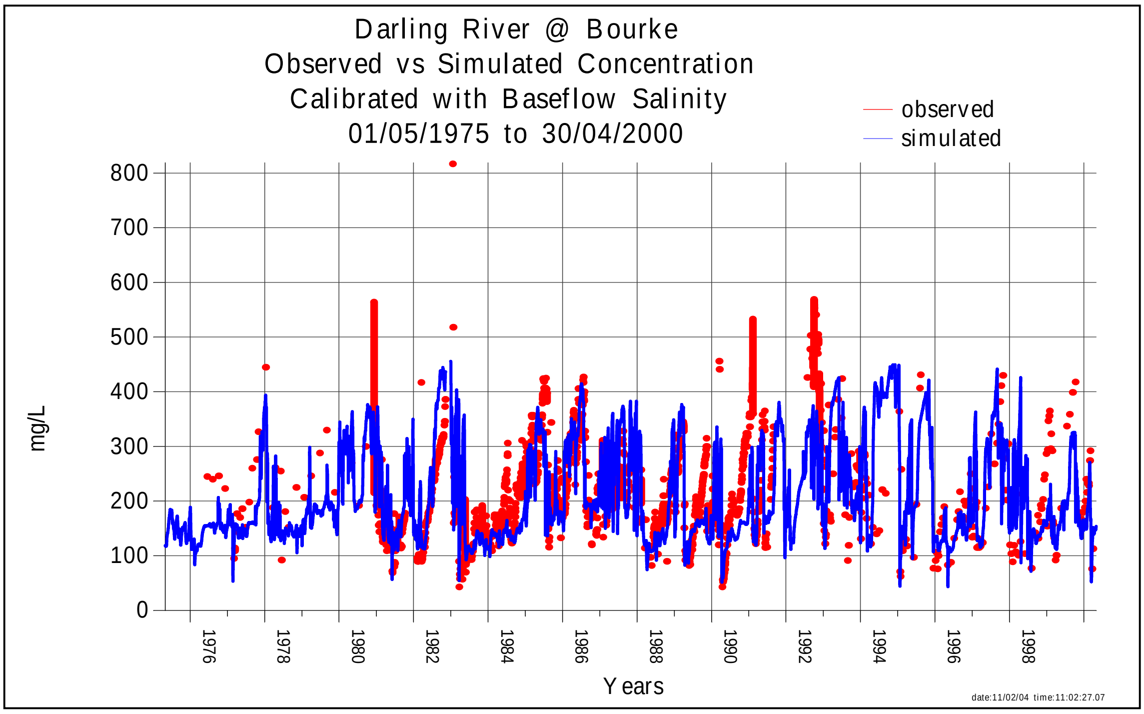


Figure 5.19. Simulated versus observed salinities (discrete data) at Station 425003: Darling River @ Bourke, using calibrated flow-salinity tables for groundwater inputs.

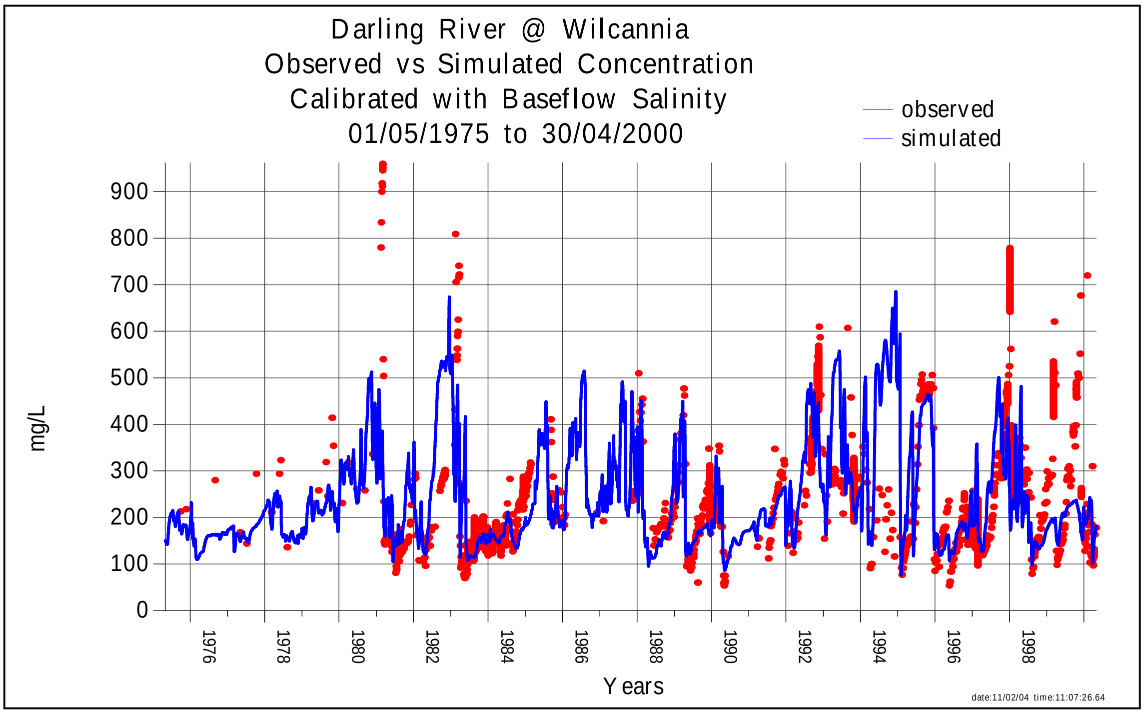


Figure 5.20. Simulated versus observed salinities (discrete data) at Station 425008: Darling River @ Wilcannia (main channel), using calibrated flow-salinity tables for groundwater inputs.

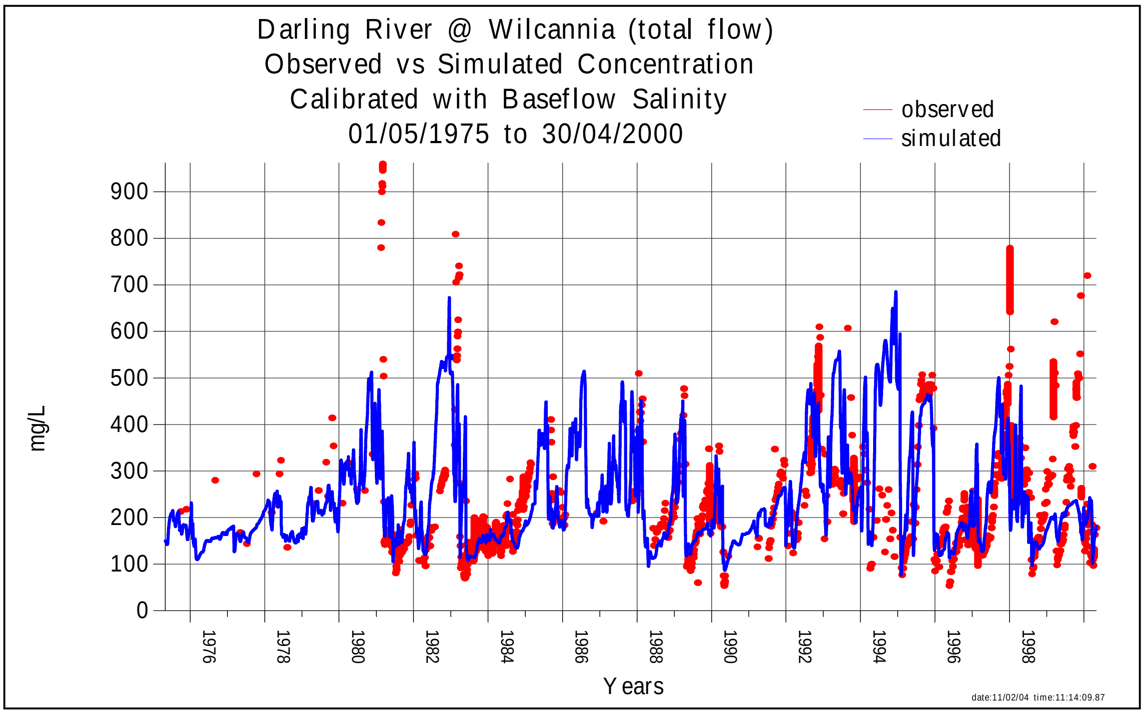


Figure 5.21. Simulated versus observed salinities (discrete data) at Station 425002: Darling River @ Wilcannia (total flow), using calibrated flow-salinity tables for groundwater inputs.

5.6.4.4. Validation of calibrated model

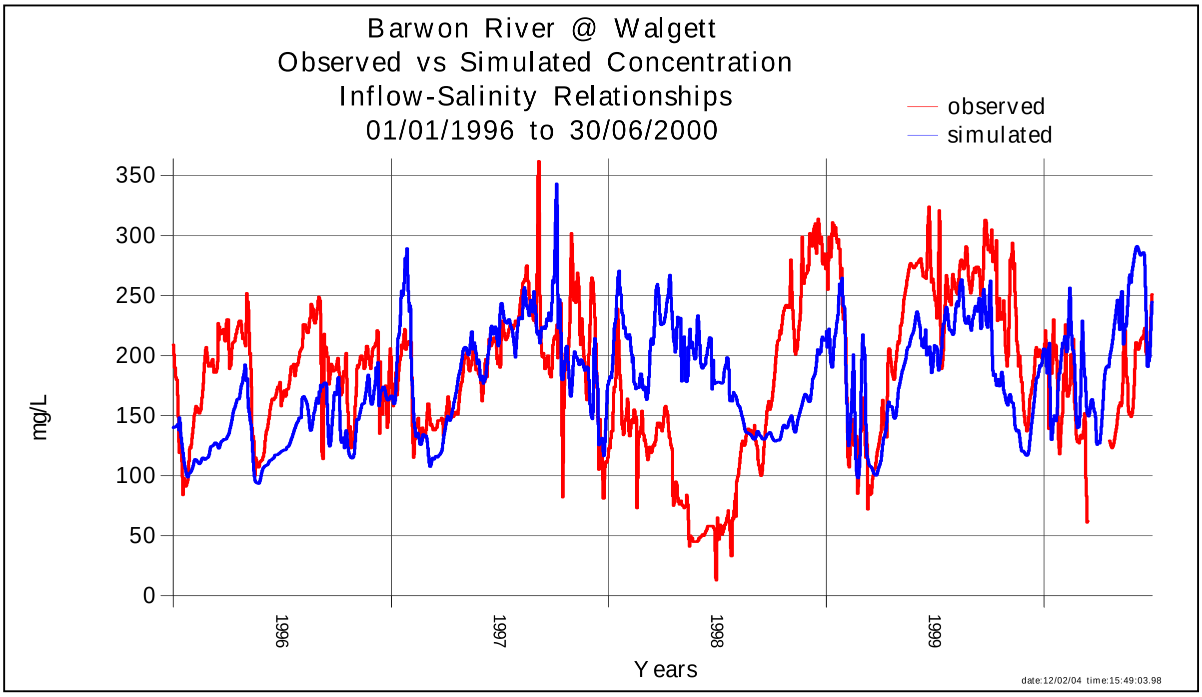


Figure 5.22. Simulated versus observed salinities (continuous data) at Station 422001: Barwon River @ Walgett, calibrated model using flow-salinity tables for all inputs.

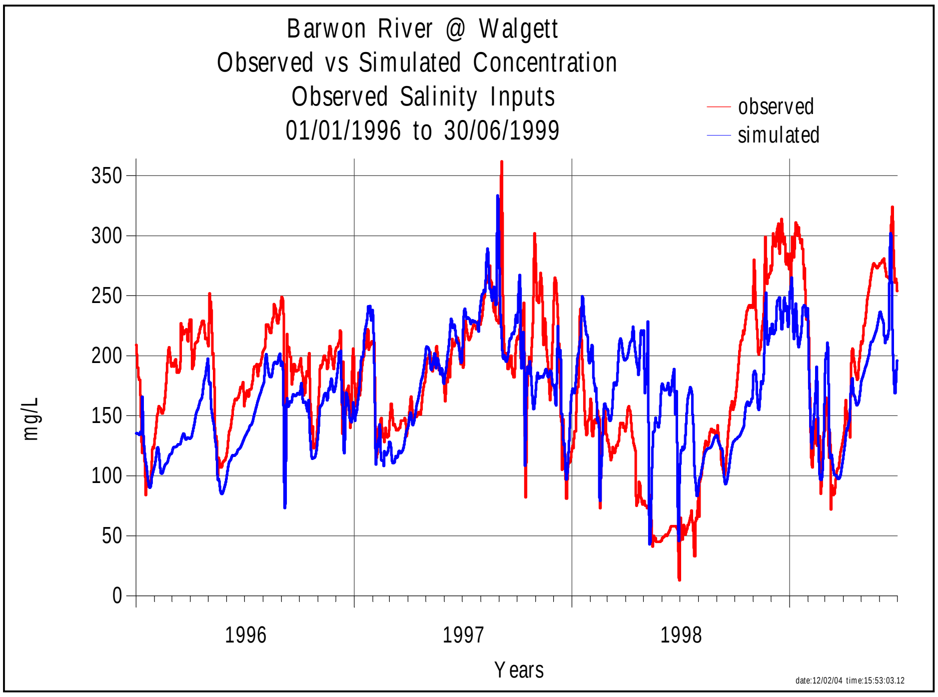


Figure 5.23. Simulated versus observed salinities (continuous data) at Station 422001: Barwon River @ Walgett, calibrated model with continuous salinity inputs for Barwon River @ Mungindi (416001) and Namoi River @ Goangra (419026).

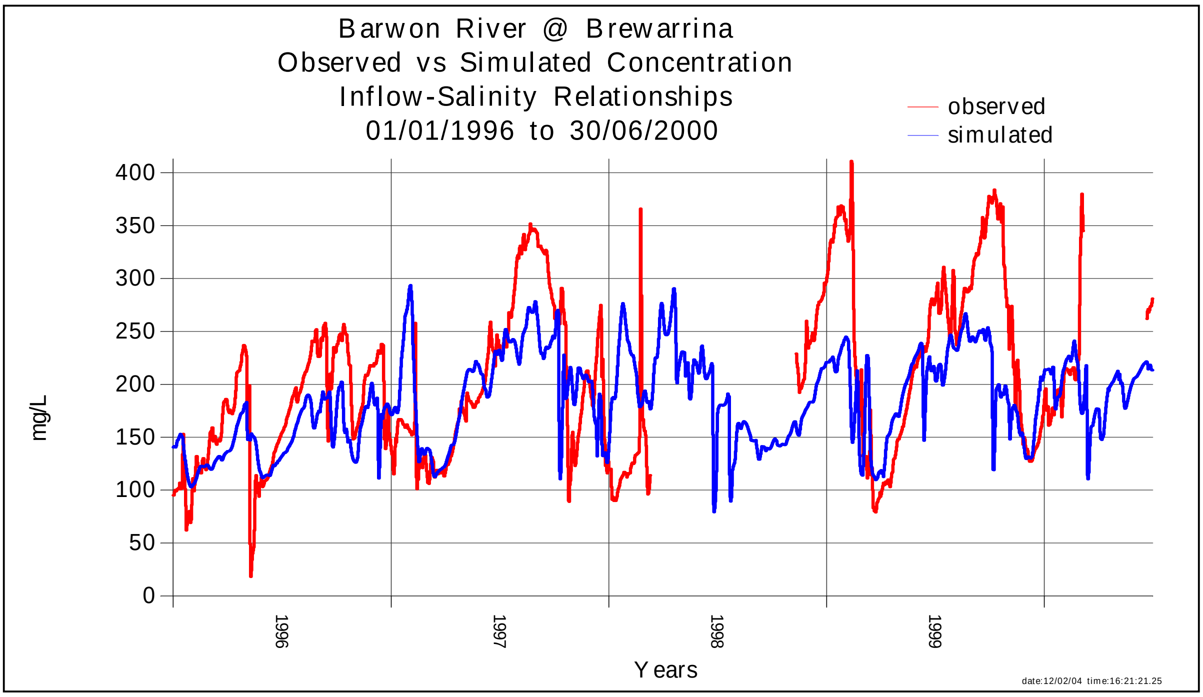


Figure 5.24. Simulated versus observed salinities (continuous data) at Station 422002: Barwon River @ Brewarrina, calibrated model using flow-salinity tables for all inputs.

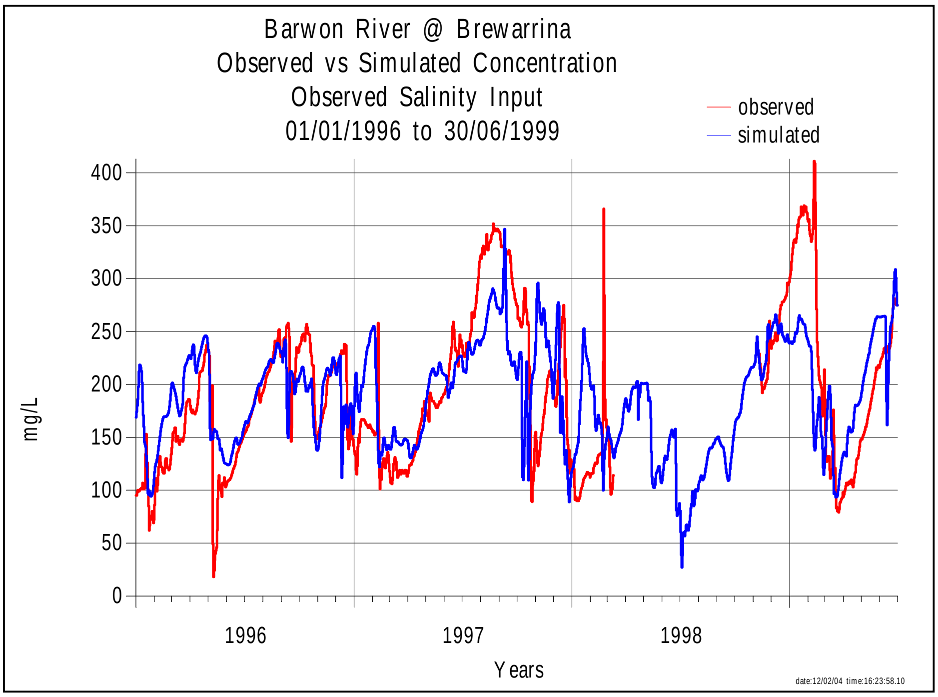


Figure 5.25. Simulated versus observed salinities (continuous data) at Station Barwon River @ Brewarrina, calibrated model with continuous salinity input for Barwon River @ Walgett (422001).

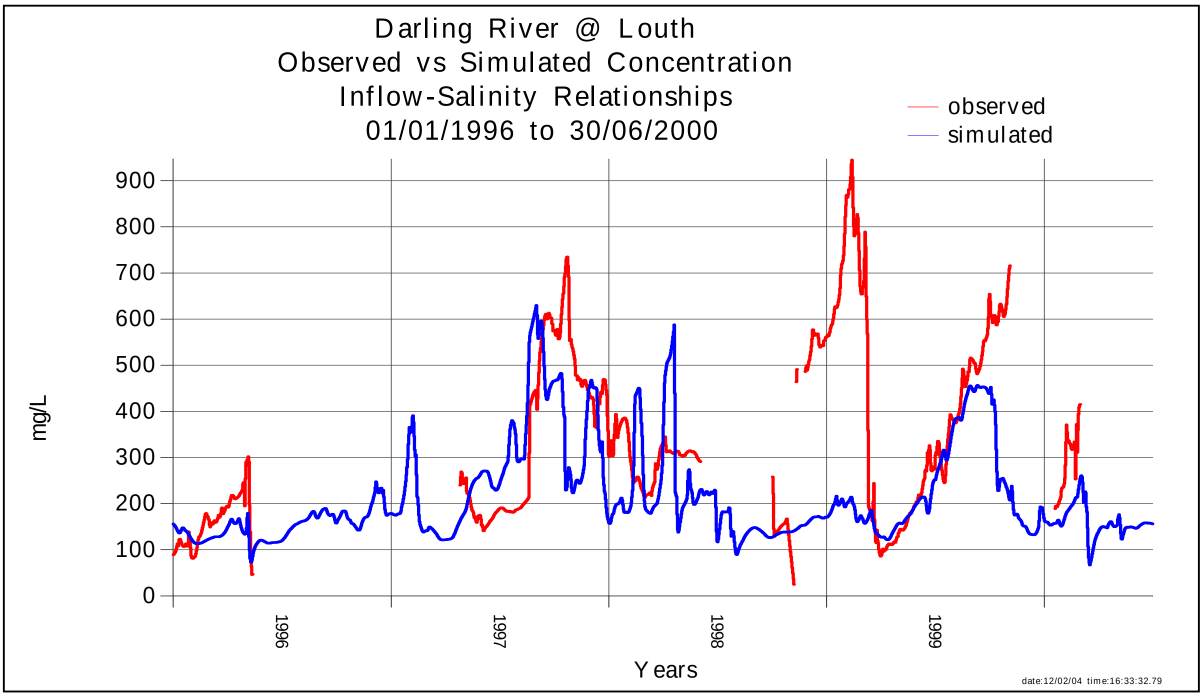


Figure 5.26. Simulated versus observed salinities (continuous data) at Station 425004: Darling River @ Louth, calibrated model using flow-salinity tables for all inputs.

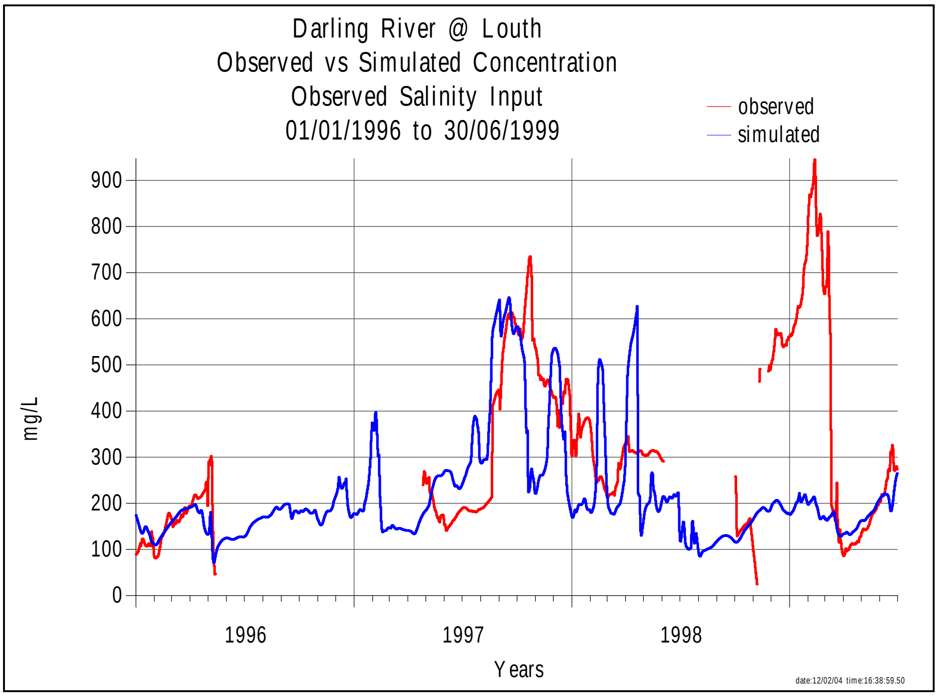


Figure 5.27. Simulated versus observed salinities (continuous data) at Station 425004: Darling River @ Louth, calibrated model with continuous salinity input for Barwon River @ Walgett (422001).

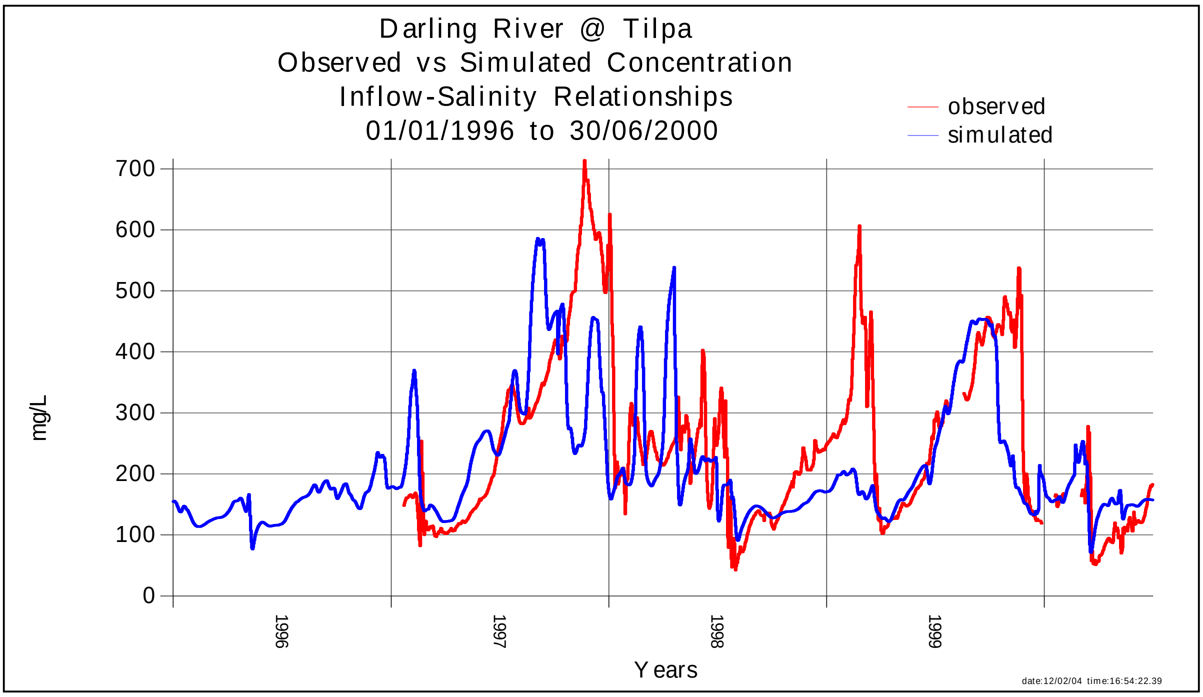


Figure 5.28. Simulated versus observed salinities (continuous data) at Station 425900: Darling River @ Tilpa, calibrated model using flow-salinity tables for all inputs.

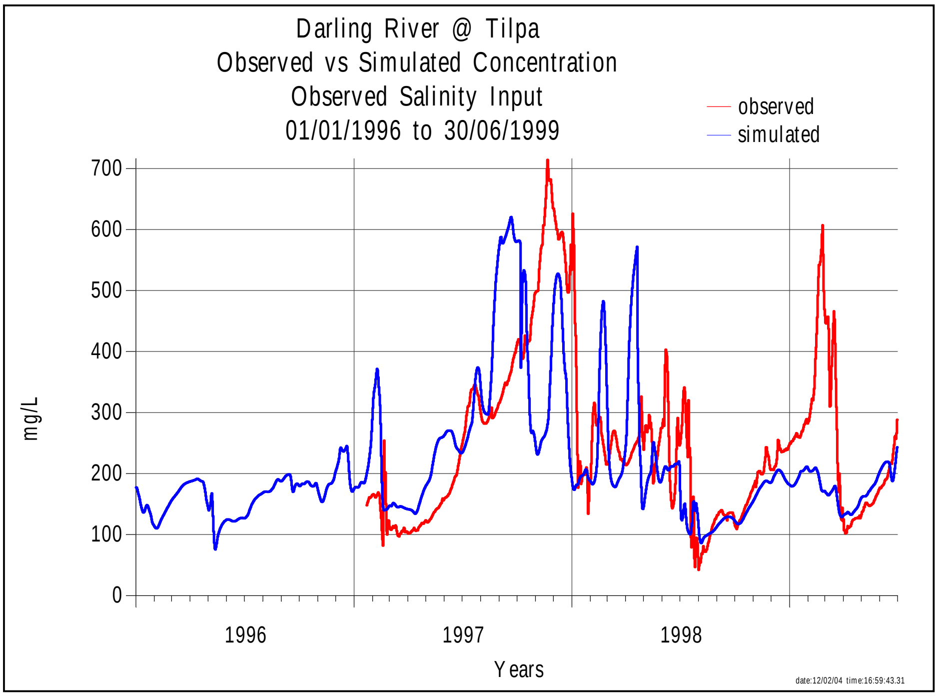


Figure 5.29. Simulated versus observed salinities (continuous data) at Station 425900: Darling River @ Tilpa, calibrated model with continuous salinity input for Barwon River @ Walgett (422001).

6. Baseline Conditions scenario

6.1. BASELINE CONDITIONS

The BSMS Schedule C requires definition of the following suite of baseline conditions in place within the catchments and rivers on 1 January 2000:

(i) land use;

(ii) water use;

(iii) land and water management policies and practices;

(iv) river operating regimes;

(v) salt interception schemes;

(vi) run-off generation and salt mobilisation processes; and

(vii) groundwater status and condition.

Points (i), (vi) and (vii) will influence the flows and salt inputs to the IQQM, whereas (ii) and (iv) are directly simulated by altering the IQQM configuration and parameterisation. Point (iii) affects both the inputs from the catchments and processes simulated in IQQM. Point (vii) may affect either catchment inflows or IQQM operation.

Defining the points affecting flow and salt inputs to the IQQM is problematic, as there is insufficient data to describe the important biophysical characteristics or to reliably estimate the quantitative response of catchments to these characteristics. Salt mobilisation and export from catchments is a dynamic process that changes in time and space. It varies with the spatial organisation of biophysical characteristics of a catchment, e.g.; geology, topography, landuse; as well as characteristics that change in time, such as climate and groundwater levels. The aggregate response to all these characteristics is measured at the catchment outlet. Unfortunately, these salinity measurements are sparse for tributaries, and cannot currently be used to separate out the effects that change over time. This situation will improve as the catchment modelling studies capture and analyse the catchment data, and additional continuous data.

For reasons of lack of suitable data to do otherwise, the flows and salt inflows were based on observations, without any adjustment for changes in catchment characteristics over the period of record.

Information is available to define water use in the Barwon-Darling River. This information has been collected, or developed in the process of setting up the IQQMs over the years. This information is summarised in Table 6.1.

The results from this simulation are reported in the following section.

Table 6.1. BSMS Baseline (01/01/2000) conditions for water sharing

Water Balance Component	Value	Units
Average annual inflows *(benchmark climatic period)*		
Barwon River from Mungindi to Walgett	2,764	GL/year
Barwon-Darling River from Walgett to Bourke	1,458	GL/year
Darling River from Bourke to Wilcannia	110	GL/year
Storages – n/a		
Irrigation		
Entitlement volume		
Large metered irrigators	447	GL/year
Small un-metered irrigators	66	GL/year
Maximum irrigable area		
Large metered irrigators	32,872	Ha
Small un-metered irrigators	1,665	Ha
Pump capacity		
Large metered irrigators	7,369	ML/day
Small un-metered irrigators	518	ML/day
On-farm storage capacity		
Large metered irrigators	275	GL
Small un-metered irrigators	1	GL

6.2. RESULTS

The model was run for the Benchmark Climate period with the calibrated salinity inflows (Table 6.2) and the water usage and policies that existed as at 1 January 2000. The results for the mean and percentile non-exceedances for daily concentrations and salt loads, at evaluation points, are reported in Table 6.3. The results for the mean and percentile non-exceedance annual salt load, at evaluation points, are reported in Table 6.4. The observed salinity, flow and salt load characteristics at Walgett, Bourke and Wilcannia during the Benchmark Climate period are described in Table 6.5. While the model results, and comparisons with the observed data, are shown in the plots at the end of the chapter (Figure 6.1 to Figure 6.30).

The Baseline salinity exceedance curves are generally consistent with the observed data at Walgett, Bourke and Wilcannia. However, the model does not reproduce the slight increase in salinity between Walgett and Bourke, nor does it match the highest 10% of salinity observations at Bourke and Wilcannia.

At Walgett, the Baseline flows and salt loads are similar to those observed over the Benchmark period. The reason for this is that the Mungindi to Walgett reach accounts for 64% of inflows but only 20% of diversions, so irrigation development during this period had little impact on flows at Walgett.

The opposite occurs in the Walgett to Bourke reach, which accounts for 34% of inflows and 60% of diversions under Baseline Conditions. In this reach, the model diverts more water than was used historically so the Baseline flow is about 11% lower than those observed at Bourke. However, as the model underestimates salinity at Bourke, the difference between the observed and Baseline salt loads is greater than that between the flows.

The Bourke to Wilcannia reach is dominated by losses and accounts for only 2.5% of inflows and 20% of diversions under Baseline Conditions. As irrigation development in this reach had little impact on flows at Wilcannia, the Baseline flows are 13% lower than the observed flows - a similar difference to that seen at Bourke. However, the difference between the observed and Baseline salt loads at Wilcannia is greater than at Bourke as the model continues to underestimate salinity.

Table 6.2. Flow and salt inflows for the Barwon-Darling IQQM – Baseline Conditions

IQQM inflow node no.	Type of input	Description	Flow input	Salt input
Barwon River from Mungindi to Walgett				
001	Gauged	416001 Barwon River @ Mungindi	Simulated: Border Rivers baseline model	
018	Gauged	416028 Boomi River @ Neeworra	Simulated: Border Rivers baseline model	
146	Floodplain	Border Rivers floodplain (includes Little Weir River)	Simulated: Border Rivers baseline model	
024	Gauged	416027 Gil Gil Creek @ Weemelah	Simulated: Gwydir R. baseline model	
028	Gauged	417001 Moonie River @ Gundablouie	Simulated: Moonie R. baseline model[(QDNRM)]	
360	Floodplain	Moonie River floodplain	Simulated: Moonie R. baseline model[(QDNRM)]	
038	Gauged	418031 Gwydir River @ Collymongle	Simulated: Gwydir R. baseline model	
343	Gauged	418055 Mehi River near Collarenebri	Simulated: Gwydir R. baseline model	
351	Floodplain	Gwydir River floodplain	Simulated: Gwydir R. baseline model	
303	Residual	Residual catchment: Mungindi-Walgett	Calibrated residual[(1)]	Constant 150 mg/L[(2)]
067	Gauged	419026 Namoi River @ Goangra	Simulated: Namoi R. baseline model	
068	Gauged	419049 Pian Creek @ Waminda	Simulated: Namoi R. baseline model	
076	Floodplain	Namoi River floodplain	Simulated: Namoi R. baseline model	
Barwon-Darling River from Walgett to Bourke				
370	Residual	Residual catchment: Walgett-Brewarrina (right hand side)	Calibrated residual[(1)]	Flow-salinity table[(2)] (Bokhara R. salinities)
085	Gauged	421012 Macquarie River @ Carinda	Simulated: Macquarie R. baseline model	
089	Gauged	421011 Marthaguy Creek @ Carinda	Simulated: Marthaguy Ck. baseline model [(1)]	Flow-salinity table[(2)] (Macquarie R. salinities)
094	Gauged	420005 Castlereagh River @ Coonamble	Simulated: Castlereagh River baseline model [(1)]	Flow-salinity table[(2)] (Castlereagh R. salinities)
371	Residual	Residual catchment: Walgett-Brewarrina (left hand side)	Calibrated residual[(1)]	Flow-salinity table[(2)] (Macquarie R. salinities)
372	Floodplain	Macquarie River floodplain (first half)	Simulated: Macquarie R. baseline model	
373	Floodplain	Condamine-Balonne floodplain (first 30%)	not yet modelled	
104	Gauged	421097 Marra Creek @ Carinda Road	Simulated: Marra Ck. baseline model [(1)]	Flow-salinity table[(2)] (Macquarie R. salinities)
182	Ungauged	Narran Lake overflow	Simulated: Narran Lake baseline model[(QDNRM)]	

IQQM inflow node no.	Type of input	Description	Flow input	Salt input
121	Gauged	422005 Bokhara River @ Bokhara	Simulated: Bokhara R. baseline model[QDNRM]	
382	Residual	Residual catchment: Brewarrina-Bourke (left hand side)	Calibrated residual[1]	Flow-salinity table[2] (Bogan R. salinities)
383	Floodplain	Macquarie River floodplain (second half)	Simulated: Macquarie R. baseline model	
384	Residual	Residual catchment: Brewarrina-Bourke (right hand side)	Calibrated residual[1]	Flow-salinity table[2] (Culgoa R. salinities)
385	Floodplain	Condamine-Balonne floodplain (remaining 70%)	not modelled	
127	Gauged	422006 Culgoa River d/s Collerina	Simulated: Culgoa R. baseline model[QDNRM]	
131	Gauged	421023 Bogan River @ Gongolgon	Simulated: BoganR. baseline model [1]	Flow-salinity table[2]
470	Salinity calibration	Groundwater inflow for salinity calibration: Walgett-Bourke	Simulated baseflow at Bourke[3]	Flow-salinity table[2]
Darling River from Bourke to Wilcannia				
401	Floodplain	Warrego River floodplain	not modelled	
402	Residual	Residual catchment: Bourke-Louth	Calibrated residual[1]	Constant 215 mg/L [2]
361	Gauged	423001 Warrego River @ Fords Bridge (main channel)	Simulated: Warrego R. baseline model[QDNRM]	
450	Salinity calibration	Groundwater inflow for salinity calibration: Bourke-Louth	Simulated baseflow at Louth[3]	Flow-salinity table[2]
403	Residual	Residual catchment: Louth-Tilpa	Calibrated residual[1]	Constant 260 mg/L [2]
404	Residual	Residual catchment: Tilpa-Wilcannia	Calibrated residual[1]	Constant 260 mg/L [2]
460	Salinity calibration	Groundwater inflow for salinity calibration: Louth-Wilcannia)[4]	Simulated baseflow at Wilcannia (main channel)[3]	Flow-salinity table[2]
405	Gauged	424001 Paroo River @ Wanaaring	not modelled	
406	Floodplain	Paroo River floodplain	not modelled	

(1) From original flow model calibration
(2) Used in initial salinity model and accepted in calibrated model
(3) Flow removed immediately to preserve modelled flow balance (ie. net inflow is zero)
(4) Input occurs upstream of Talyawalka Creek effluent
(QDNRM) Model developed by Queensland Department of Natural Resources and Mines

Table 6.3. Simulated results of salinity and salt load for MDBMC BSMS Baseline, using calibrated relationships applied to 1/1/2000 conditions model, based on analysis of daily results 01/05/1975-30/04/2000

Target Site		Concentration (mg/L)				Salt Load (T/day)			
Number	Name	*Mean*	*Percentile non exceedance*			*Mean*	*Percentile non exceedance*		
			20	*50*	*80*		*20*	*50*	*80*
422001	Barwon River @ Walgett	204	142	185	261	884	25	123	1,013
425003	Darling River @ Bourke	210	145	186	300	1,229	118	248	1,596
425002	Darling River @ Wilcannia (total flow)	252	156	212	311	1,059	114	268	1,722

- Note: In Bewsher (2004) it has been recommended that the Barwon Darling River model be classified as Class 3. This means there is low confidence in statistical variability of baseline conditions from this model. However, there should be some confidence that mean salt loads are of the right order. Predictions of changes in salinity are likely to be more accurate by comparing results from model runs.

Table 6.4. Simulated results of salt loads for MDBMC BSMS Baseline, using calibrated relationships applied to 1/1/2000 conditions model, based on analysis of annual results 01/05/1975-30/04/2000

Target Site		Salt load (x 1000 T/year)			
Number	Name	*Mean*	*Percentile non exceedance*		
			20	*50*	*80*
422001	Barwon River @ Walgett	323	42	231	429
425003	Darling River @ Bourke	449	62	324	615
425002	Darling River @ Wilcannia (total flow)	387	61	309	567

- Note: In Bewsher (2004) it has been recommended that the Barwon Darling River model be classified as Class 3. This means there is low confidence in statistical variability of baseline conditions from this model. However, there should be some confidence that mean salt loads are of the right order. Predictions of changes in salinity are likely to be more accurate by comparing results from model runs.

Table 6.5. Statistics of observed data for flow, salinity and salt load, 01/05/1975-30/04/2000

Site	Units	*Mean*	*Percentile non exceedance*		
			20	*50*	*80*
Concentration (mg/L)					
422001	Barwon River @ Walgett	190	126	170	253
425003	Darling River @ Bourke	215	140	196	290
425002	Darling River @ Wilcannia (total flow)	224	136	184	288
Flow (ML/d)					
422001	Barwon River @ Walgett	6,421	210	849	6,794
425003	Darling River @ Bourke	10,250	420	1,501	11,137
425002	Darling River @ Wilcannia (total flow)	8,189	335	1,439	12,505
Salt Load (T/d)					
422001	Barwon River @ Walgett	620	42	129	607
425003	Darling River @ Bourke	1,568	120	447	2,252
425002	Darling River @ Wilcannia (total flow)	1,635	99	575	2,672

6.2.1. Results at Station 422001: Barwon River @ Walgett

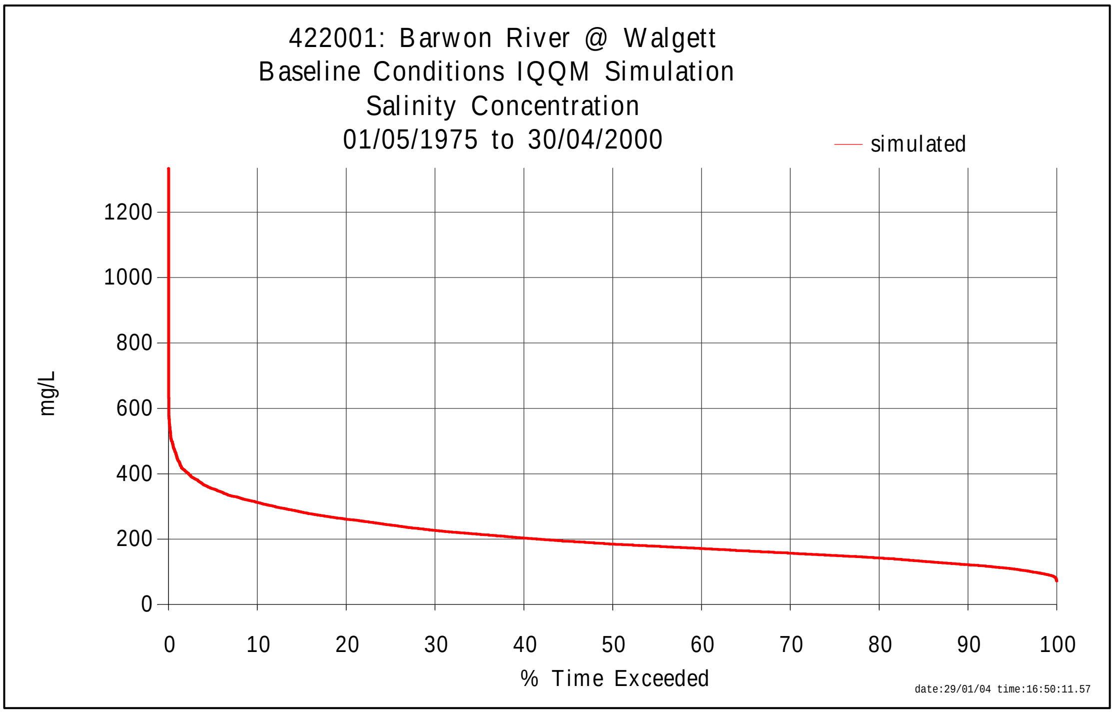


Figure 6.1. Frequency of exceedance of simulated salinity for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 422001: Barwon River @ Walgett

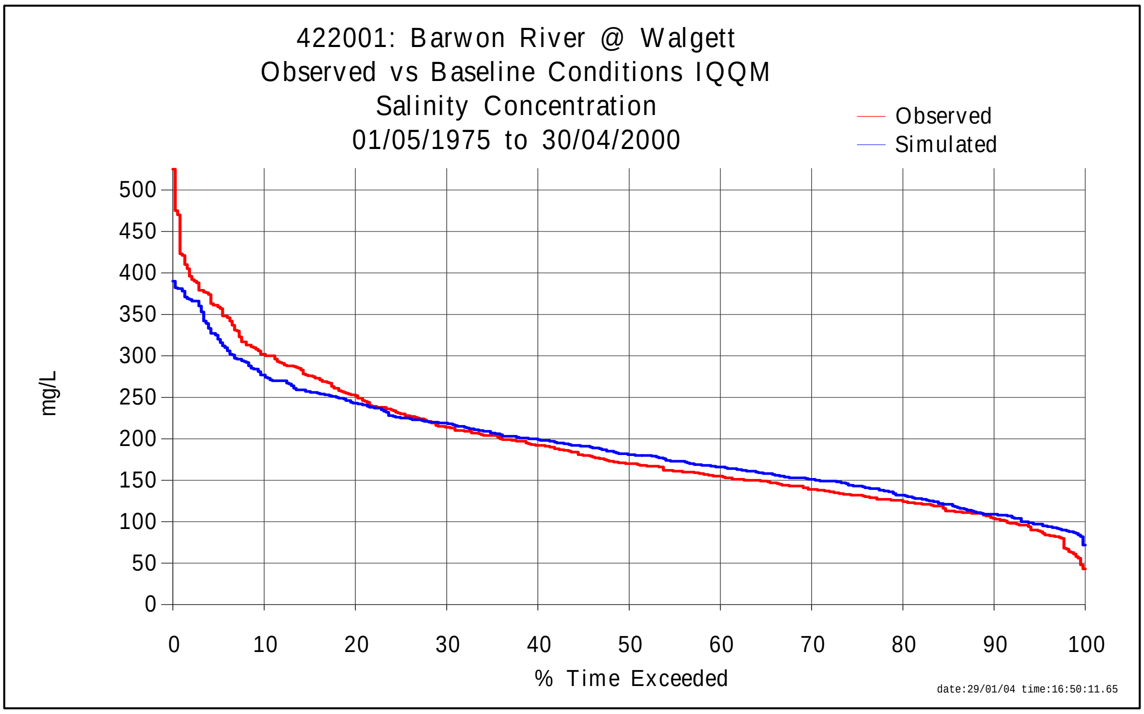


Figure 6.2. Frequency of exceedance of simulated salinity for Baseline Conditions scenario on days with salinity observations (1/5/1975-30/4/2000), compared with salinity observations for Station 422001: Barwon River @ Walgett

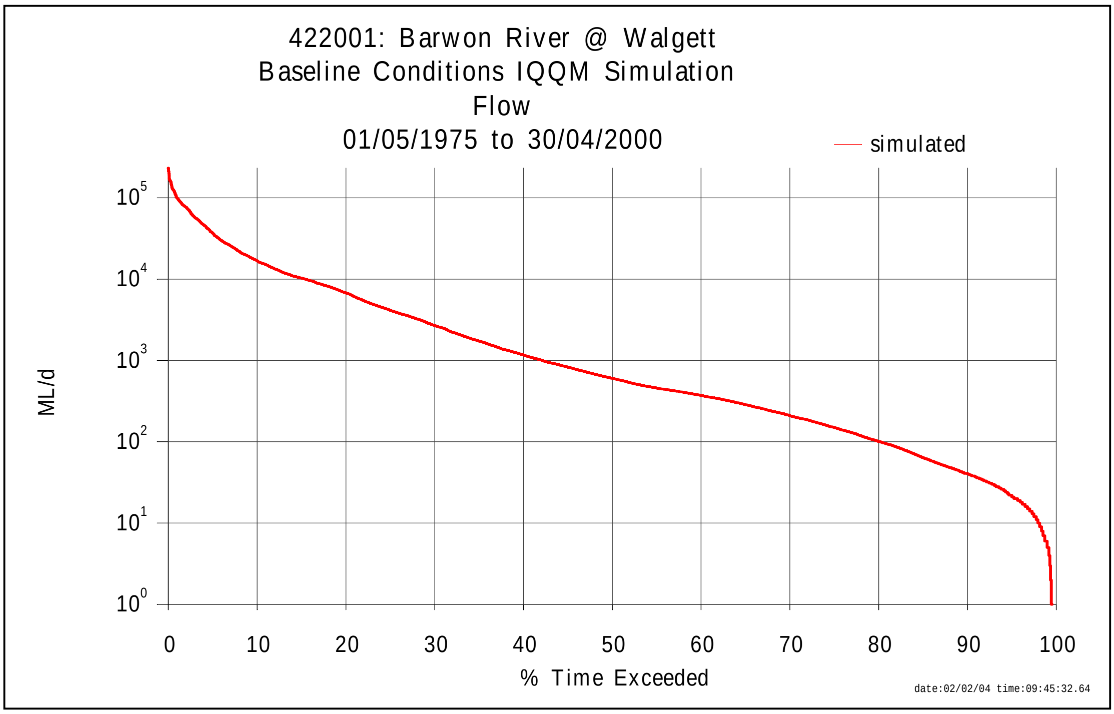


Figure 6.3. Frequency of exceedance of simulated flow for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 422001: Barwon River @ Walgett

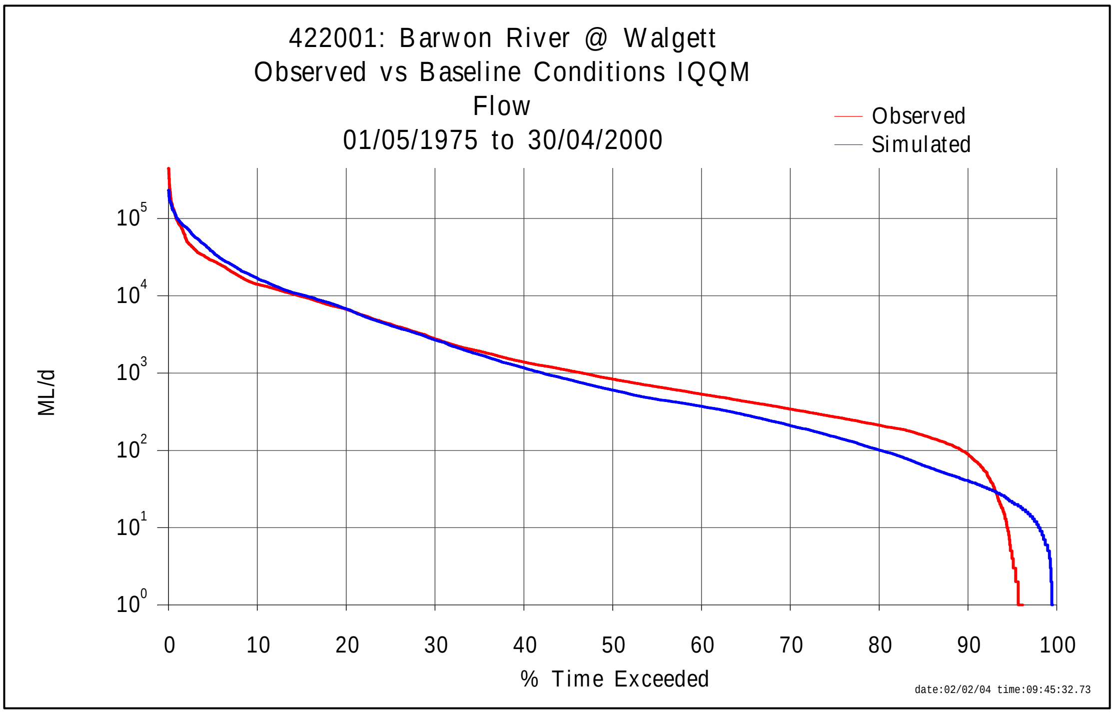


Figure 6.4. Frequency of exceedance of simulated flow for Baseline Conditions scenario on days with flow observations (1/5/1975-30/4/2000), compared with observed flow for Station 422001: Barwon River @ Walgett

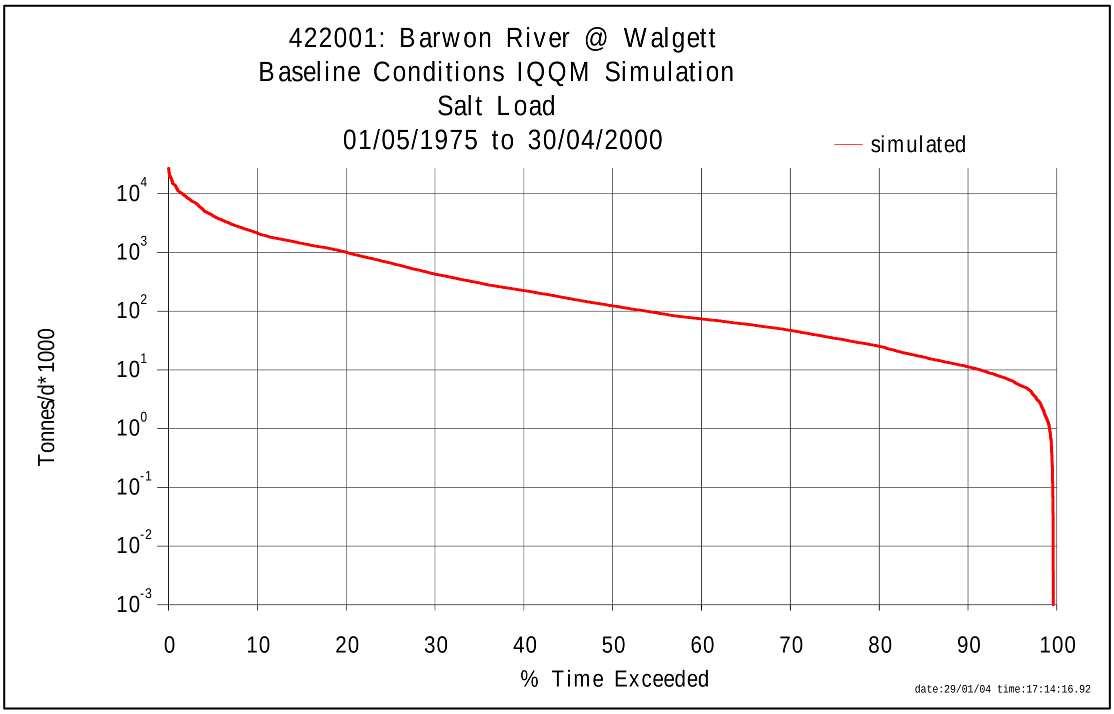


Figure 6.5. Frequency of exceedance of simulated salt load for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 422001: Barwon River @ Walgett

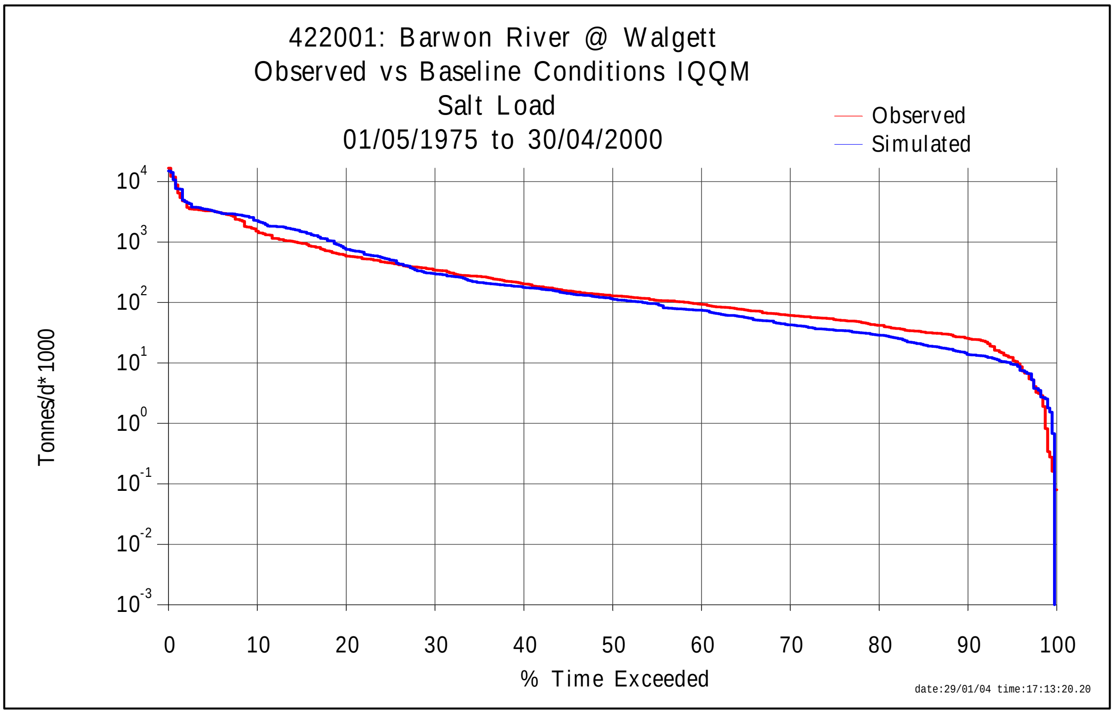


Figure 6.6. Frequency of exceedance of simulated salt load for Baseline Conditions scenario on days with salinity and flow observations (1/5/1975-30/4/2000), compared with salinity observations for Station 422001: Barwon River @ Walgett

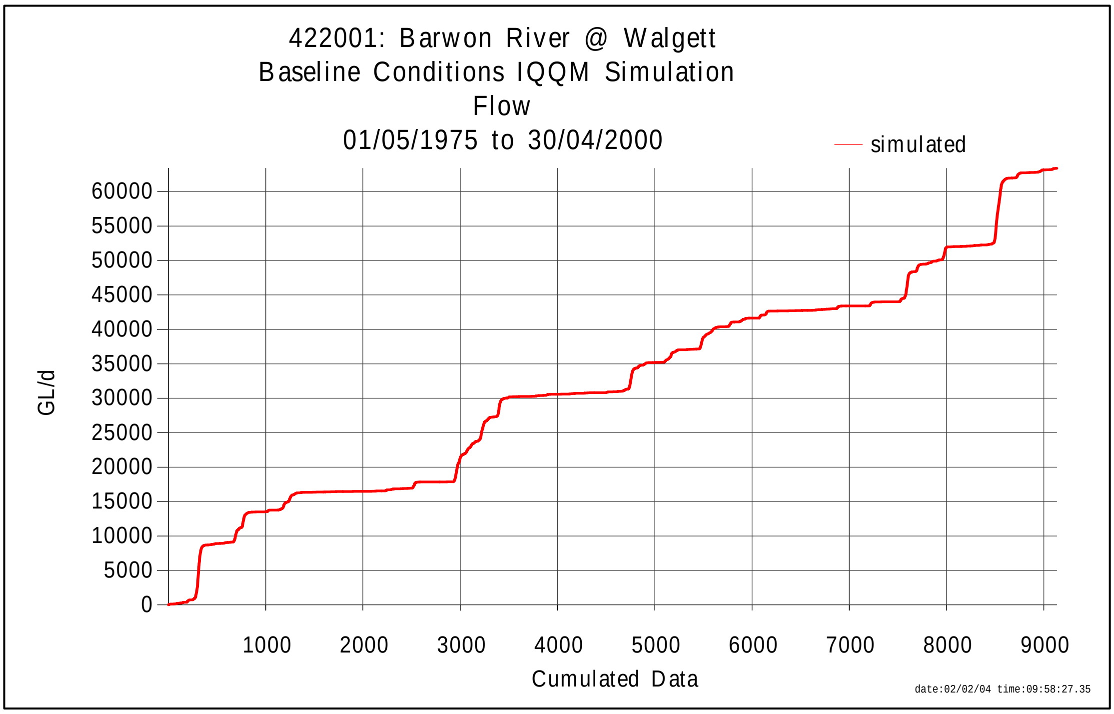


Figure 6.7. Cumulative simulated flow for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 422001: Barwon River @ Walgett

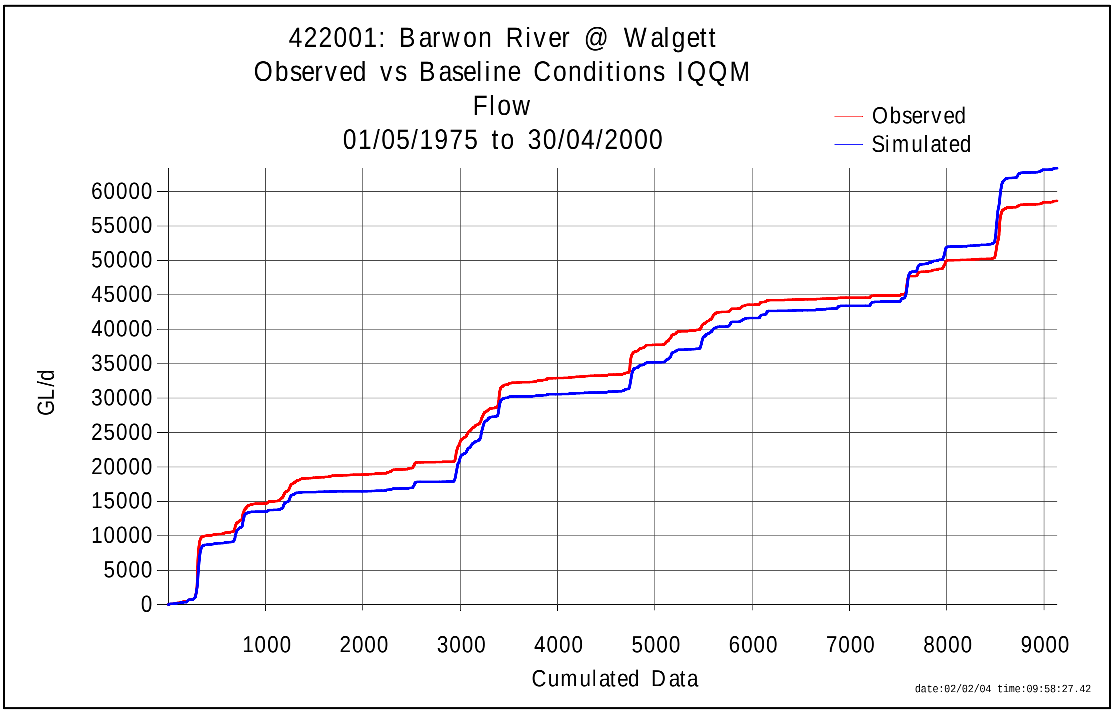


Figure 6.8. Cumulative simulated flow for Baseline Conditions scenario on days with observed flow (1/5/1975-30/4/2000) for Station 422001: Barwon River @ Walgett

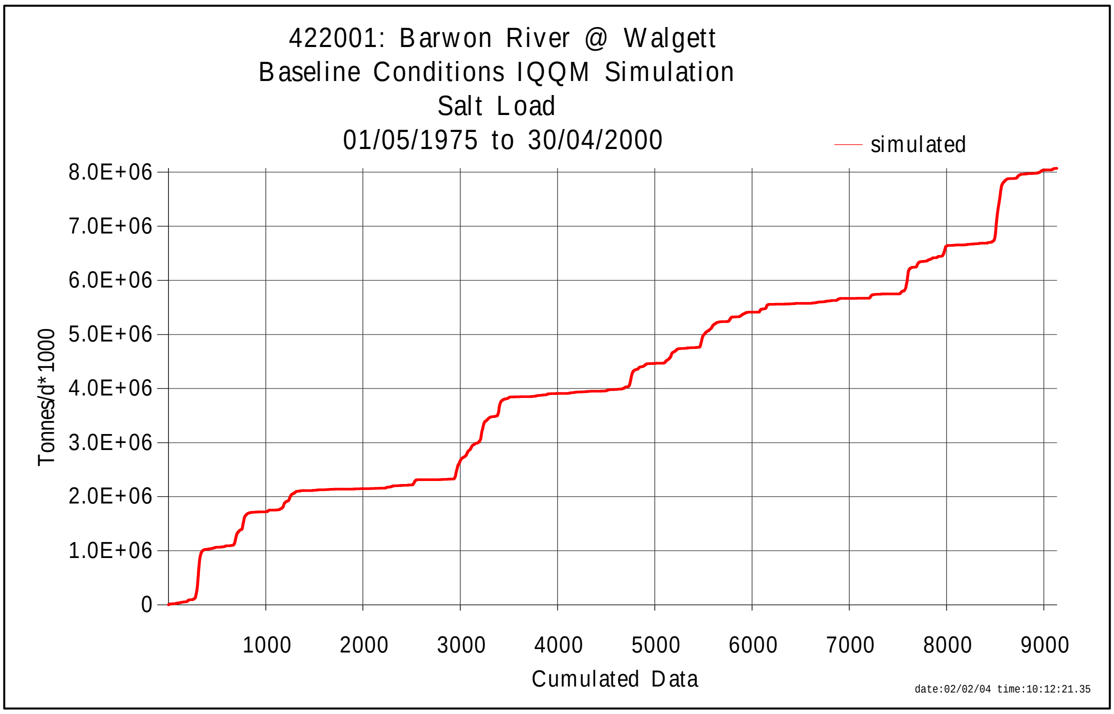


Figure 6.9. Cumulative simulated salt load for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 422001: Barwon River @ Walgett

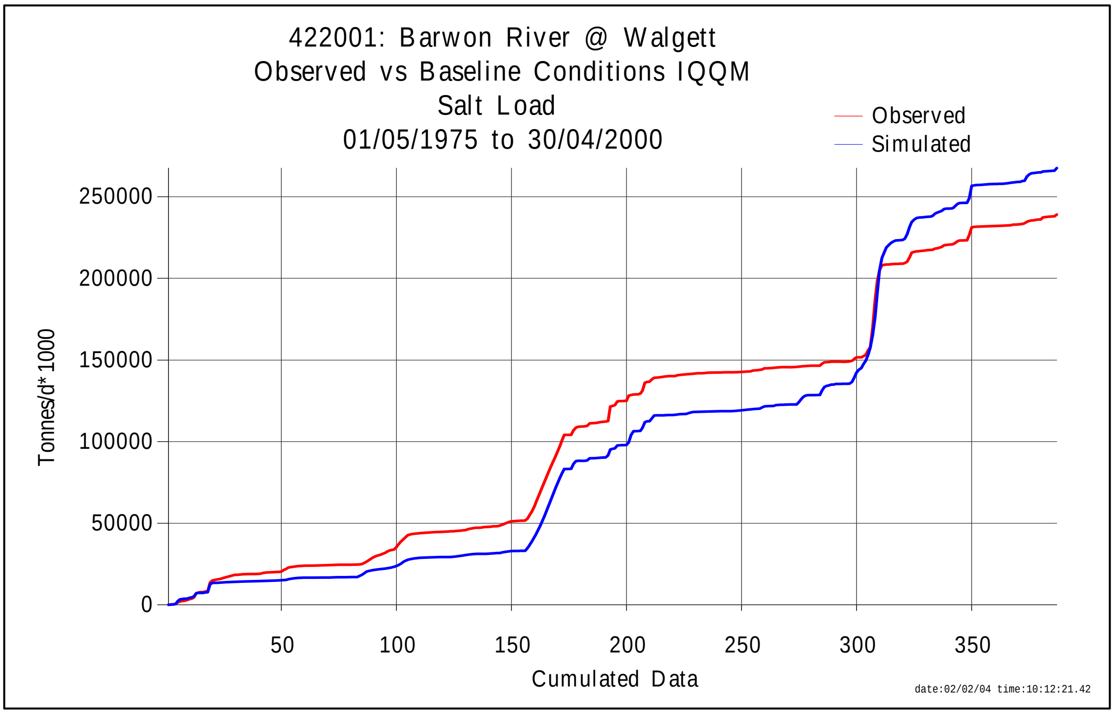


Figure 6.10. Cumulative simulated salt load for Baseline Conditions scenario on days with salinity and flow observations (1/5/1975-30/4/2000) for Station 422001: Barwon River @ Walgett

6.2.2. Results at Station 425003: Darling River @ Bourke

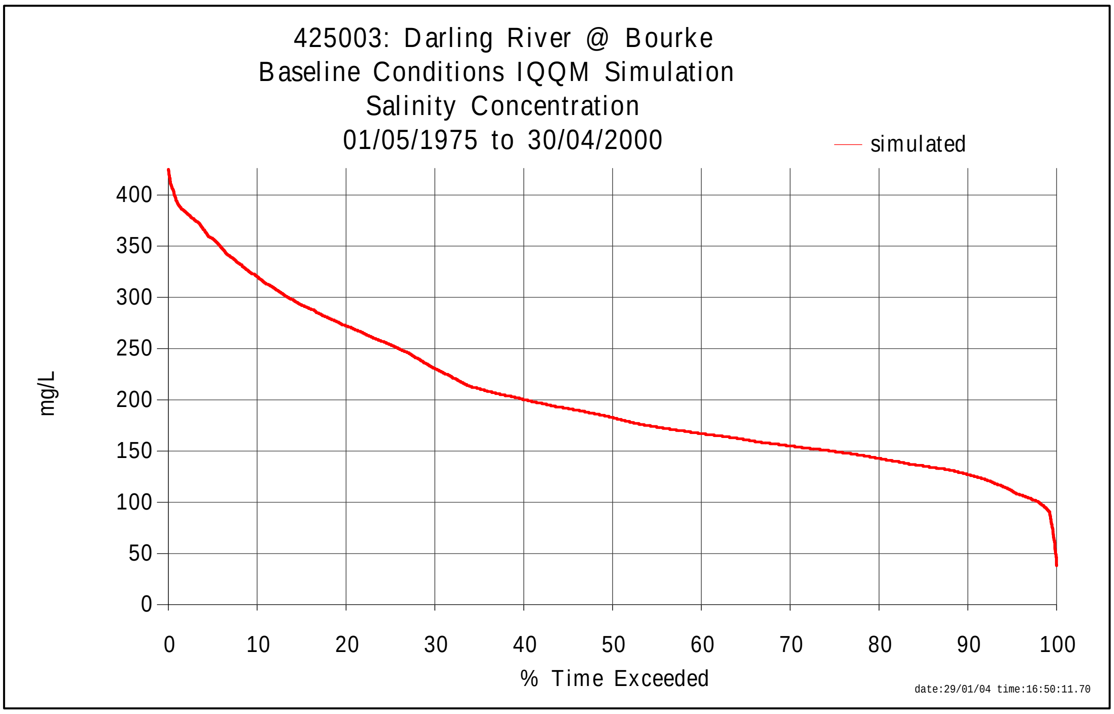


Figure 6.11. Frequency of exceedance of simulated salinity for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 425003: Darling River @ Bourke

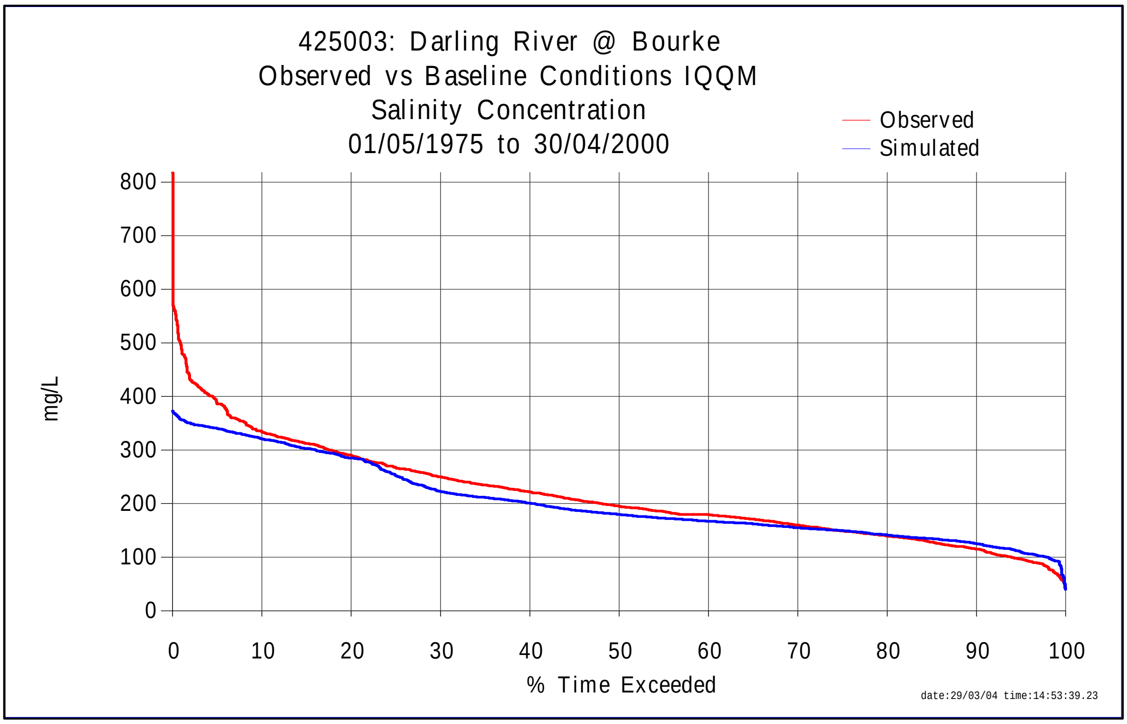


Figure 6.12. Frequency of exceedance of simulated salinity for Baseline Conditions scenario on days with salinity observations (1/5/1975-30/4/2000), compared with salinity observations for Station 425003: Darling River @ Bourke

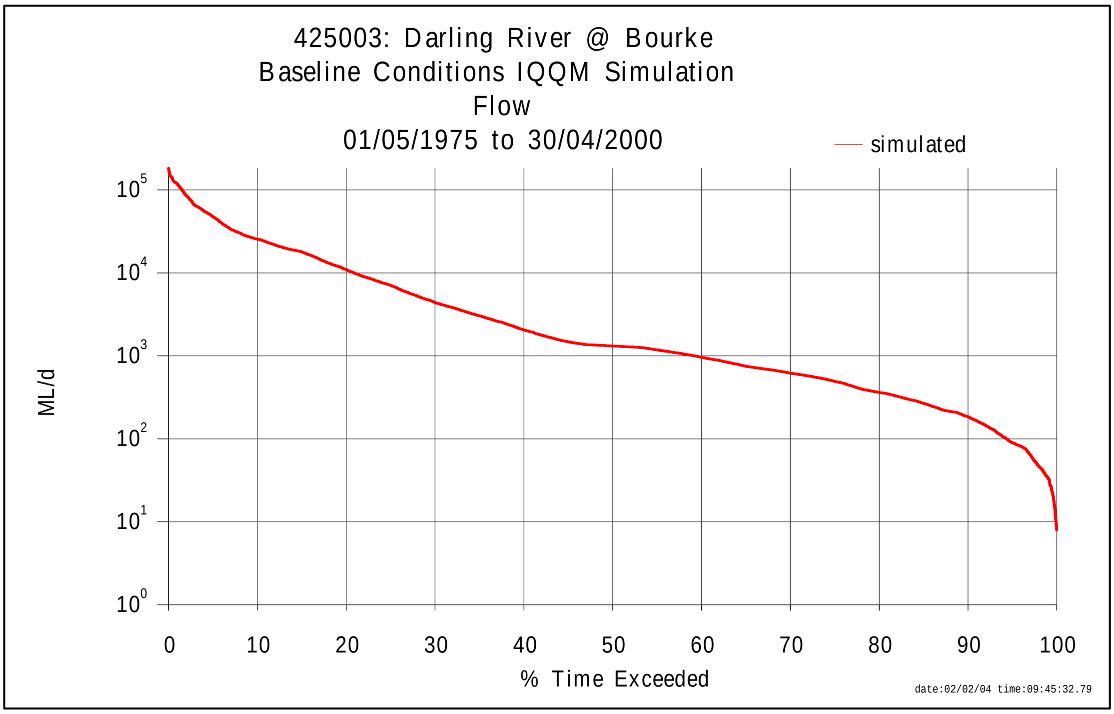


Figure 6.13. Frequency of exceedance of simulated flow for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 425003: Darling River @ Bourke

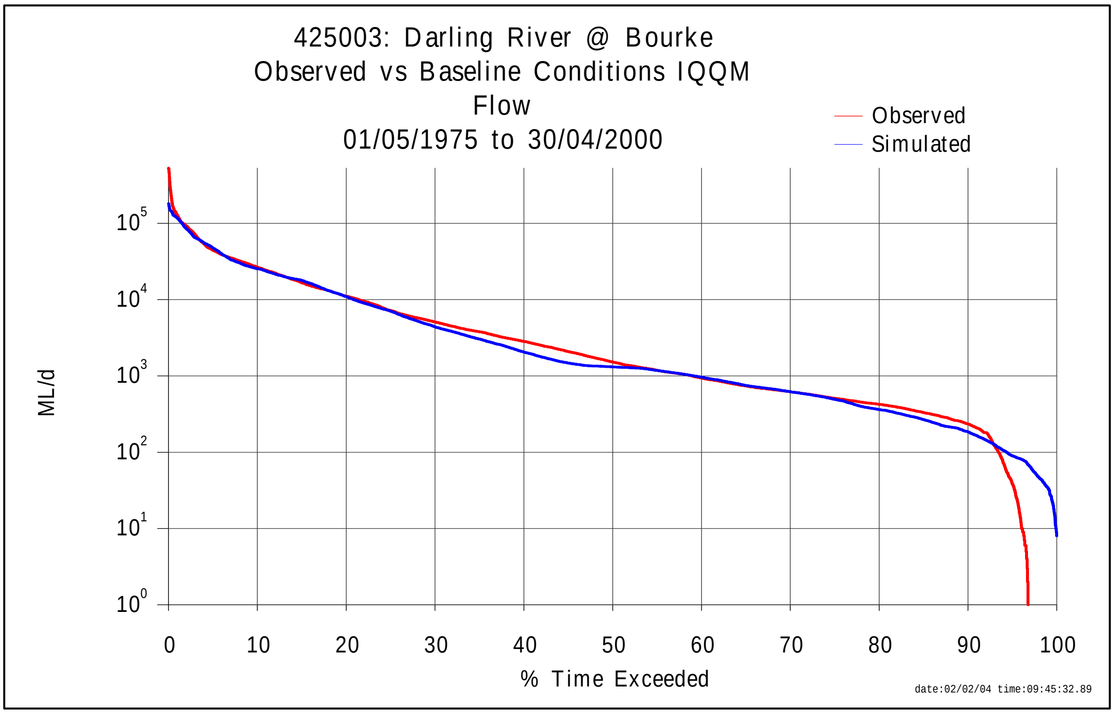


Figure 6.14. Frequency of exceedance of simulated flow for Baseline Conditions scenario on days with flow observations (1/5/1975-30/4/2000), compared with observed flow for Station 425003: Darling River @ Bourke

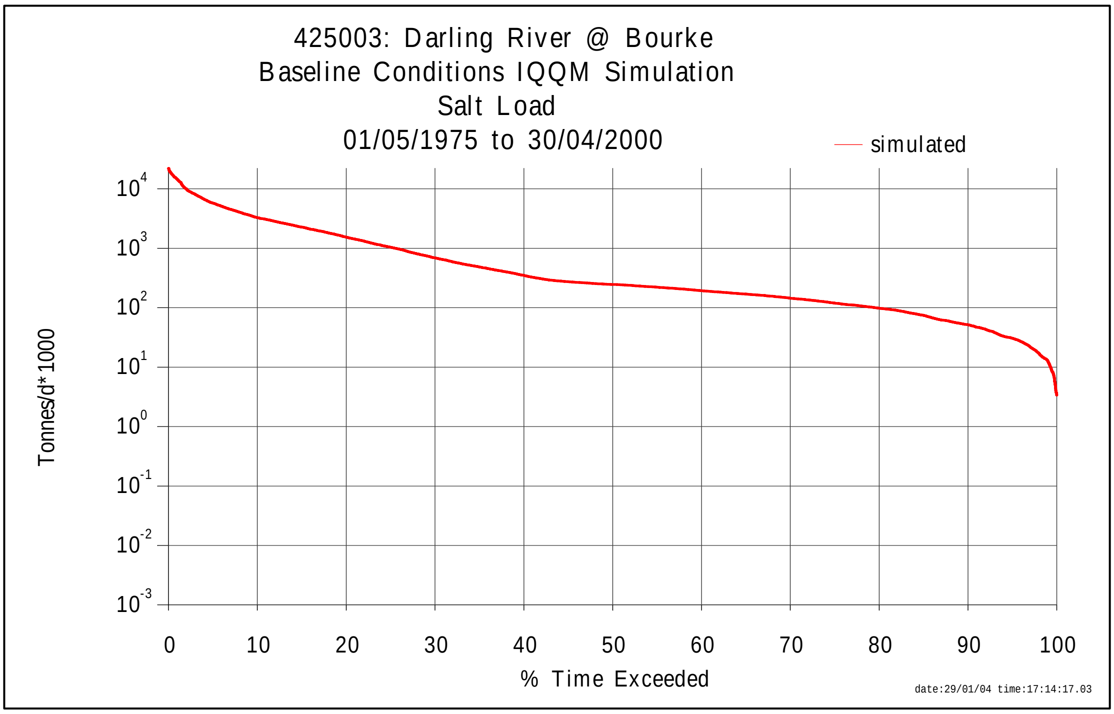


Figure 6.15. Frequency of exceedance of simulated salt load for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 425003: Darling River @ Bourke

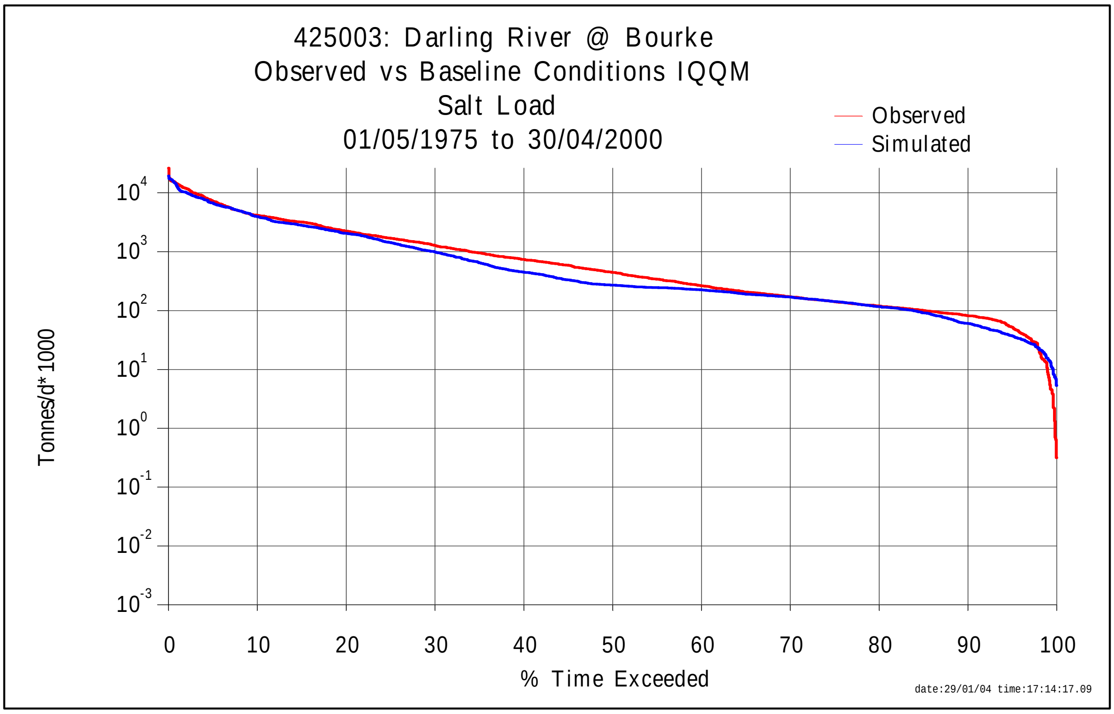


Figure 6.16. Frequency of exceedance of simulated salt load for Baseline Conditions scenario on days with salinity and flow observations (1/5/1975-30/4/2000), compared with salinity observations for Station 425003: Darling River @ Bourke

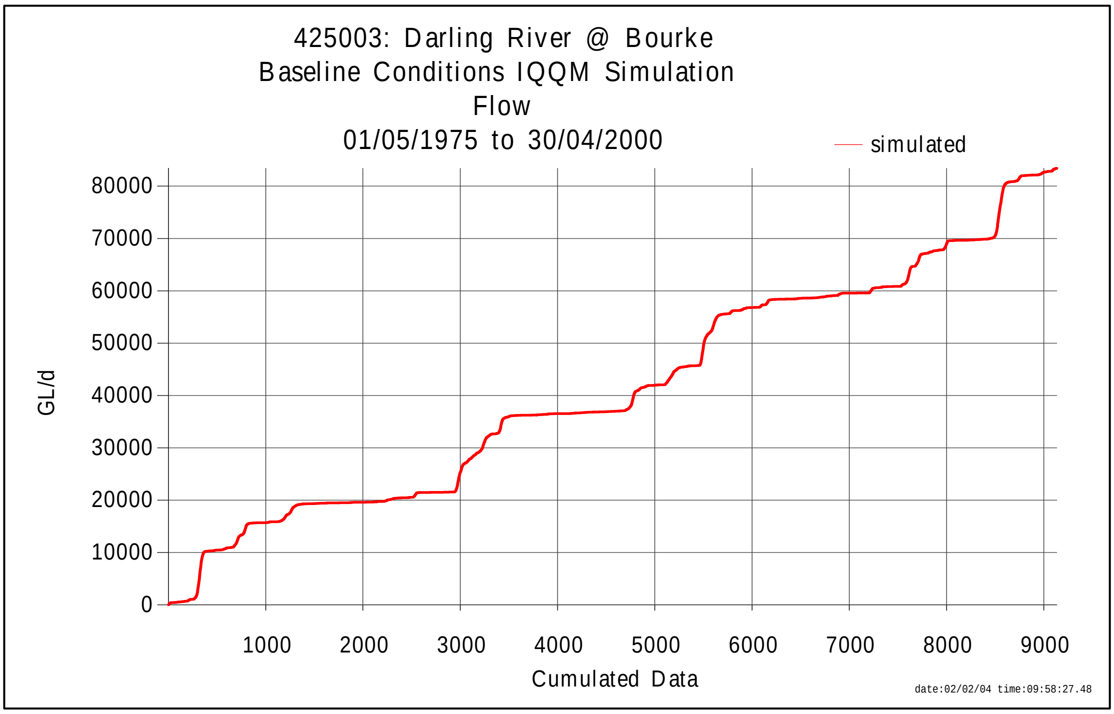


Figure 6.17. Cumulative simulated flow for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 425003: Darling River @ Bourke

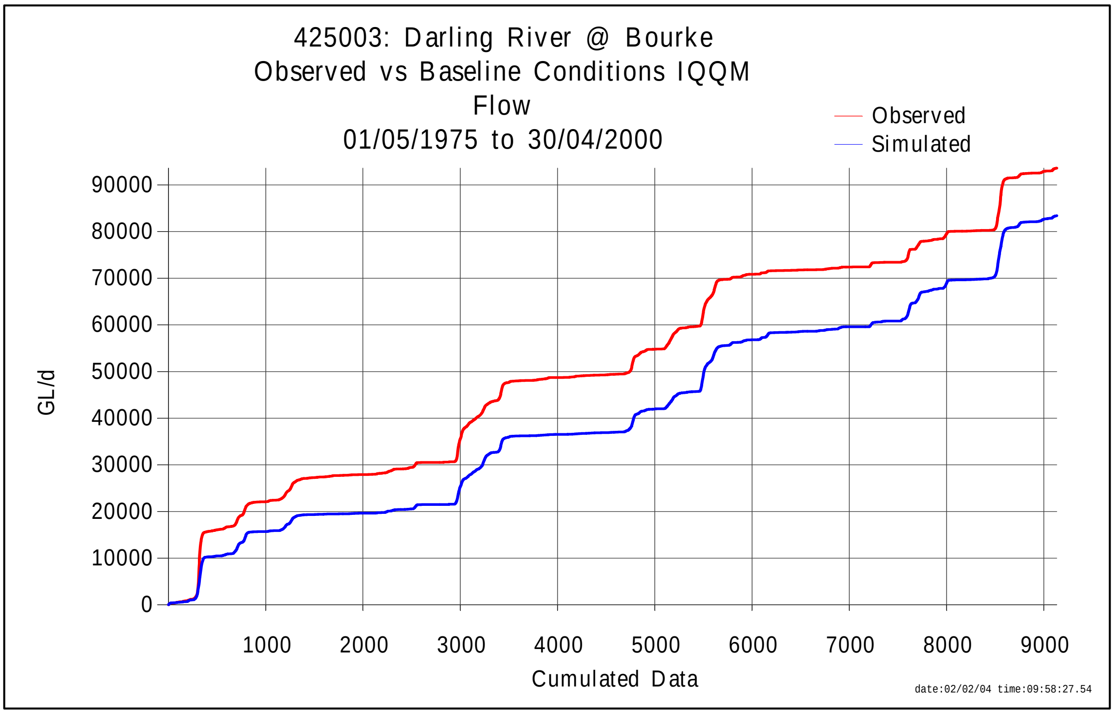


Figure 6.18. Cumulative simulated flow for Baseline Conditions scenario on days with observed flow (1/5/1975-30/4/2000) for Station 425003: Darling River @ Bourke

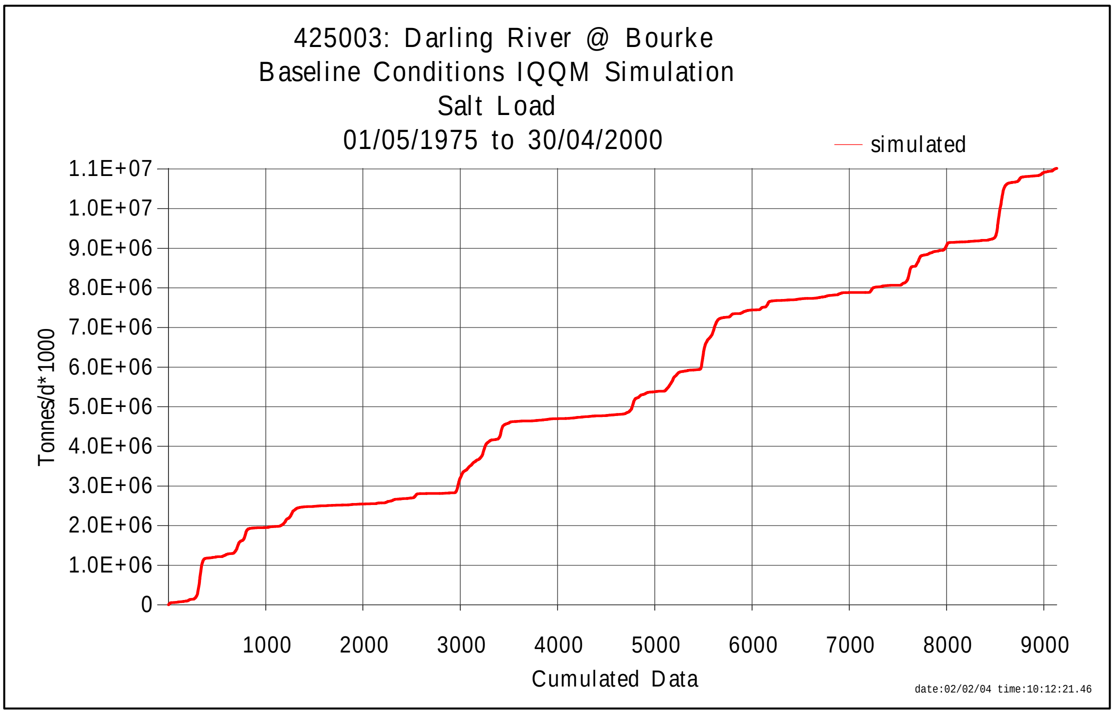


Figure 6.19. Cumulative simulated salt load for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 425003: Darling River @ Bourke

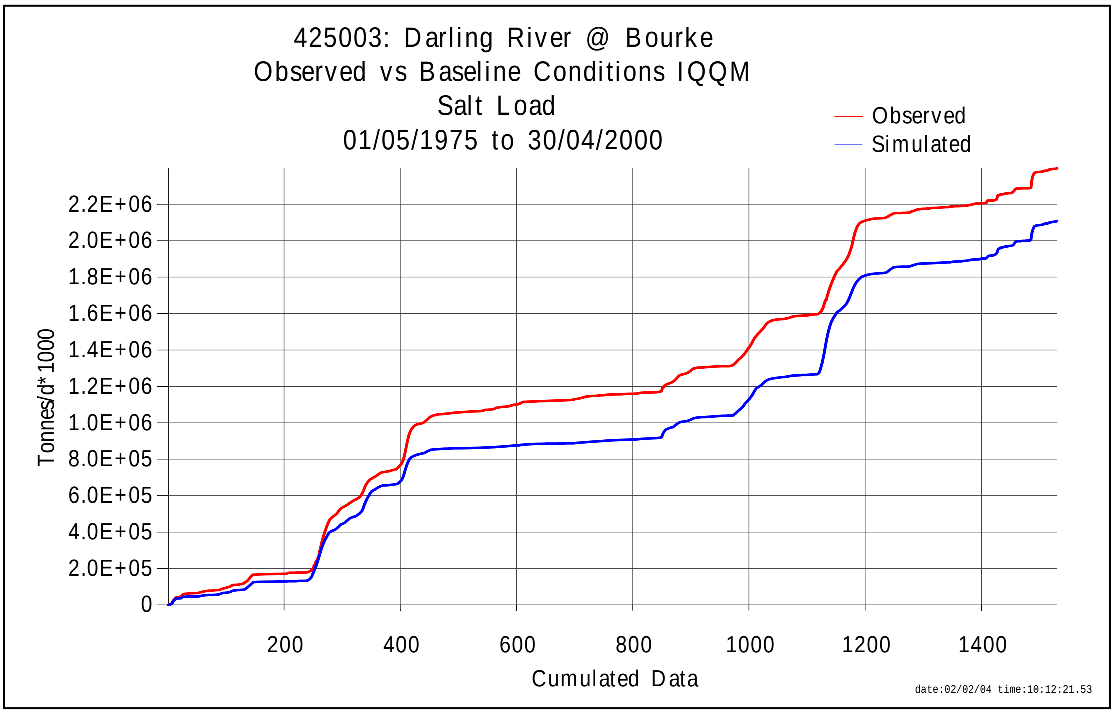


Figure 6.20. Cumulative simulated salt load for Baseline Conditions scenario on days with salinity and flow observations (1/5/1975-30/4/2000) for Station 425003: Darling River @ Bourke

6.2.3. Results at Station 425002: Darling River @ Wilcannia (main channel)

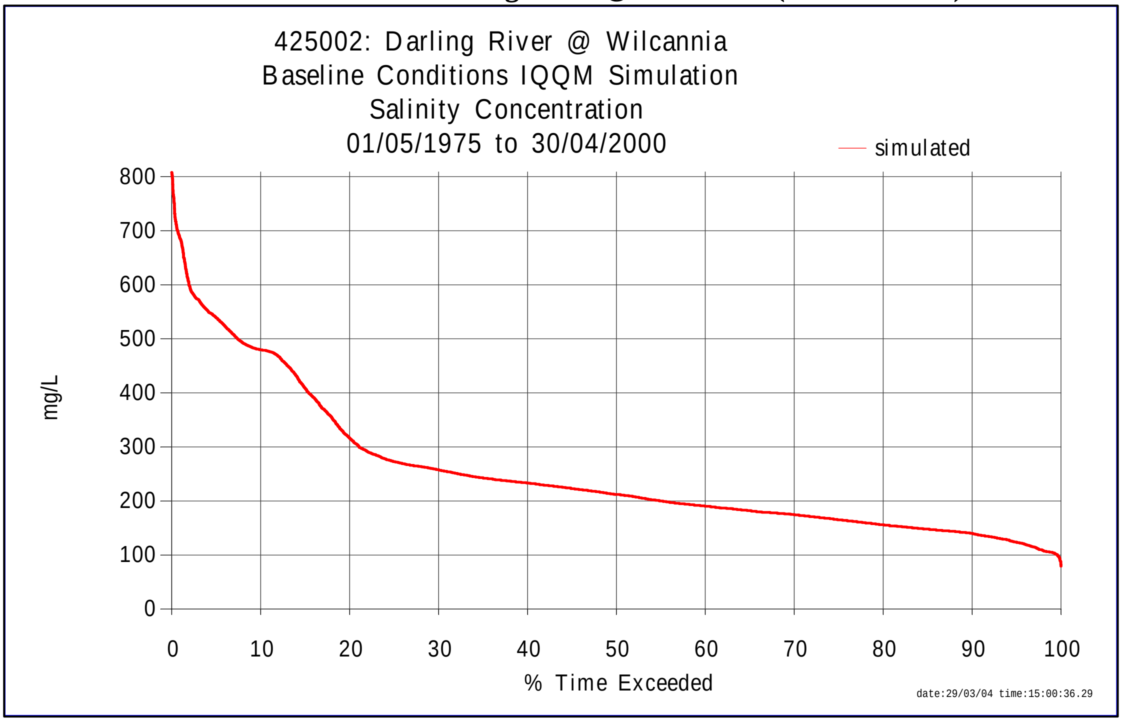


Figure 6.21. Frequency of exceedance of simulated salinity for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 425002: Darling River @ Wilcannia (total flow)

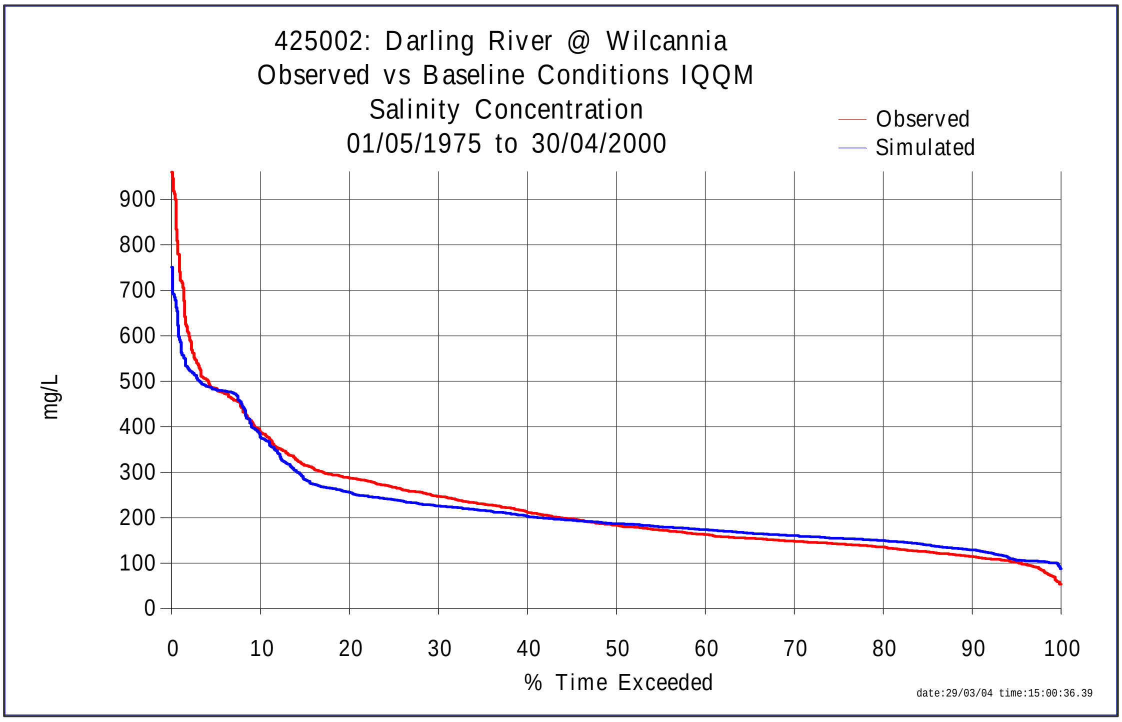


Figure 6.22. Frequency of exceedance of simulated salinity for Baseline Conditions scenario on days with salinity observations (1/5/1975-30/4/2000), compared with salinity observations for Station 425002: Darling River @ Wilcannia (total flow)

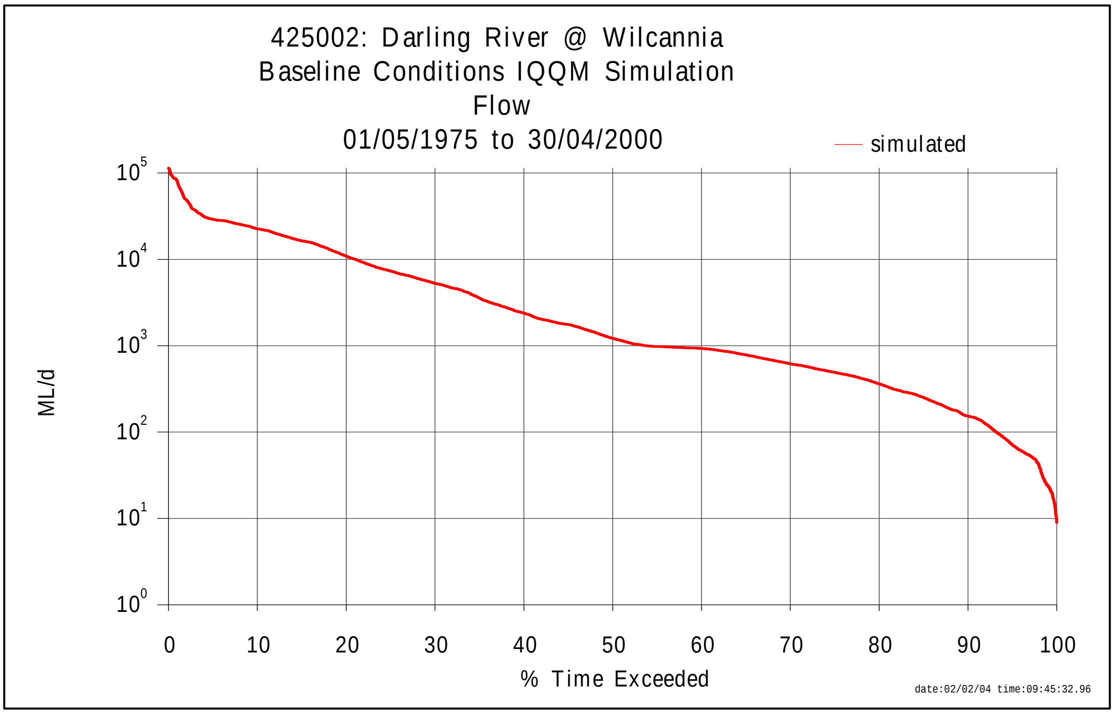


Figure 6.23. Frequency of exceedance of simulated flow for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 425002: Darling River @ Wilcannia (total flow)

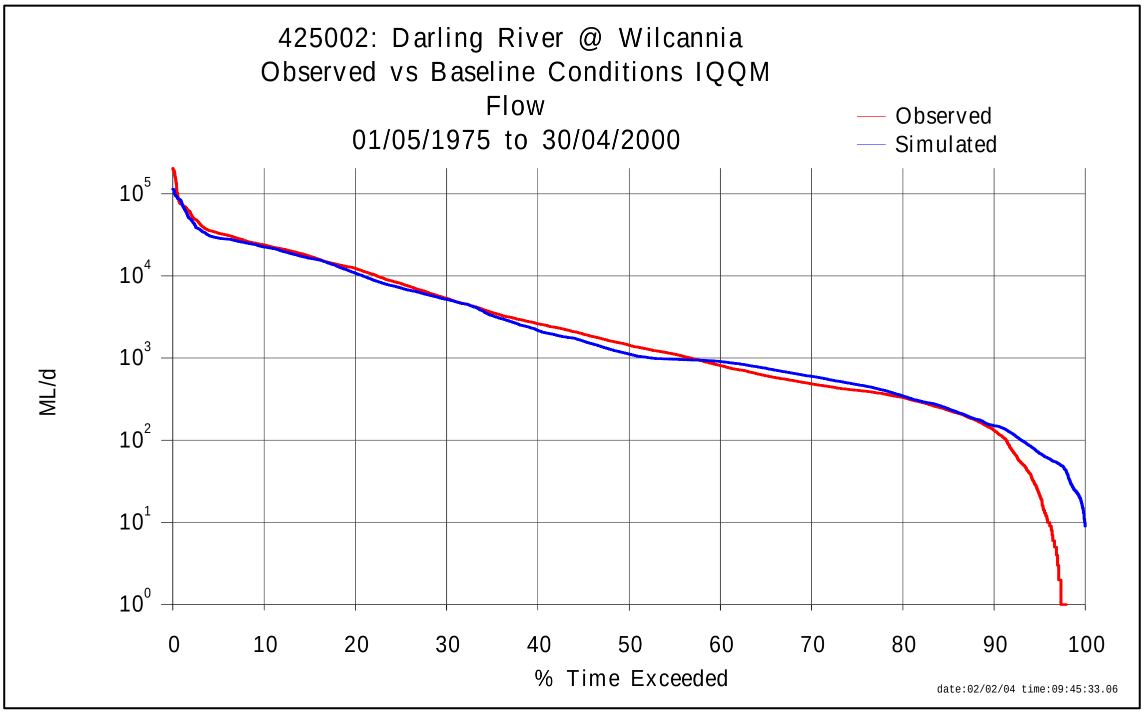


Figure 6.24. Frequency of exceedance of simulated flow for Baseline Conditions scenario on days with flow observations (1/5/1975-30/4/2000), compared with observed flow for Station 425002: Darling River @ Wilcannia (total flow)

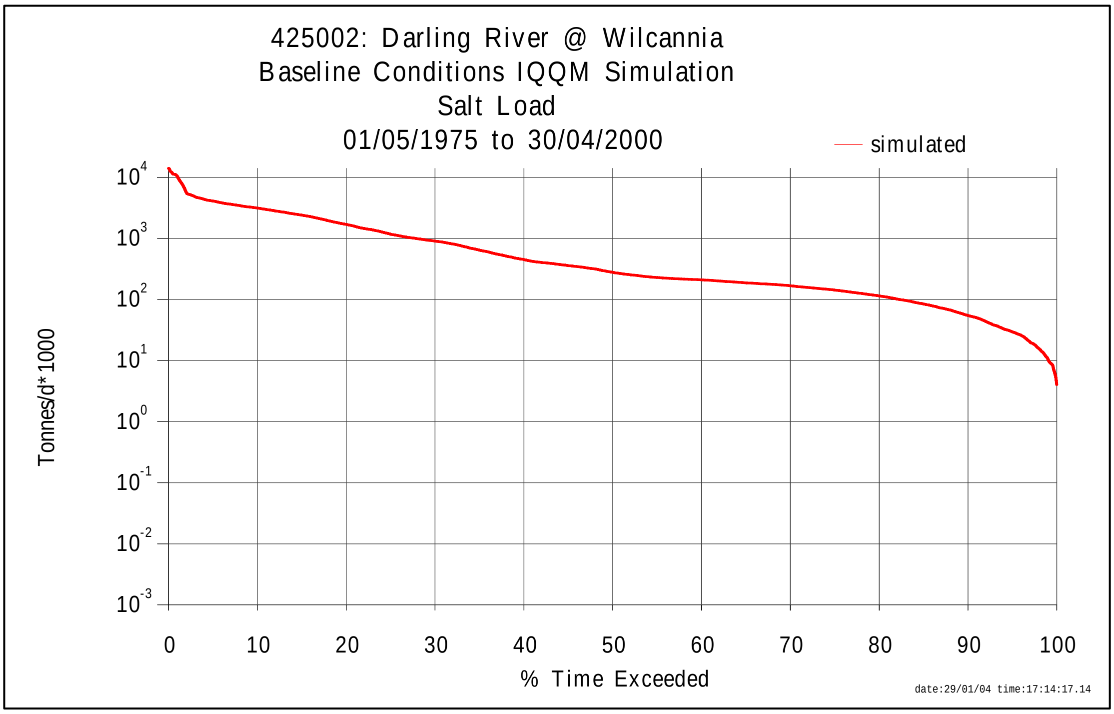


Figure 6.25. Frequency of exceedance of simulated salt load for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 425002: Darling River @ Wilcannia (total flow)

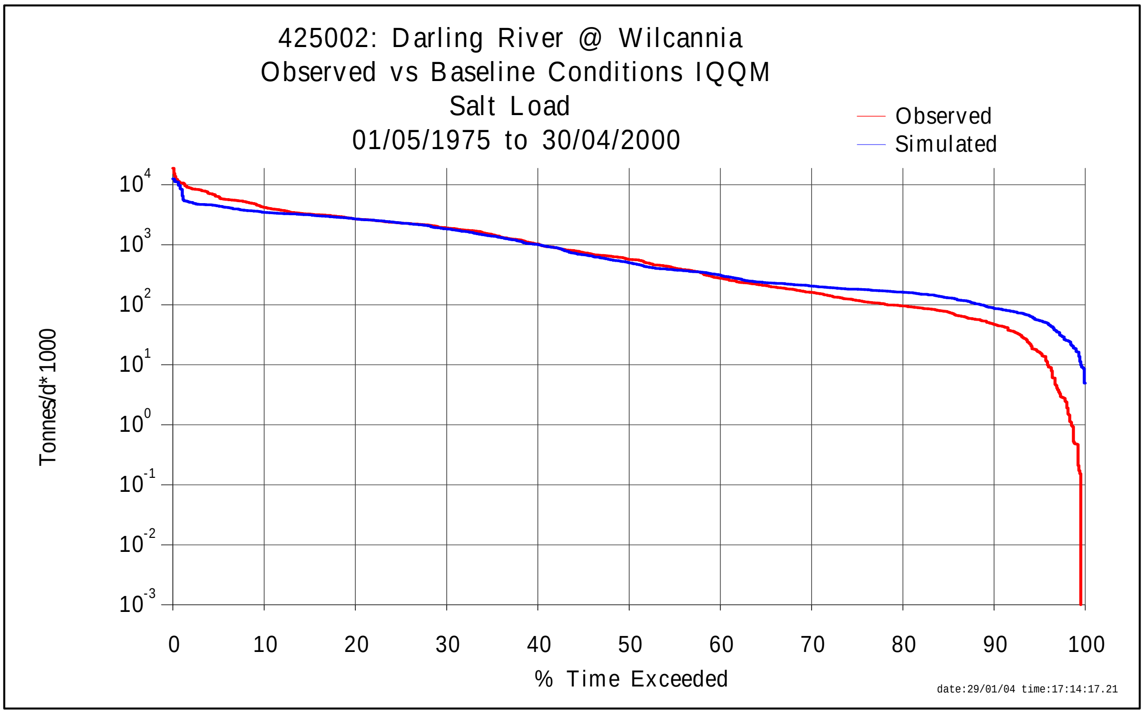


Figure 6.26. Frequency of exceedance of simulated salt load for Baseline Conditions scenario on days with salinity and flow observations (1/5/1975-30/4/2000), compared with salinity observations for Station 425002: Darling River @ Wilcannia (total flow)

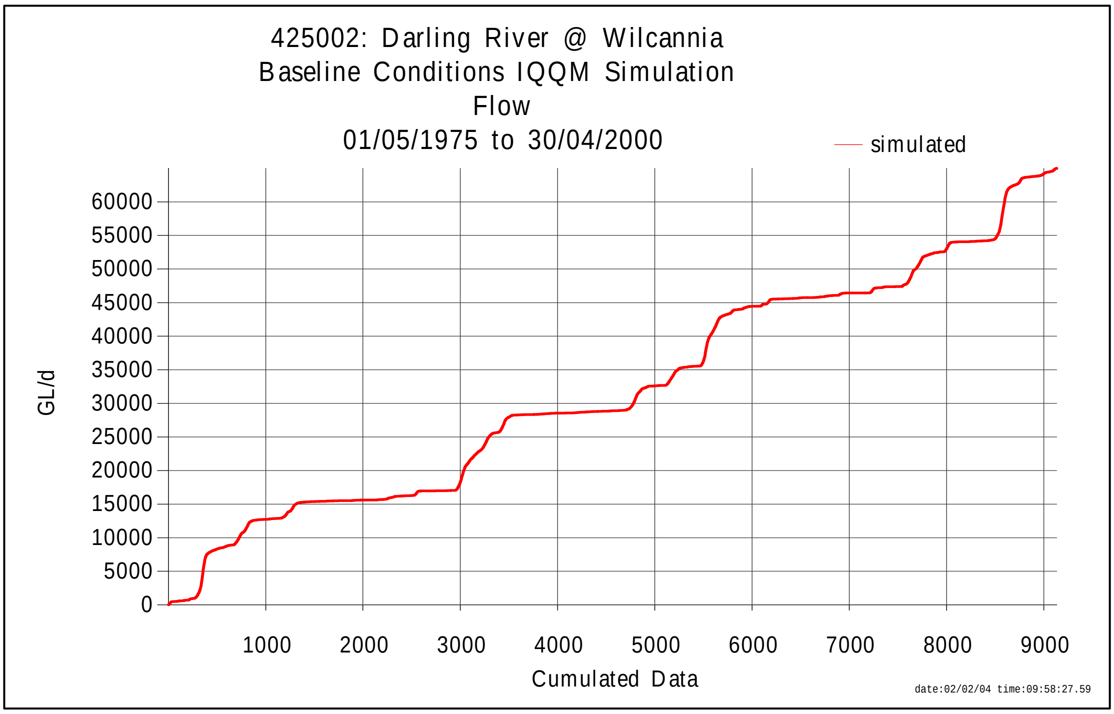


Figure 6.27. Cumulative simulated flow for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 425002: Darling River @ Wilcannia (total flow)

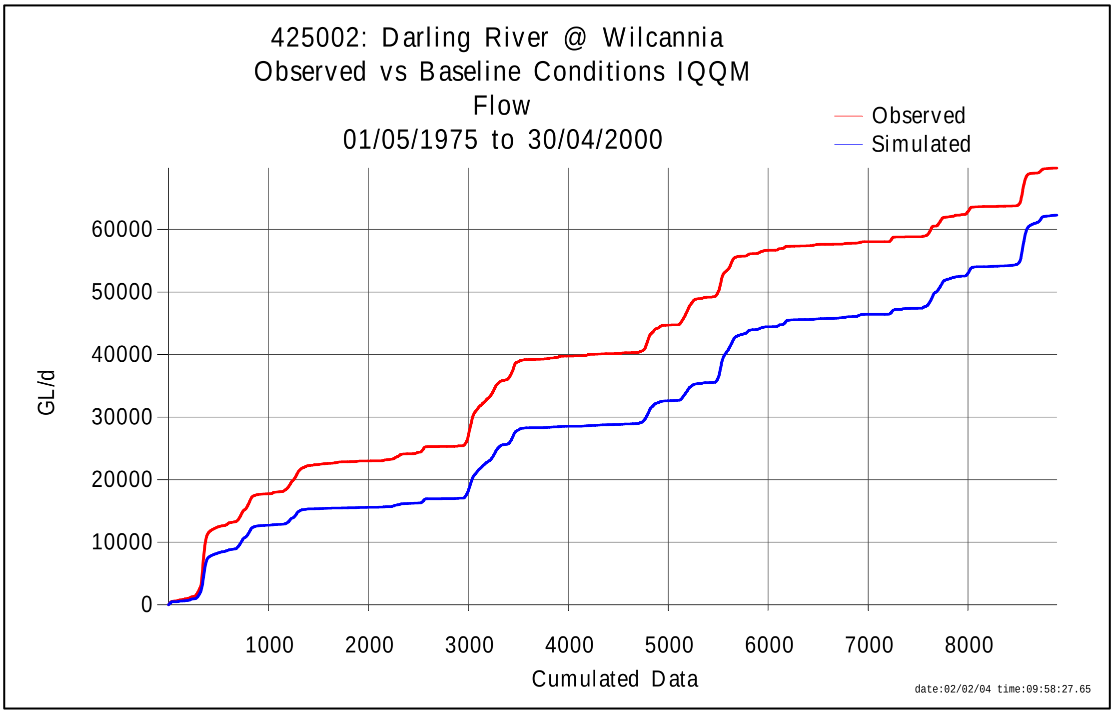


Figure 6.28. Cumulative simulated flow for Baseline Conditions scenario on days with observed flow (1/5/1975-30/4/2000) for Station 425002: Darling River @ Wilcannia (total flow)

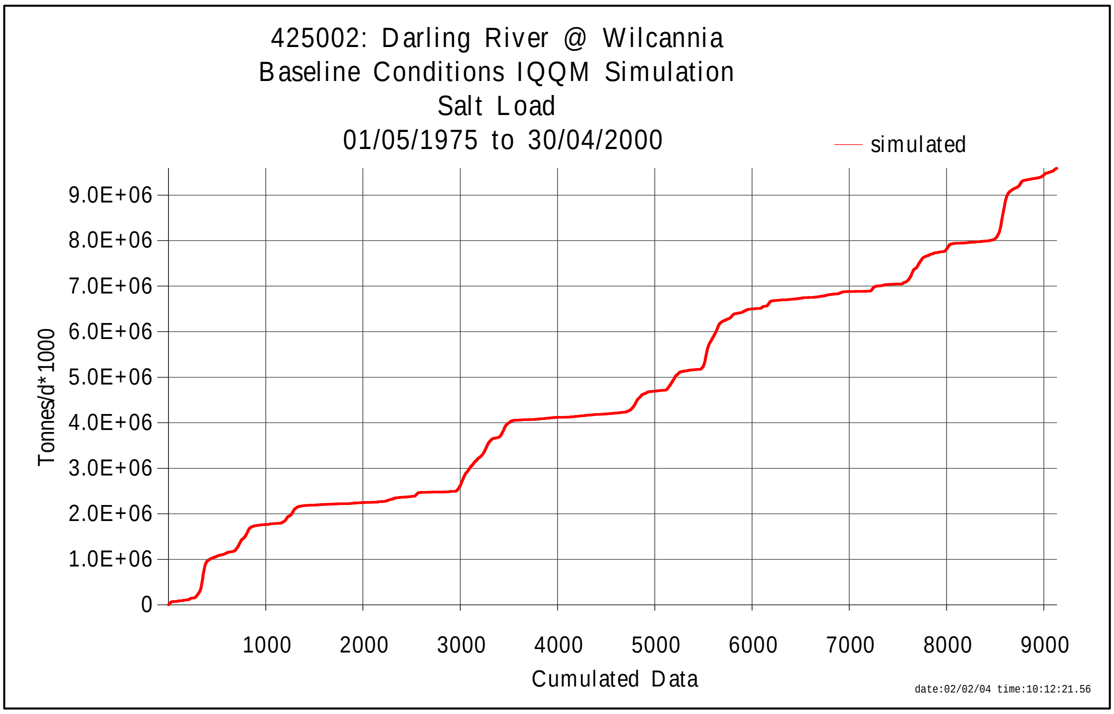


Figure 6.29. Cumulative simulated salt load for Baseline Conditions scenario (1/5/1975-30/4/2000) for Station 425002: Darling River @ Wilcannia (total flow)

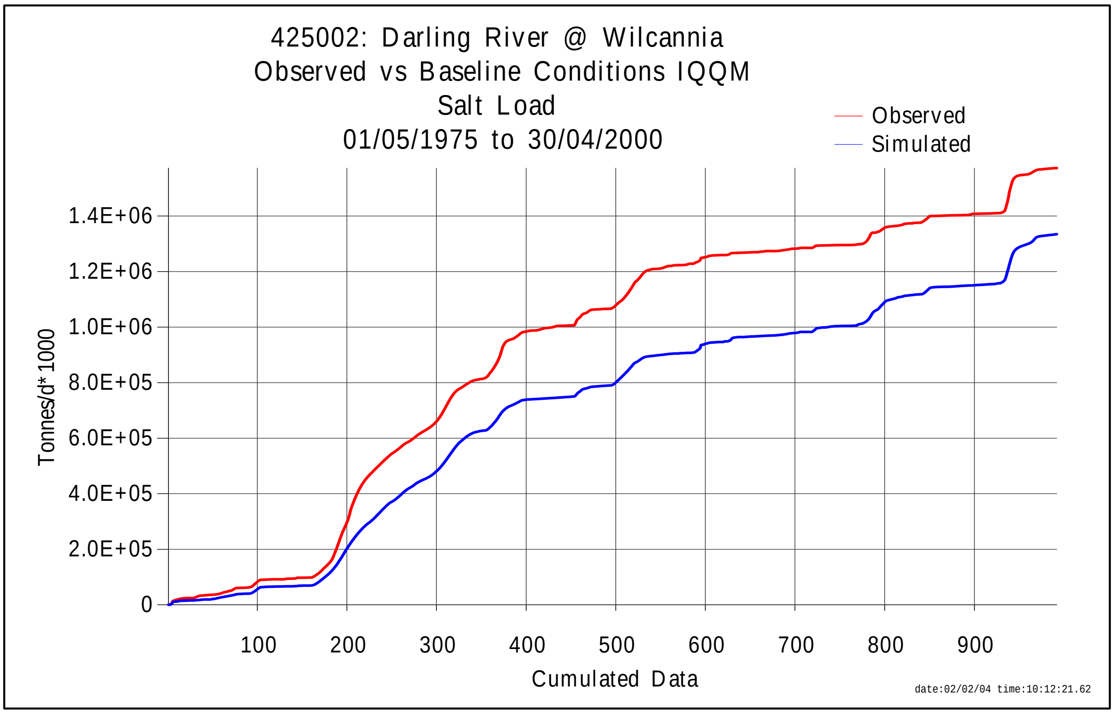


Figure 6.30. Cumulative simulated salt load for Baseline Conditions scenario on days with salinity and flow observations (1/5/1975-30/4/2000) for Station 425002: Darling River @ Wilcannia (total flow)

7. Conclusion and recommendations

7.1. CONCLUSION

The Barwon-Darling River IQQM salinity calibration produced simulated concentration within 10% of the observed at most of evaluation points. This comparison was achieved in all flow ranges. The simulated salt loads are lower than the observed loads, especially in the medium and high flow ranges, due primarily to underestimation of salinity.

The Barwon-Darling River IQQM produced a time series of flows and salt loads for the Benchmark Climatic Period under Baseline Conditions. The results show that the 2000 development conditions produce lower flows than observed especially in the medium and high flow ranges. The former is mainly due to increases in irrigation development over the Benchmark period whilst the latter is due to difficulties in modelling flood peaks.

The Barwon-Darling IQQM is capable of estimating the flow and salinity impacts of water sharing policies. However, because of a limited understanding of the extent of groundwater-surfacewater interaction, there are difficulties in achieving the correct distribution of salinities and hence salt loads, especially in the Macintyre-Barwon river system. These limitations will restrict the model's ability to accurately predict salinity changes.

7.2. RECOMMENDATIONS ON MODEL IMPROVEMENTS

Review of the available salinity data and development of this valley model to simulate Baseline Conditions have highlighted a number of areas where the model could be improved. The timetable for these improvements will depend on additional data becoming available, other projects underway to meet NSW salinity strategy and priority of modelling work within the Department. The Department is committed to developing the salinity models, however, the timetable for the model improvements will be part of future work planning. The following points outline the areas of model improvement.

- The Condamine-Balonne floodplain needs to be modelled now that this valley model has been made available by Queensland Department of Natural Resources and Mines.

- The salinity of inflows from un-modelled Macquarie- Castlereagh Basin tributaries needs to be reviewed. Currently the salinities of Marthaguy Creek and Castlereagh River only reflect Macquarie River salinities at Carinda. While the salinity of the Bogan River is based on a flow-salinity table. The extension of salinity to the existing flow models for these catchments would enable better estimates of the effects of land use changes in these catchments as well as improving downstream salinities in the Barwon and Darling Rivers.

- There are significant groundwater interactions in the Barwon-Darling River downstream of Walgett. A re-calibration of transmission losses and salinity interactions should be undertaken to improve estimation of salt exports. This will involve a review of instream flow and salinity data.

7.3. RECOMMENDED FUTURE DATA COLLECTION

7.3.1. Main stream salinity data

Sufficient continuous EC data at all gauging stations will improve estimates of salt balance in river reaches at all flow regimes, wet and dry periods, and summer and winter seasons. Both continuos and discrete data are required for quality checking the data. Priority should be given to the sites outlined in table.

Data coverage along the Barwon and Darling Rivers is widespread, with collection sites located at regular intervals. However the modelling is somewhat limited by the length of the continuous data sets available, with only four sites having over 5 years of continuous data (Figure 3.2). For the remainder of sites with discrete EC data there is only 2 sites were data sets in-excess of 1000 days are available (Figure 3.1). More continuous data sets are required to fully understand in-stream process, a priority list of sites is outlined in Table 7.1.

Table 7.1: Main stream priority sites for continuous salinity data collection

Station Code	Station Name
42503?	Darling River @ Glen Villa
422003	Barwon River @ Collarenebri
422026	Barwon River @ U/S Maquarie Junction
422028	Barwon River @ U/S Culgoa Junction

Note continuous data is now collected at Bourke and Wilcannia (Stn. Code 425003 and 425008)

7.3.2. Inflow salinity data

Improved salinity inflow relationships will result from the continuation of salinity data collection at the sites listed in Table 7.2. Where it is possible continuous data probes should be installed. Flow data is required to support the salinity concentration data.

Table 7.2: Tributary stream priority sites for discrete and continuous salinity data collection

Station Code	Station Name
416028	Boomi River @ Neeworra
416027	Gil Gil Creek @ Weemalah
417001	Moonie River @ Gundablouie
419049	Pian Creek @ Waminda
421011	Marthaguy Creek @ Carinda
421097	Marra Creek @ Carinda Rd.
422005	Bokhara River @ Bokhara
422006	Culgoa River D/S Collerina

7.4. MODEL UNCERTAINTY AND RECOMMENDED USE OF MODEL RESULTS

The issues of model uncertainty and how the model results might be used is important to understand. Whilst the models were derived using the best available information and modelling techniques having regard to financial and resource constraints, they nevertheless contain considerable uncertainties.

Uncertainty in the baseline conditions arises from two sources. Firstly, the model inputs, and secondly, the internal modelling processes which translate the model inputs into the model outputs. Whilst there is presently no clear indication of the uncertainty introduced by this latter mechanism, it is clear that there is very large uncertainty introduced into the model outputs by the model inputs.

In using the model results the following key issues should be considered:

- *absolute accuracy of the model results has not been quantified* — the model should be used cautiously because the uncertainty in results hasn't been quantified.

- *complexity of natural systems* — the natural systems being modelled are very complex and the salinity and to a lesser extent, the flow processes, are not fully understood. This makes modelling difficult.

- *lack of data, data quality & data accuracy* — in some locations there is a lack of comprehensive flow and salinity data. This makes calibration and verification of models difficult, and increases the uncertainty in the model results.

- *using models to predict the impacts of changes* — these types of models are most often used to measure the impact of changed operation or inputs. To do this, the difference between two model runs is determined. The 'relative accuracy' of the model used in this manner is usually higher than the 'absolute accuracy' obtained if the results of a single model run are compared with the real world.

- *flow ~ salinity relationships* — in nearly all cases the salinity inputs to the models have been derived from empirical relationships between salinity and flow. These relationships are approximate and whilst calibrated to the available data (i.e. to reproduce longer term salt loads), often confidence in the relationships is poor. However in the absence of further data collection and further scientific research, the relationships are probably the best available.

- *inappropriate use of model results* — models should not be used to 'predict' or back-calculate salinities (and to a lesser extent, flows), on any given day or longer time period. Rather, when viewed over the whole of the benchmark period, the model results provide a reasonable indication of the probabilities of obtaining flows of given magnitudes, and average salt loads, at key locations.

The above text was substantially taken from Bewsher (2004).

8. References

Beale, G.T.H., R. Beecham, K. Harris, D. O'Neill, H. Schroo, N.K. Tuteja and R.M. Williams (1999). *Salinity predictions for NSW rivers within the Murray-Darling Basin* CNR 99.048. NSW DLWC (Parramatta).

Beecham, R. and P. Arranz (2001). Data driven model development for estimating salt export from irrigation areas. *Proceedings MODSIM 2001*, pp 609-614.

Bewsher D (2004), *Assessment of NSW Tributary IQQM Models*, Bewsher Consulting Pty Ltd, January 2004. Report prepared for Baseline Conditions Technical Subcommittee, Murray Darling Basin Commission.

Braaten, R. and G. Gates (2002). *Groundwater-surface water interaction in NSW: a discussion paper*. NSW DLWC (Sydney).

Department of Environment and Climate Change (2006). NSW Sate of the environment 2006. (Sydney)

Department of Environment and Climate Change (2007). *Salinity Audit: Upland catchments of NSW* (*draft*). (Sydney).

He, H. (2004). *Review of Inflows to Barwon-darling River IQQM using Mass Balance.* CNR ??.???. NSW DWR (Parramatta).

Murray Darling Basin Ministerial Council (1999). *The Salinity Audit of the Murray Darling Basin. A 100 year perspective 1999*. MDBC (Canberra).

Murray Darling Basin Ministerial Council (2001). *Basin Salinity Management Strategy 2001-2015*. MDBC (Canberra).

Nathan R.J. and T.A. McMahon (1990). *Evaluation of Automated Techniques for Base Flow and Recession Analysis*. dept. of Civil and agricultural Engineering, University of Melbourne (Water Resources Research, Vol. 26, No. 7, pages 1465-1473).

Natural Resources Commission (2005) Standard for Quality Natural Resources Management (Sydney).

New South Wales Government (2000a). *NSW Salinity Strategy: Taking the challenge*. NSW DLWC (Sydney).

New South Wales Government (2000b). *NSW Salinity Strategy: Salinity Targets Supplementary Paper*. NSW DLWC (Sydney).

Rajendran, R. and P. Sharma (1995). *Integrated Quantity Quality Model (IQQM): Barwon-Darling River System Calibration Report.* TS 94.035. Hydrology Unit, NSW DWR (Parramatta).

Summerell, G.K., Miller, M., Beale, G., Emery, K. & Lucas, S. (2005), *Current and predicted minimum and maximum extents of land salinisation in the upland portion of the Murray–Darling Basin.* **in** A. Zerger & R.M. Argent (editors) MODSIM 2005 International Congress on Modelling and Simulation, Modelling and Simulation Society of Australia and New Zealand, December 2005

Williams, R.M. (1993). *Saline Groundwater Inflows into the Darling River at Glen Villa, near Bourke.* TS 93.038. Hydrgeology Unit, NSW DWR (Parramatta).

Woolley, D.R. (1997). *Thermal infrared survey: Darling River and Baldry-Yeoval areas, NSW.* CNR 97.066. NSW DLWC (Parramatta).

Appendix A. Salinity data

Table A.8.1. EC data in the Barwon-Darling River valley

Station number	Station name	Lat (S)	Lon (E)	Data type	Period collected	Number of data days
416001	Barwon R @ Mungindi	28.967	148.983	Continuous	1995-2002	2,182
416001	Barwon R @ Mungindi	28.967	148.983	Discrete	1968-2001	536
416027	Gil Gil Ck @ Weemelah	29.050	149.159	Discrete	1969-1989	73
416028	Boomi R @ Neeworra	29.023	149.062	Discrete	1969-1989	69
417001	Moonie R @ Gundablouie	29.168	148.629	Discrete	1977-1990	24
418031	Gwydir R @ Collymongle	29.391	148.812	Discrete	1971-1989	19
418055	Mehi R @ near Collarenebri	29.513	148.723	Discrete	1980-2001	94
419026	Namoi R @ Goangra	30.144	148.386	Continuous	1995-2002	2,391
419026	Namoi R @ Goangra	30.144	148.386	Discrete	1969-2002	198
419049	Pian Ck @ Waminda	29.924	148.386	Discrete	1976-2002	120
420005	Castlereagh R @ Coonamble	30.571	148.234	Discrete	1970-1991	83
421011	Marthaguy Ck @ Carinda	30.280	147.410	Discrete	1976-1991	55
421012	Macquarie R @ Carinda	30.433	147.566	Continuous	1998-2002	745
421012	Macquarie R @ Carinda	30.433	147.566	Discrete	1976-1998	242
421023	Bogan R @ Gongolgon	30.350	146.900	Continuous	2000-2002	398
421023	Bogan R @ Gongolgon	30.350	146.900	Discrete	1970-2001	162
421107	Marra Ck @ Billybingbone Brdge	30.223	147.112	Discrete	1977-1991	62
422001	Barwon R @ Walgett	30.017	148.059	Continuous	1995-2002	2,383
422001	Barwon R @ Walgett	30.017	148.059	Discrete	1968-2002	484
422002	Barwon R @ Brewarrina	29.967	146.867	Continuous	1995-2002	2,169
422002	Barwon R @ Brewarrina	29.967	146.867	Discrete	1964-2002	209
422003	Barwon R @ Collarenebri	29.550	148.583	Discrete	1968-2002	340
422004	Barwon R @ Mogil Mogil	29.354	148.687	Discrete	1970-1991	93
422005	Bokhara R @ Bokhara	29.626	147.018	Discrete	1968-1990	47
422006	Culgoa R @ d/s Collerina	29.775	146.517	Discrete	1969-1991	138
423001	Warrego R @ Fords Br	29.753	145.425	Discrete	1971-1990	21
425003	Darling R @ Bourke	30.083	145.933	Discrete	1964-2002	1,597
425004	Darling R @ Louth	30.533	145.114	Continuous	1995-2001	1,399
425004	Darling R @ Louth	30.533	145.114	Discrete	1964-1997	179
425008	Darling R @ Wilcannia (main channel)	31.567	143.367	Continuous	2001-2001	75
425008	Darling R @ Wilcannia (main channel)	31.567	143.367	Discrete	1965-2001	1,204

Station number	Station name	Lat (S)	Lon (E)	Data type	Period collected	Number of data days
425900	Darling R @ Tilpa	30.936	144.418	Continuous	1995-2001	1,268
425900	Darling R @ Tilpa	30.936	144.418	Discrete	1995-2001	57

Appendix B. Flow-salinity tables

B.1. FLOW-SALINITY TABLES USED IN INDIVIDUAL REACH MODELS

Table B.8.1. Flow-salinity tables for inflow nodes between Mungindi and Walgett

IQQM inflow node number and name		Flow (ML/d)	Salinity (mg/L)	Flow (ML/d)	Salinity (mg/L)
001	416001 Barwon River @ Mungindi	0.001	339	249	149
		5	240	342	145
		14	213	448	139
		26	197	539	133
		52	189	680	128
		78	180	962	121
		103	176	1,478	115
		142	169	2,009	109
		182	163	3,278	100
		219	156	1e37	100
018	416028 Boomi River @ Neeworra	0.001	270	224	159
		3	250	270	151
		23	232	336	148
		31	213	430	143
		47	205	524	141
		63	203	558	139
		73	194	731	124
		98	182	1,424	113
		142	169	1,902	110
		189	161	1e37	110
146	Border Rivers floodplain (includes Little Weir River)	0.001	250	57	159
		2	232	320	141
		4	205	1,423	110
		8	194	1e37	110
024	416027 Gil Gil Creek @ Weemelah	0.001	520	76	223
		1	462	96	216
		3	396	105	199
		4	357	133	185
		10	317	175	158
		16	301	223	151
		26	268	364	143

		31	260	522	139
		42	254	803	130
		52	242	1e37	130
028	417001 Moonie River @ Gundablouie	0.001	117	62	85
		1	101	89	82
		3	99	134	79
		5	98	206	76
		8	96	358	73
		12	95	665	71
		16	93	1,286	69
		22	92	2,469	65
		31	90	5,613	61
		43	88	1e37	61
360	Moonie River floodplain	0.001	117		
		2	52		
		1e37	52		
038	418031 Gwydir River @ Collymongle	0.001	762	59	220
		1	683	81	209
		2	444	149	204
		10	333	189	197
		22	285	216	187
		23	280	323	168
		28	273	476	153
		44	263	720	145
		53	250	801	137
		58	235	1e37	137
343	418055 Mehi River near Collarenebri	0.001	502	87	228
		2	410	108	218
		4	378	128	211
		9	362	157	202
		16	344	178	184
		20	309	347	164
		28	288	653	141
		34	279	859	133
		52	267	1,772	119
		56	254	1e37	92

		69	240		
351	Gwydir River floodplain	0.001	362	18	211
		1	362	35	202
		2	309	78	184
		3	288	167	164
		4	267	423	141
		5	254	1,008	133
		6	240	2,498	119
		8	228	1e37	92
		11	218		
067	419026 Namoi River @ Goangra	0.001	535	181	268
		14	428	214	256
		22	404	261	243
		51	375	288	234
		63	348	374	223
		86	336	436	207
		105	311	757	193
		125	300	1,608	177
		151	293	1e37	177
		163	282		
068	419049 Pian Creek @ Waminda	0.001	736	36	300
		1	457	52	289
		2	423	66	274
		3	400	74	265
		4	386	93	249
		6	370	170	221
		9	365	295	205
		12	353	458	179
		18	339	914	159
		24	322	2,104	135
		31	314	1e37	135
076	Namoi River floodplain	0.001	736	33	265
		1	353	47	249
		3	339	79	221
		6	322	155	205
		9	314	384	179

		13	300	1,358	159
		18	289	2,104	135
		25	274	1e37	135

Table B.8.2. Flow-salinity tables for inflow nodes between Walgett and Bourke

IQQM inflow node number and name		Flow (ML/d)	Salinity (mg/L)	Flow (ML/d)	Salinity (mg/L)
370	Residual catchment:	0	408	433	70
	Walgett-Brewarrina	3	89	1e37	70
	(right hand side)	23	79		
085	421012 Macquarie River @	1	658	87	267
	Carinda	9	397	165	253
		18	352	278	234
		23	328	1,146	196
		29	309	11,246	150
		34	293	1e37	150
		55	281		
089	421011 Marthaguy Creek @	0	658	1,108	196
	Carinda	6	253	17,226	150
		51	234	1e37	150
094	425005 Castlereagh River @	0	751	1423	203
	Coonamble	4	751	2970	174
		38	701	6,767	157
		98	570	28,914	142
		149	463570	94,888	100
		314	423	1e37	100
		601	340		
371	Residual catchment:	0	658		
	Walgett-Brewarrina	3	196		
	(left hand side)	1189	150		
		1e37	150		
372	Macquarie River floodplain	5	658	54	267
	(first half)	7	397	101	253
		9	352	207	234
		11	328	1,094	196

		15	309	11,130	150
		23	293	1e37	150
		35	281		
104	421097 Marra Creek @ Carinda Road	0	658	324	196
		1	267	2,976	150
		6	253	1e37	150
		79	234		
182	Narran Lake overflow	0.001	408	722	106
		208	119	1e37	106
		349	111		
121	422005 Bokhara River @ Bokhara	0.001	408	122	165
		4	240	171	148
		8	228	211	137
		12	196	238	127
		27	192	474	119
		38	182	518	111
		79	179	676	106
382	Residual catchment: Brewarrina-Bourke (left hand side)	0	385		
		43	67		
		19,662	30		
		1e37	30		
383	Macquarie River floodplain (second half)	6	385	216	154
		8	298	487	130
		18	263	987	109
		27	238	3,715	67
		42	216	21,918	30
		70	193	1e37	30
		155	182		
384	Residual catchment: Brewarrina-Bourke (right hand side)	0	327		
		64	70		
		7,896	30		
		1e37	30		
127	422006 Culgoa River d/s Collerina	0.001	327	250	141
		23	283	290	137

		63	248	376	129
		81	206	520	119
		93	168	640	112
		116	156	925	104
		165	148	1e37	104
131	421023 Bogan River @ Gongolgon	0.001	385	105	183
		4	309	147	157
		12	289	170	153
		15	276	187	139
		21	262	257	125
		28	246	412	116
		36	234	1,067	96
		43	225	1,911	81
		56	215	10,223	63
		69	202	1e37	63
		86	190		

Appendix C. Marthaguy Creek Flow and Salt Loads

C.1. CATCHMENT DESCRIPTION

The Marthaguy Creek catchment is located between the catchments of Castlereagh River and the Macquarie Rivers. From its origins north of Narromine, this catchment extends in a north westerly direction towards its confluence with the Macquarie River. The total area of the Marthaguy Creek catchment is approximately 6500 km^2.

From its origin, Marthaguy Creek is soon joined by Boothaguy Creek. The combined stream changes its course, and flows in a north-westerly direction. For the major part of its course, the river is in close proximity to the western boundary of its catchment. Marthaguy Creek is further joined by Merrigal Creek, Bamabung Creek and Bullagreen Creek, all of which arise from the eastern part of the catchment. Towards its downstream end, Marthaguy Creek is joined by a number of effluents from the Macquarie River. These streams carry significant volumes of water and Marthaguy Creek, in it's lower reaches, could be viewed as an effluent of the Macquarie River.

Mean annual rainfall over the catchment varies from 400 mm in the south east to 350 mm in the north west.

C.2. QUANTITY MODEL

The Marthaguy IQQM extends from its headwaters, above Quambone (421062) streamflow gauging station, down to Carinda streamflow gauging station (421011). The model was developed to supply water to the Barwon-Darling IQQM and is a simple model with 7 nodes. The structure of the model is shown in Figure C.1

A comparison of observed & simulated flows at Carinda gauging station (Table C.1) shows that for all ranges similar statistical characteristics have been achieved.

Table C.1 Comparison of simulated and observed flows Marthaguy Creek @ Carinda (421001) (Calibration period 6/3/1971 – 30/12/2001)

Flow Range		Mean	SD	Minimum	Maximum
Low	Obs	0	0	0	0
	Sim	0	0	0	0
Medium	Obs	6.26	13.45	0	64
	Sim	19.55	19.42	0	92
High	Obs	1854	2920	64	18426
	Sim	1289	1459	92	9115
All	Obs	373.5	1499	0	18426
	Sim	268.7	826.8	0	9115

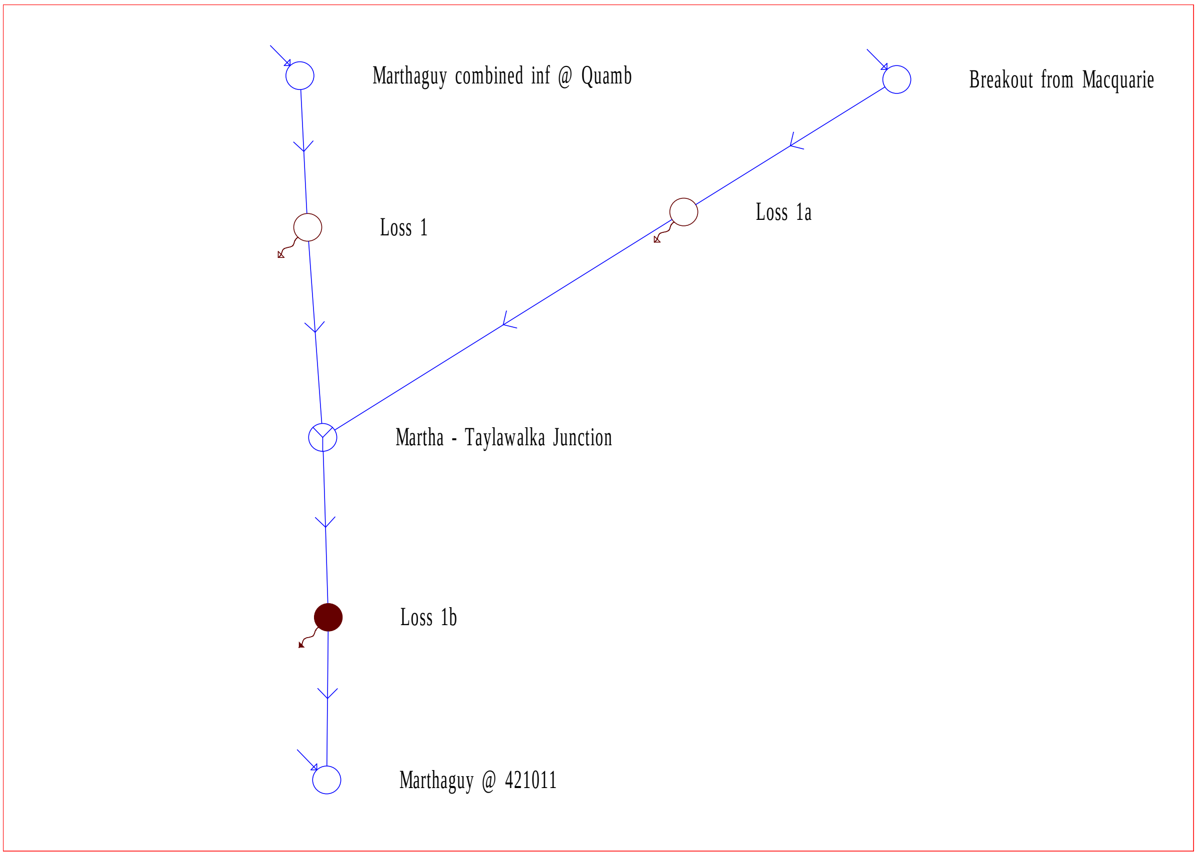


Figure C1: Schematic of Marthaguy Creek IQQM

C.3. HISTORICAL SALT DATA

Only 55 salinity samples have been collected at Carinda streamflow gauging station (421011). Samples have been collected spasmodically, over the period (3/6/1976 to 12/2/1991), with more frequent sampling during 1977-78, 1981 and 1986. The salinity ranges from about 60 to 690 mg/L, with a median salinity of 313 mg/L.

C.4. HOW SALT LOAD ESTIMATED

Salt load inflows for Marthaguy Creek were estimated using simulated salinity data from Macquarie River at Carinda (421012). The method estimates Marthaguy Creek salt loads using a flow verses concentration look-up tables (LUT), based on ordinates from exceedance curves for Macquarie River @ Carinda streamflow gauging station (ie Macquarie River @ Carinda translated to Marthaguy Creek @ Carinda). See Appendix B for details of the LUT.

The flow versus concentration LUT is based on the assumption that flow is inversely related to concentration (Equation C.1). This relationship is defined using corresponding pairs of data [(Q_1,C_1), (Q_2,C_2), …(Q_n,C_n)]. These points are taken from corresponding exceedance and non-exceedance ordinates on the ranked plots of data, to form a Table of relationships.

$$C \propto \frac{1}{Q} \qquad \text{(C.1)}$$

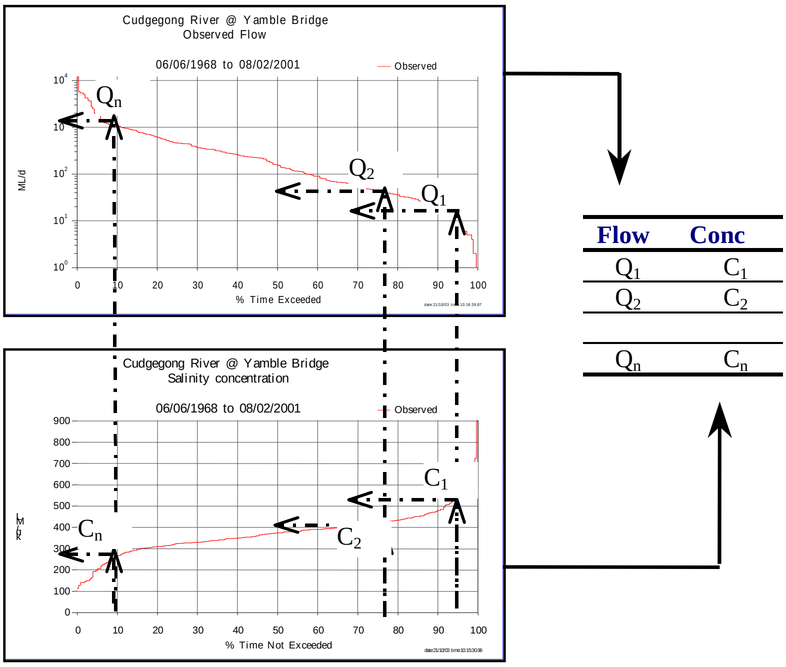


Figure C.2. Derivation of flow versus concentration LUT from exceedance curves

C.5. BASE LINE CONDITIONS

The flow versus concentration LUT that was transposed from the observed data taken from Macquarie River at Carinda is used unchanged in the Base line conditions. Base line effluent flows from the Macquarie IQQM are used as inflows to the Marthaguy IQQM. Table C2 and Table C3 detail the baseline salt concentration and salt loads.

Table C.2. Simulated results of salinity and salt load for MDBMC BSMS Baseline, using calibrated relationships applied to 1/1/2000 conditions model, based on analysis of daily results 01/05/1975-30/04/2000

Target Site Target Site		Concentration (kg/ML)				Salt Load (x1,000 T/day)			
Number	Name	*Mean*	*Percentile non exceedance*			*Mean*	*Percentile non exceedance*		
			20	*50*	*80*		*20*	*50*	*80*
421011	Marthaguy Creek @ Carinda	266	224	242	253	79	2	8	72

Table C.3. Simulated results of salt loads for MDBMC BSMS Baseline, using calibrated relationships applied to 1/1/2000 conditions model, based on analysis of annual results 01/05/1975-30/04/2000

Target Site		Salt load (x 10^6 T/year)			
Number	Name	*Mean*	*Percentile non exceedance*		
			20	*50*	*80*
421011	Marthaguy Creek @ Carinda	29	7	19	40

Table C.4. Statistics of observed data for flow, salinity and salt load(01/05/1975-30/04/2000) at Marthaguy Creek at Carinda

Parameter	Units	Mean	Percent non-exceedance		
			20	50	80
Flow	(ML/d)	308	0	0	83
Salinity	(mg/L)	186	89	184	280
Salt load	(x1,000 T/d)	226	2	13	200

Appendix D. Castlereagh River Flow and Salt Loads

D.1. CATCHMENT DESCRIPTION

The Castlereagh River joins the Macquarie River before the combined streams meet the Barwon-Darling River. The Castlereagh River rises in the Warrumbungle Ranges at an elevation of 800 m. Most of the catchment is predominantly flat with slopes of 3 percent or less. The total catchment area of the Castlereagh River Valley is about 17500 Km^2.

From its origins, the Castlereagh River flows easterly towards Coonabarabran. A number of tributaries (Belar, Greenbah, Ulimambra, Weetaliba, Merrygoen Creeks) join the river, and the river flows in a south-westerly direction towards Mendooran. Downstream of Mendooran, the river changes its course to north-west towards Gilgandra and is joined by Piangula and Wallumburrawang Creeks. Downstream of Gilgandra, the river is joined by Terrabile and Gulargambone Creeks, before the river reaches Coonamble.

At Coonamble, the Coonamble Creek system joins Warrena Creek that, in addition to receiving runoff from its own catchment also carries overbank flows from Castlereagh River. A number of tributaries that contribute little or no runoff (except during flood periods) also join the river downstream of Coonamble.

Mean annual rainfall over the catchment generally varies between 500 mm/year and 650 mm/year. The wettest area is near Coonabarabran in the Warrumbungle Ranges.

D.2. QUANTITY MODEL

The Castlereagh River IQQM extends from its headwaters, above Mendoran streamflow gauging station (421004), down to Coonamble. The model was developed to supply water to the Barwon-Darling IQQM and is a simple model with only 6 nodes. The structure of the model is shown in Figure D.1

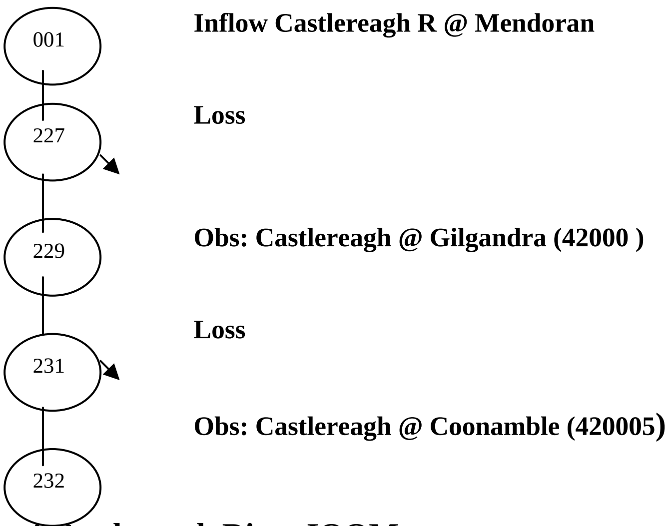


Figure D.1 Schematic of Castlereagh River IQQM

A comparison of observed and simulated flows at Coonamble streamflow gauging station (Table D.1) shows that for all ranges similar statistical characteristics have been achieved.

Table D1 Comparison of simulated and observed flows Castlereagh River @ Coonamble (425005) (Calibration period 1/1/1960 – 30/12/1996)

Flow Range		Mean	SD	Minimum	Maximum
Low	Obs	0		0	
	Sim	0		0	
Medium	Obs	57.2	45.1	0	167
	Sim	59.2	38.8	0	156
High	Obs	1504	49.3	167	66200
	Sim	1432	44.7	156	77050
All	Obs	581.3	3048	0	66200
	Sim	556.2	2768	0	77050

D.3. HISTORICAL SALT DATA

Data has been collected fairly consistently at Coonamble streamflow gauging station (421005). Samples have been collected every 2-4 months, over the evaluation period (1/5/1975 to 30/4/2000), except for gaps during 1980 and 1992- 2000. The salinity ranges from about 60 to 790 mg/L, with a median salinity of 440 mg/L.

With such little data available (only 68 data points) it is not surprising that not all flow ranges and months are fully represented (Table D.2). There no flow in the low flow range. Table D.3 shows that sampling in the entire medium and high flow ranges tends to be biased towards the lower.

Table D.2. Distribution of flow with discrete EC across flow ranges and months for Station 420005: Castlereagh River @ Coonamble

Flow range	Period	Number Points	Number of months with data											
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Low	1975-2000	4	1	0	0	0	0	1	0	0	0	1	0	1
Medium		38	1	0	3	2	2	5	4	4	4	5	4	2
High		37	3	3	1	1	2	4	4	4	2	2	2	1
All		79	5	3	4	3	6	9	9	8	4	8	6	4

Table D.3. Comparison of statistics within flow ranges of all observed flows versus observed flows on days with discrete EC data during evaluation period for Station 420005

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	0.0			
	With EC obs	0.0			
Medium	*All*	73.4	60.9	1	224
	With EC obs	92.9	51.6	4	224
High	*All*	2048	6247	224	94888
	With EC obs	6532	12512	224	58500
ALL	*All*	439	2903	0	94888
	With EC obs	3104	9099	0	58500

D.4. HOW SALT LOAD ESTIMATED

Salt load inflows for the Castlereagh catchment were estimated using all available salinity data at Coonamble gauging station. The method estimates these loads using flow versus concentration look-up tables (LUT), based on ordinates from exceedance curves. See Appendix B for details of the LUT.

The flow versus concentration LUT is based on the assumption that flow is inversely related to concentration (Equation D.1). This relationship is defined using corresponding pairs of data [(Q_1,C_1), (Q_2,C_2), …(Q_n,C_n)]. These points are taken from corresponding exceedance and non-exceedance ordinates on the ranked plots of data, to form a Table of relationships.

$$C \propto \frac{1}{Q} \qquad \text{(D.1)}$$

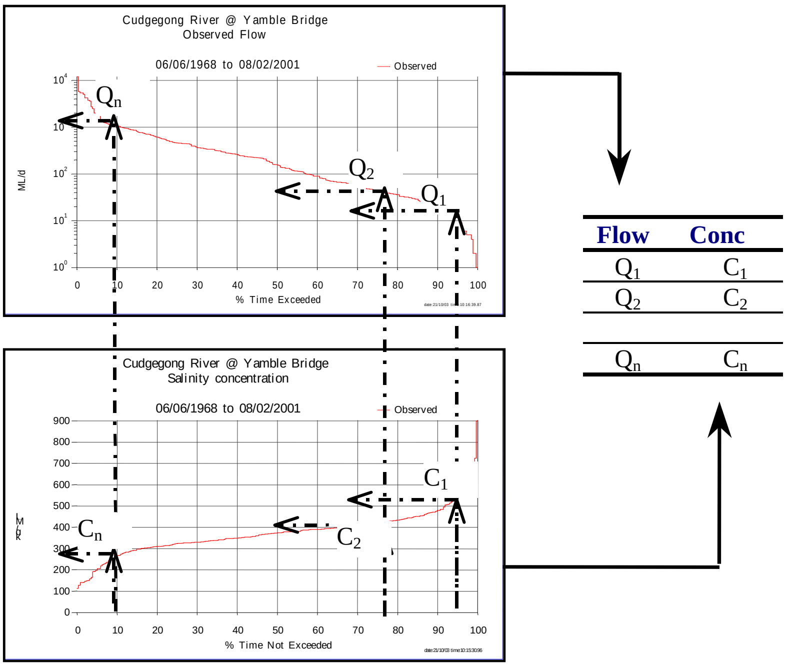


Figure D.2. Derivation of flow versus concentration LUT from exceedance curves

D.5. BASE LINE CONDITIONS

The flow versus concentration LUT that was derived from observed data was used unchanged in baseline conditions. Observed and extended flows from the Castlereagh catchment are also unchanged. The baseline conditions are detailed in Table D4 and Table D5.

Table D.4. Simulated results of salinity and salt load for MDBMC BSMS Baseline, using calibrated relationships applied to 1/1/2000 conditions model, based on analysis of daily results 01/05/1975-30/04/2000

Target Site Target Site		**Concentration (kg/ML)**				**Salt Load (x1,000 T/day)**			
Number	Name	*Mean*	*Percentile non exceedance*			*Mean*	*Percentile non exceedance*		
			20	*50*	*80*		*20*	*50*	*80*
420005	Castlereagh River @ Coonamble	539	386	572	722	77	0	12	90

Table D.5. Simulated results of salt loads for MDBMC BSMS Baseline, using calibrated relationships applied to 1/1/2000 conditions model, based on analysis of annual results 01/05/1975-30/04/2000

Target Site		**Salt load (x 10^6 T/year)**			
Number	Name	*Mean*	*Percentile non exceedance*		
			20	*50*	*80*
420005	Castlereagh River @ Coonamble	28	6	24	37

Table D.6. Statistics of observed data for flow, salinity and salt load(01/05/1975-30/04/2000) at Castlereagh River at Coonamble

Parameter	Units	Mean	Percent non-exceedance		
			20	50	80
Flow	(ML/d)	334	0	16	199
Salinity	(mg/L)	436	206	444	600
Salt load	(x1,000 T/d)	356	37	85	400

Appendix E. Marra Creek Flow and Salt Loads

E.1. CATCHMENT DESCRIPTION

Marra Creek is an effluent stream located between the catchments of Macquarie and Bogan Rivers. From its origin it extends in a north-westerly direction, towards its confluence with the Barwon-Darling River.

The upstream segment of Marra Creek receives considerable effluent flows from its neighbouring streams, namely the Macquarie River and the Crooked Creek. It receives further inflows from the Marebone Weir Pool on the Macquarie River through an offtake channel. The stream flows in a north west direction and is joined by Crooked Creek. At some distance downstream of its confluence, the combined stream slightly change it course towards north, and receives a number of minor effluents from the Macquarie and Bogan River catchments.

The mean annual rainfall of this catchment is about 350 mm.

E.2. QUANTITY MODEL

Marra Creek IQQM is comprised of 10 nodes. Inflows to the model have been estimated at two locations, the inflow from Crooked Creek and Macquarie River (from Macquarie IQQM) and the inflows from the weir pool around Marebone Weir (from Macquarie IQQM). The model has been calibrated (using loss nodes) to match observed flows at Carinda Road (421097), Billybingbone Bridge (421097) and Yarrawin (421024). The structure of the model is shown in Figure E.1.

A comparison of observed & simulated flows at Billybingbone Bridge (Table E.1) shows that for all ranges similar statistical characteristics have been achieved.

Table E1 Comparison of simulated and observed flows Marra Creek @ Billybingbone Bridge

Flow Range		Mean	SD	Minimum	Maximum
Low	Obs				
	Sim				
Medium	Obs	8	12	0	48
	Sim	4	9	0	44
High	Obs	194	172	48	818
	Sim	160	118	44	738
All	Obs	44	109	0	818
	Sim	35	83	0	738

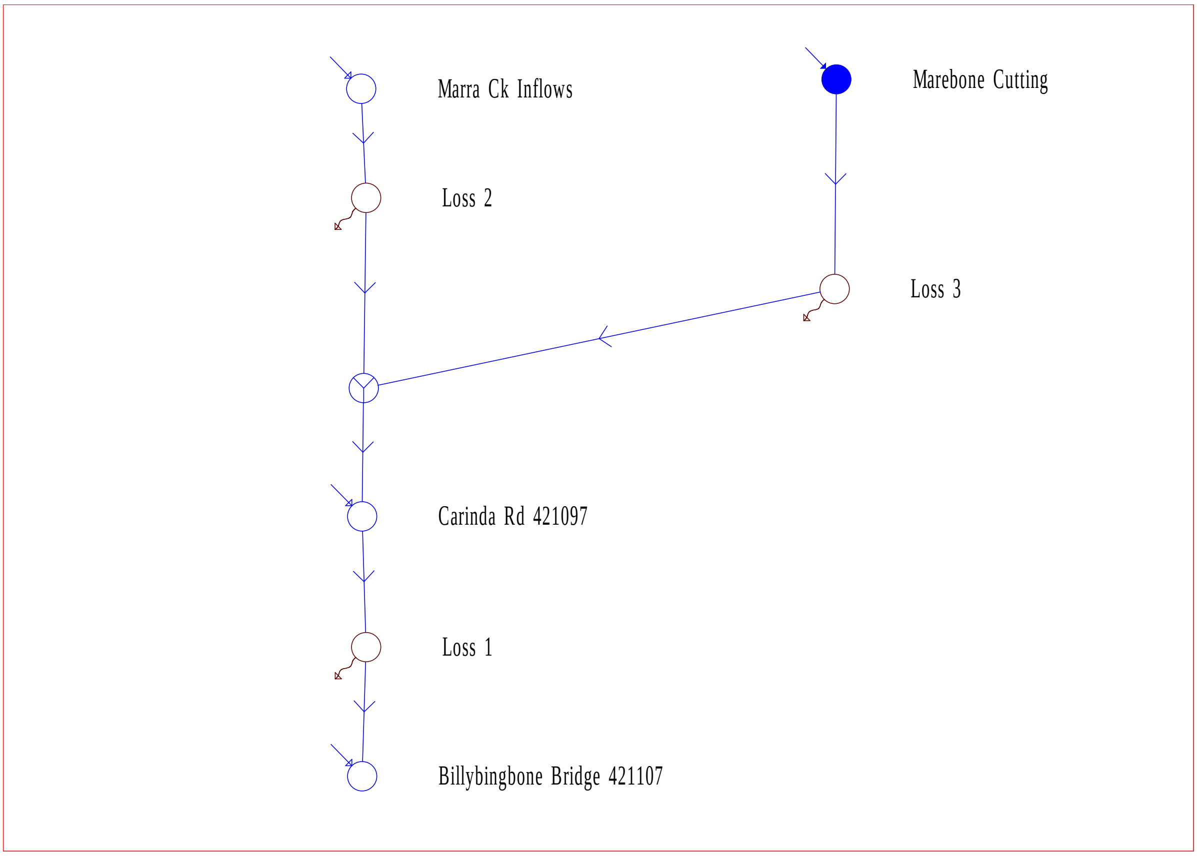


Figure E1: Schematic of Marra Creek IQQM

E.3. HISTORICAL SALT DATA

Only 26 salinity samples have been collected at the Billybingbone Bridge gauging station. Samples have been collected approximately quarterly, over the period (26/8/1980 to 29/05/1991), with less frequent sampling during 1987 and 1988. The salinity ranges from about 109 to 440 mg/L, with a median salinity of 278 mg/L.

E.4. HOW SALT LOAD ESTIMATED

Salt load inflows for Marra Creek were estimated using simulated salinity data from Macquarie River at Carinda (421012). The method estimates Marra Creek loads using flow versus concentration look-up tables (LUT), based on ordinates from exceedance curves at Carinda gauge translated to Billybingbone Bridge gauge. Appendix B details the LUT.

The flow versus concentration LUT is based on the assumption that flow is inversely related to concentration (Equation E.1). This relationship is defined using corresponding pairs of data [(Q_1,C_1), (Q_2,C_2), …(Q_n,C_n)]. These points are taken from corresponding exceedance and non-exceedance ordinates on the ranked plots of data, to form a Table of relationships.

$$C \propto \frac{1}{Q} \qquad \text{(E.1)}$$

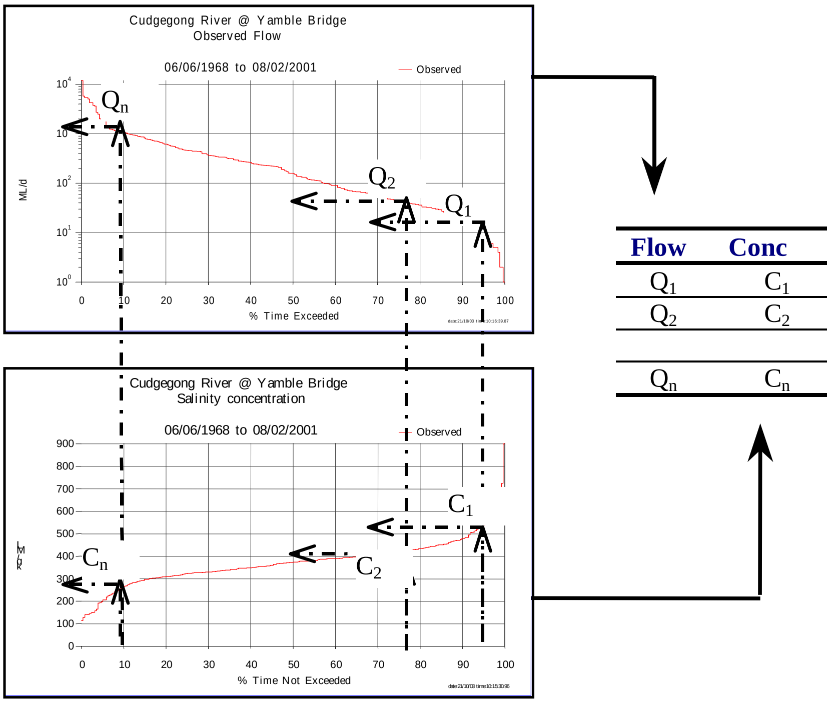


Figure E.2. Derivation of flow versus concentration LUT from exceedance curves

E.5. BASE LINE CONDITIONS

The flow versus concentration LUT that was transposed from the observed data taken from Macquarie River at Carinda is used unchanged in the baseline conditions. Baseline effluent flows from the Macquarie IQQM are used as inflows to the Marra IQQM. Tables E2 and E3 detail the baseline conditions.

Table E.2. Simulated results of salinity and salt load for MDBMC BSMS Baseline, using calibrated relationships applied to 1/1/2000 conditions model, based on analysis of daily results 01/05/1975-30/04/2000

Target Site Target Site		Concentration (kg/ML)				Salt Load (x1,000 T/day)			
Number	Name	*Mean*	*Percentile non exceedance*			*Mean*	*Percentile non exceedance*		
			20	*50*	*80*		*20*	*50*	*80*
421107	Marra Creek @ Billybingbone	254	219	237	255	24	0	1	32

Table E.3. Simulated results of salt loads for MDBMC BSMS Baseline, using calibrated relationships applied to 1/1/2000 conditions model, based on analysis of annual results 01/05/1975-30/04/2000

Target Site		Salt load (x 10^6 T/year)			
Number	Name	*Mean*	*Percentile non exceedance*		
			20	*50*	*80*
421107	Marra Creek @ Billybingbone	9	2	4	11

There is insufficient flow and salinity data at the Marra Creek at Billybingbone Bridge gauging station to make any statistics worthwhile.

Appendix F. Bogan River Flow and Salt Loads

F.1. CATCHMENT DESCRIPTION

The Bogan River joins the Barwon River upstream of Bourke and downstream of the Barwon River's confluence with the Macquarie River. Most of the catchment consists of broad flat plains with land slopes of 2% or less.

The total catchment area of the Bogan River Valley is about 30,000 km^2, with the streamflow gauge at Gongolgon (421023), commanding most of the catchment area.

The Bogan River originates in the south-east part of the catchment, and flows in a north-west direction. Downstream of Peak Hill, the river is joined by Generan and Bullock creeks, before it reaches Dandaloo. Downstream of Dandaloo, the river is joined by tributaries (Bulbodney and Tiger creeks) that drain southern part of the catchment. The river changes its course towards the north and traverses through Neurie plains and is joined by south-west tributaries (Pangee and Whitbarrow creeks). before reaching Nyngan. Downstream of Nyngan, the Bogan River flow is greatly influenced by interchange of flows between it and the Macquarie River. The pathways for these interchanges are through the creeks of Gunningbar, Duck and Crooked, and the Albert Priest Channel.

Mean annual rainfall over the catchment varies from 350 mm/year in the west to 550 mm/year in the east.

The Bogan River joins the Barwon River upstream of Bourke and downstream of the Barwon River's confluence with the Macquarie River. Most of the catchment consists of broad flat plains with land slopes of 2% or less.

The total catchment area of the Bogan River Valley is about 30,000 km^2, with the streamflow gauge at Gongolgon (421023), commanding most of the catchment area.

The Bogan River originates in the south-east part of the catchment, and flows in a north-west direction. Downstream of Peak Hill, the river is joined by Generan and Bullock creeks, before it reaches Dandaloo. Downstream of Dandaloo, the river is joined by tributaries (Bulbodney and Tiger creeks) that drain southern part of the catchment. The river changes its course towards the north and traverses through Neurie plains and is joined by south-west tributaries (Pangee and Whitbarrow creeks). before reaching Nyngan. Downstream of Nyngan, the Bogan River flow is greatly influenced by interchange of flows between it and the Macquarie River. The pathways for these interchanges are through the creeks of Gunningbar, Duck and Crooked, and the Albert Priest Channel.

Mean annual rainfall over the catchment varies from 350 mm/year in the west to 550 mm/year in the east.

F.2. QUANTITY MODEL

The Bogan IQQM is comprised of about 20 nodes. Major inflows to the model are estimated at Peak Hill (421076), Belingar Creek (from Macquarie IQQM), Gunningbar Creek (from Macquarie IQQM) and Duck Creek (from Macquarie IQQM). In addition 4 residual inflows have been estimated to account for the ungauged catchments. The model has been calibrated (using loss nodes) to match observed flows at Dandaloo (421083), Neurie Plains (421039), Broonfield (421069) and Gongolgan (421023). The structure of the model is shown in Figure F1.

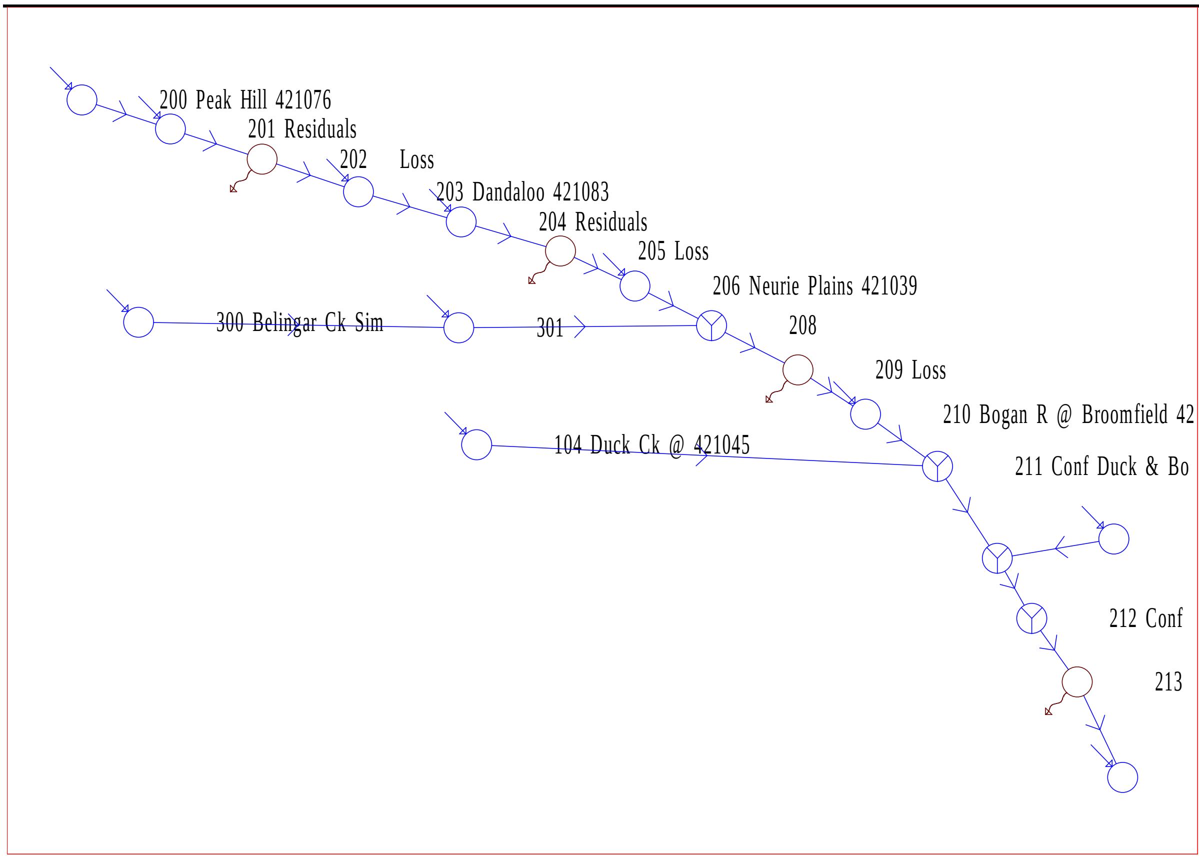


Figure F.1: Schematic of Bogan River IQQM

A comparison of observed & simulated flows at Gongolgon (Table F.1) shows that for low and medium flow ranges simulated flows are overestimated but overall simulated flows are an underestimate of observed flows.

Table F.1 Comparison of simulated and observed flows Bogan River @ Gongolgon (421107)

Flow Range		Mean	SD	Minimum	Maximum
Low	Obs	9	4.1	0	15
	Sim	11	4.9	0	18
Medium	Obs	52	30	15	146
	Sim	138	85	18	295
High	Obs	2330	3635	146	22,410
	Sim	1290	1600	295	14,075
All	Obs	540	1939	0	22,410
	Sim	370	892	0	14,075

F.3. SALINITY DATA

Data has been collected fairly consistently at Gongolgon gauging station. Samples have been collected every 2-4 months, over the evaluation period (1/5/1975 to 30/4/2000), except for a gaps during 1975/76 to 1977/78 and more frequent sampling during 1983-85 and 1992-2000. The salinity ranges from about 30 to 460 mg/L, with a median salinity of 195 mg/L.

With such little data available it is not surprising that not all flow ranges and months are fully represented (Table F.2). Low flow ranges, particularly during July to September are under-represented compared with the exceedance probability range. Table F.3 shows that sampling in all of the low and high flow ranges tends to be biased towards the higher flows whilst in the medium flow range, data was collected during slightly lower than average flows.

Table F.2. Distribution of flow with discrete EC across flow ranges and months for Station 421023: Bogan River @ Gongolgon

Flow range	Period	Number Points	Number of months with data											
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Low	1975-2000	13	1	1	1	2	3	0	0	0	0	2	1	2
Medium		80	5	6	8	3	5	7	11	6	5	6	6	8
High		25	2	2	2	2	1	1	0	1	2	3	2	1
All		118	9	9	11	7	9	8	11	7	9	11	9	11

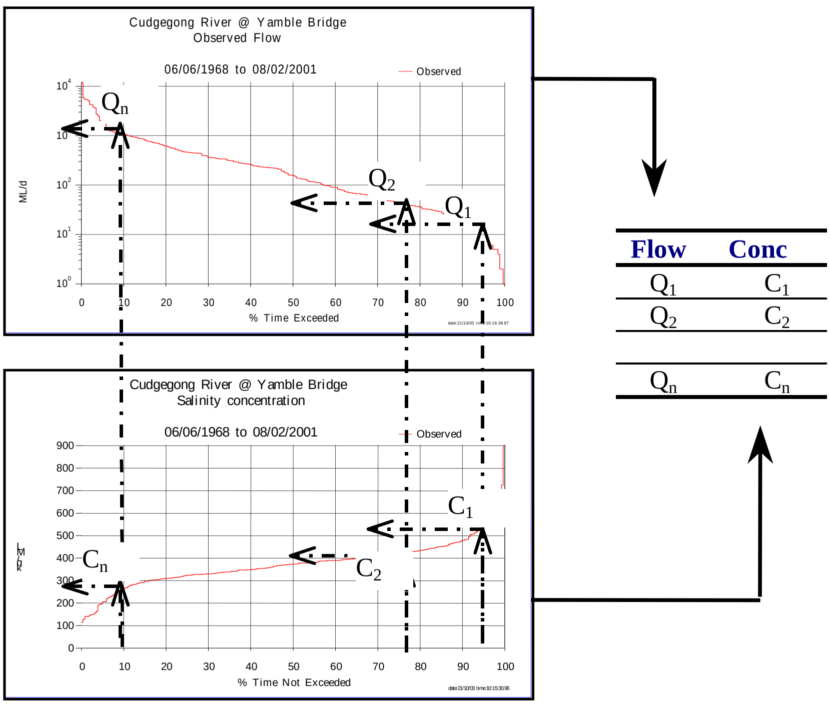
Table F.3. Comparison of statistics within flow ranges of all observed flows versus observed flows on days with discrete EC data during evaluation period for Station 421023

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	2.7	4.1	0	12
	With EC obs	6.2	4.3	0	12
Medium	*All*	102.8	88.3	13	362
	With EC obs	94.8	77.7	13	316
High	*All*	3032.9	5390.6	363	73752
	With EC obs	5937.1	9725.4	377	46410
ALL	*All*	667.8	2684	0	73752
	With EC obs	1322.8	5017.9	0	46410

F.4. HOW SALT LOAD ESTIMATED

Salt load inflows for Bogan catchment were estimated using all available salinity data at Gongolgon. The method estimates these loads using flow versus concentration look-up tables (LUT), based on ordinates from exceedance curves. Appendix B details the LUT.

The flow versus concentration LUT is based on the assumption that flow is inversely related to concentration (Equation F.1). This relationship is defined using corresponding pairs of data [(Q_1,C_1), (Q_2,C_2), …(Q_n,C_n)]. These points are taken from corresponding exceedance and non-exceedance ordinates on the ranked plots of data, to form a Table of relationships.



$$C \propto \frac{1}{Q} \qquad \text{(F.1)}$$

Figure F.2. Derivation of flow versus concentration LUT from exceedance curves

F.5. BASE LINE CONDITIONS

The flow versus concentration LUT that was derived from observed data is used unchanged for baseline conditions. However, baseline effluent flows from the Macquarie catchment (ie Belingar Creek, Gunningbar Creek and Duck Creek) are used in the Bogan IQQM. Tables F4 and F5 detail the baseline conditions.

Table F.4. Simulated results of salinity and salt load for MDBMC BSMS Baseline, using calibrated relationships applied to 1/1/2000 conditions model, based on analysis of daily results 01/05/1975-30/04/2000

Target Site Target Site		Concentration (kg/ML)				Salt Load (x1,000 T/day)			
Number	Name	*Mean*	*Percentile non exceedance*			*Mean*	*Percentile non exceedance*		
			20	*50*	*80*		*20*	*50*	*80*
421023	Bogan River @ Gongolgon	164	123	153	210	42	13	26	36

Table F.5. Simulated results of salt loads for MDBMC BSMS Baseline, using calibrated relationships applied to 1/1/2000 conditions model, based on analysis of annual results 01/05/1975-30/04/2000

Target Site		Salt load (x 10^6 T/year)			
Number	Name	*Mean*	*Percentile non exceedance*		
			20	*50*	*80*
421023	Bogan River @ Gongolgon	15	7	14	19

Table F.6. Statistics of observed data for flow, salinity and salt load(01/05/1975-30/04/2000) at Bogan River at Gongolgon

Parameter	Units	Mean	Percent non-exceedance		
			20	50	80
Flow	(ML/d)	668	12	69	362
Salinity	(mg/L)	186	115	190	262
Salt load	(x1,000 T/d)	103	5	14	64

The results show that under baseline conditions there are more medium to lower flows then was observed at Gongolgon (FigureF.3a). The impact of these changed inflows is seen in the lower salinities during the same medium to lower flows, the salinities are changed by as much as 50 mg/L (Figure F.3b).

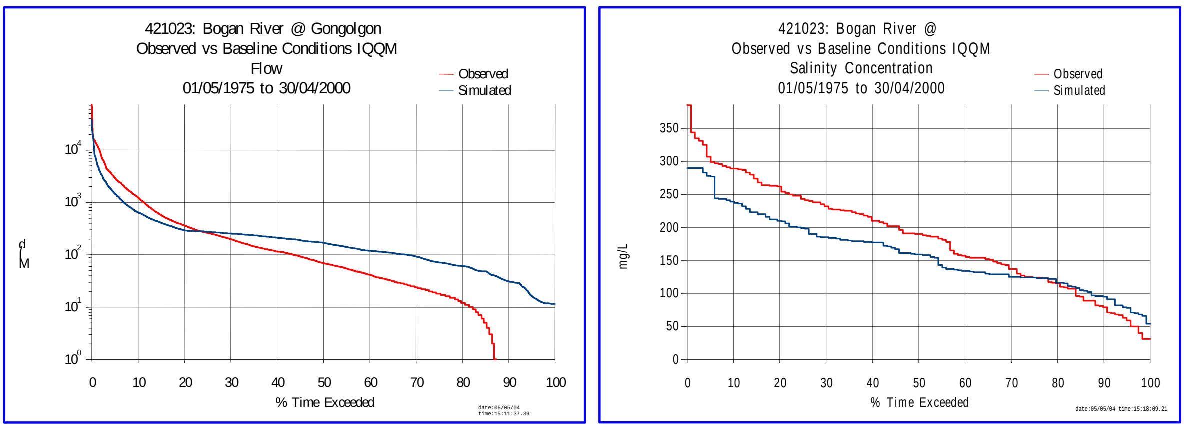


Figure F.3. Station 421023: Bogan River @ Gongolgon; (a) Exceedance curve for observed versus simulated baselineflow, (b) Non-exceedance curve for observed discrete versus simulated basline salinity

Appendix G. Model Details

The following details the IQQM used for the Barwon Darling River Baseline conditions scenario run.

- IQQM version = 6.73.7
- System file = Darlb01.sqq (all other files needed are detailed in the system files)