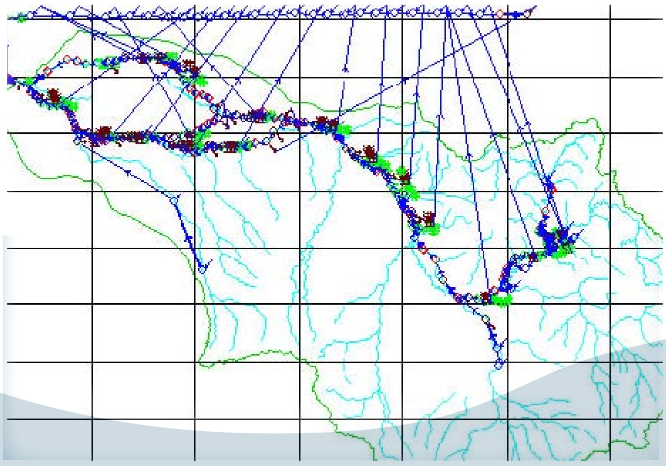
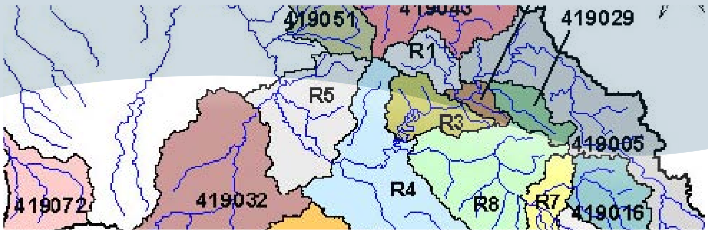
Instream salinity models of NSW tributaries in the Murray-Darling Basin

Volume 3 – Namoi River Salinity Integrated Quantity and Quality Model





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Volume 3 – Namoi River Salinity Integrated Quantity and Quality Model

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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

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1 Introduction

1.1. PURPOSE OF REPORT

The purpose of this report is to document the results of work carried out to develop a Namoi 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 Namoi 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 2. 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 Namoi 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 Namoi IQQM and software testing is described in Chapter 4.

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 biophyscial 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 0.1.

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.

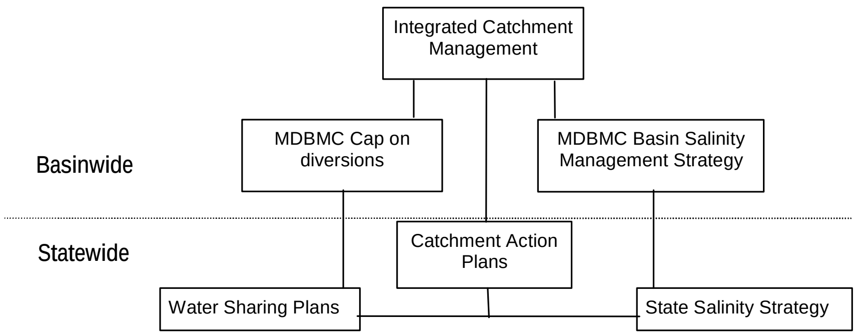


Figure .1. Relationship of Basinwide and Statewide policies and plans

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

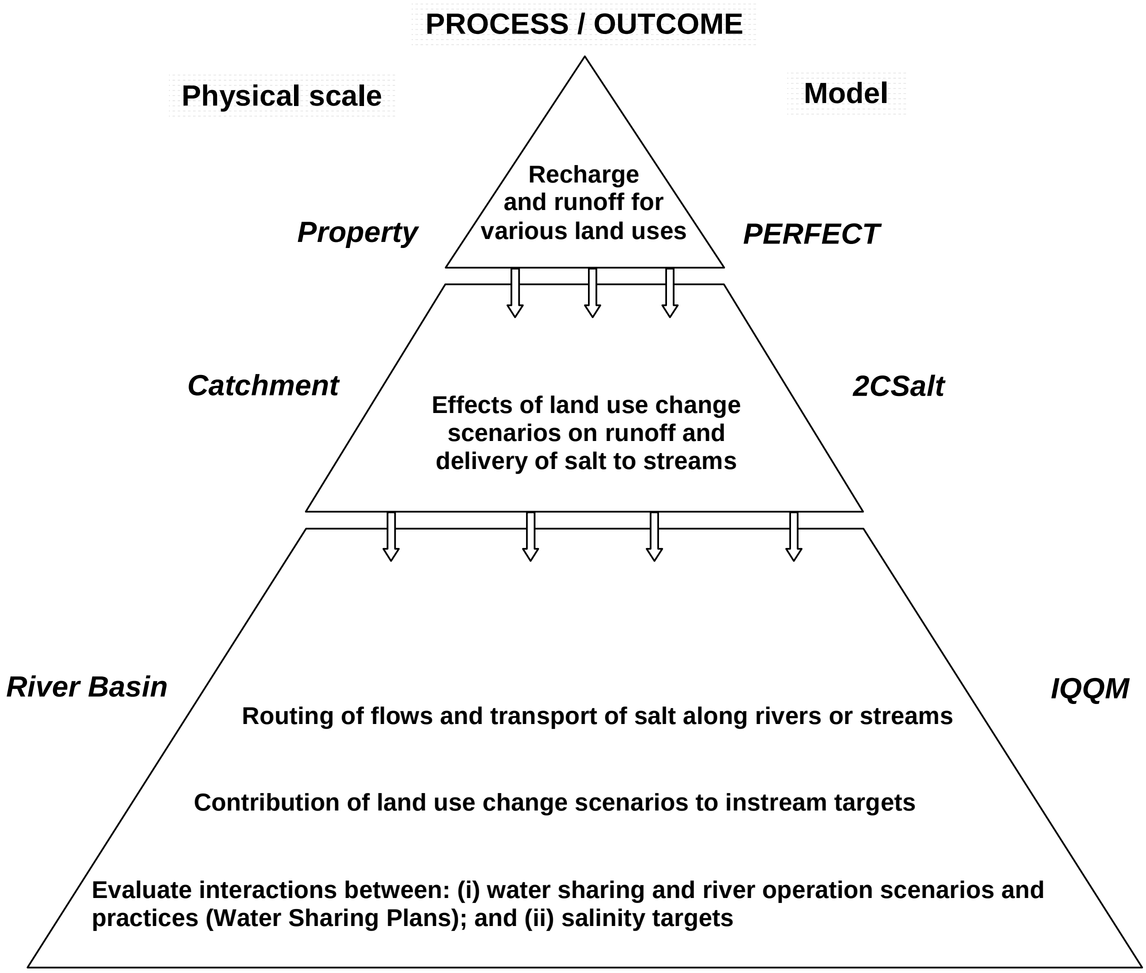


Figure.2. Applications and linkages of DECC and DWE models at different scales

1.5. STAGED MODEL DEVELOPMENT

The work reported here was developed in logical stages as shown in Figure 0.3. 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.

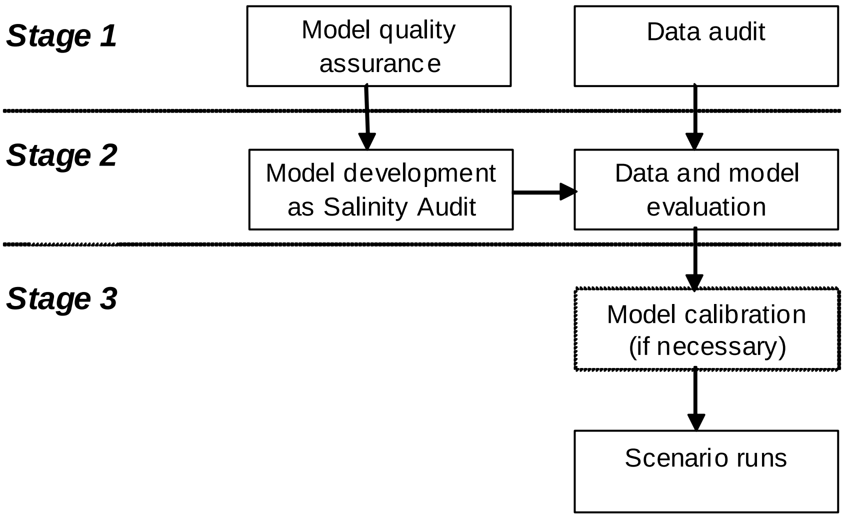


Figure.3. Stages of model development

1.5.1. Stage 1: Model QA and Data Audit

The existent IQQM that had been configured and calibrated for the Namoi 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 Namoi-Peel System

2.1. PHYSICAL FEATURES OF THE CATCHMENT

2.1.1. General

The Namoi-Peel system is one of the major NSW sub-catchments of the Murray-Darling Basin (Figure 2.1). It covers a total area of about 42,000 km^2 from the Great Dividing Range near Tamworth to the Barwon River near Walgett.

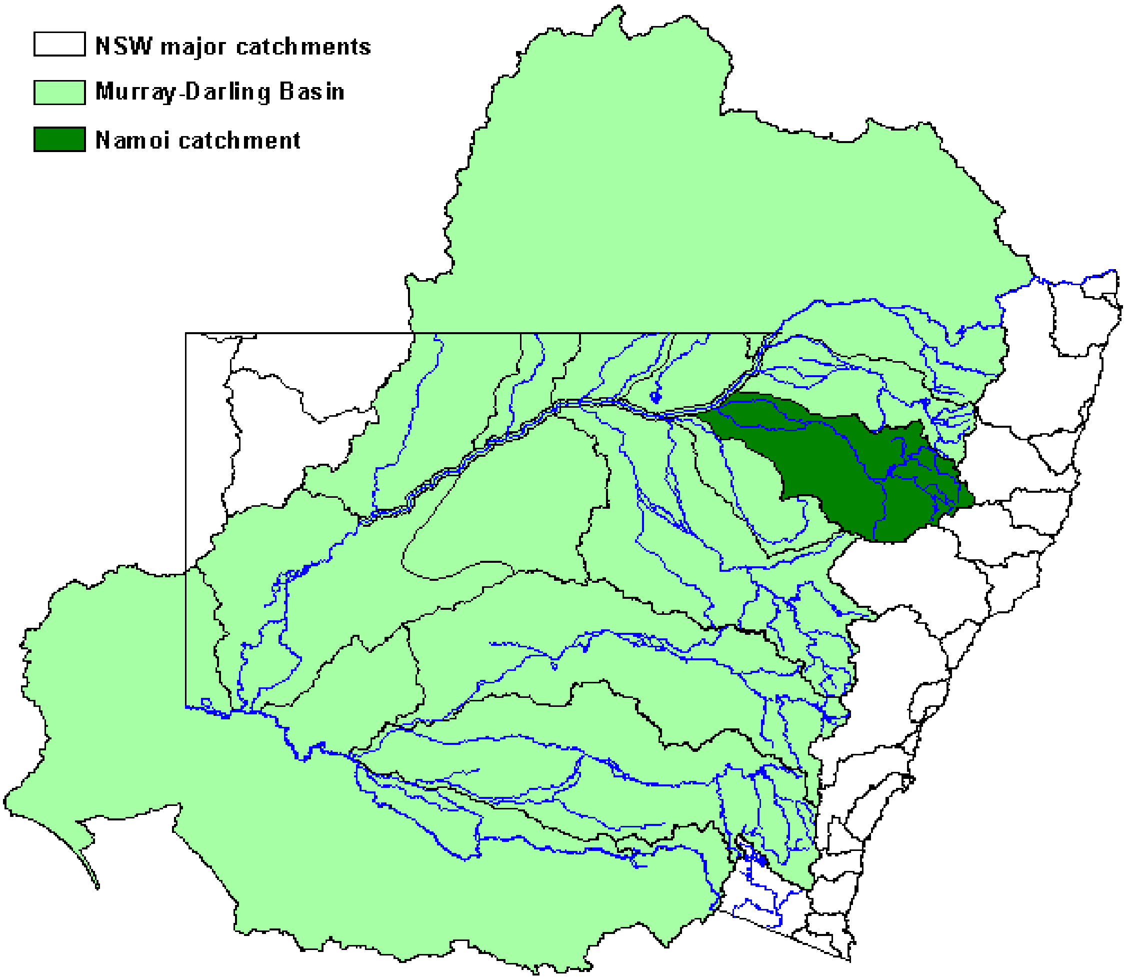


Figure 2.1. Relationship of Namoi-Peel catchments to Murray-Darling Basin

The Namoi-Peel catchments include a number of larger towns (Figure 2.2) including Tamworth (population about 34,500), Gunnedah (population about 9600) and Narrabri (population about 7,500. There are also a number of smaller towns with populations ranging from 600-3,000 people. The total urban population in the Namoi catchment is around 65,000 to 70,000 people.

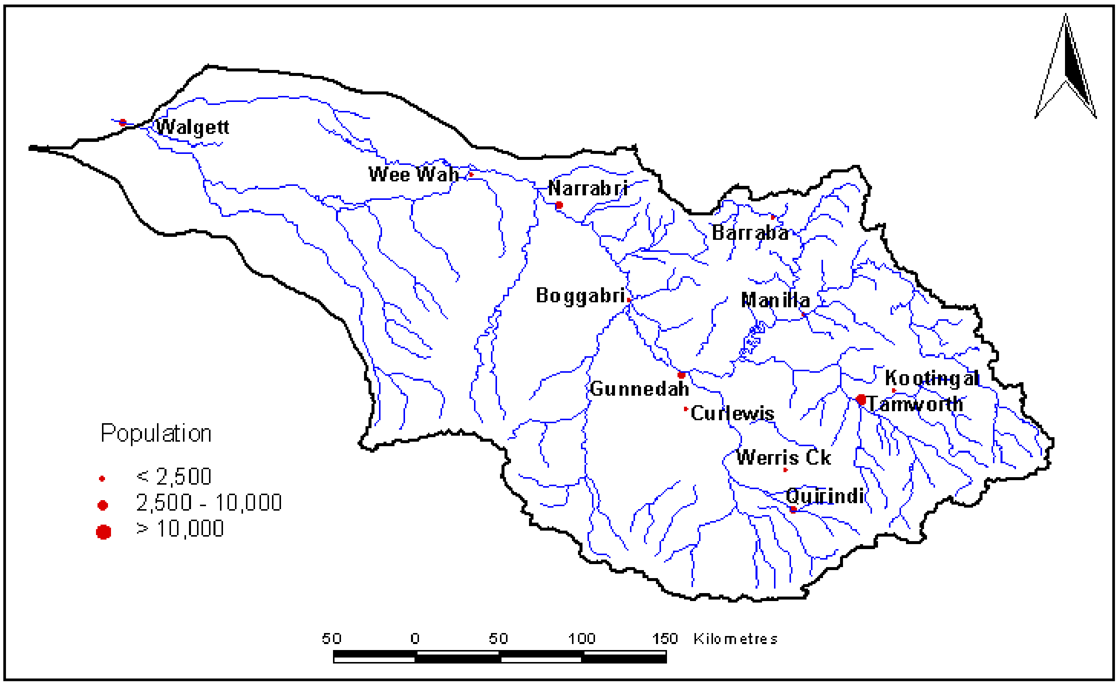


Figure 2.2. Cities and towns in the Namoi-Peel catchment.

The catchment can be considered as four regions (Figure 2.3), based on whether it is a source region of streamflow, or whether it is a region of extraction.

(i) Upper Namoi (source region)

(ii) Peel River including Chaffey Dam (source and extraction region)

(iii) Upstream Boggabri (source region)

(iv) Lower Namoi (extraction region)

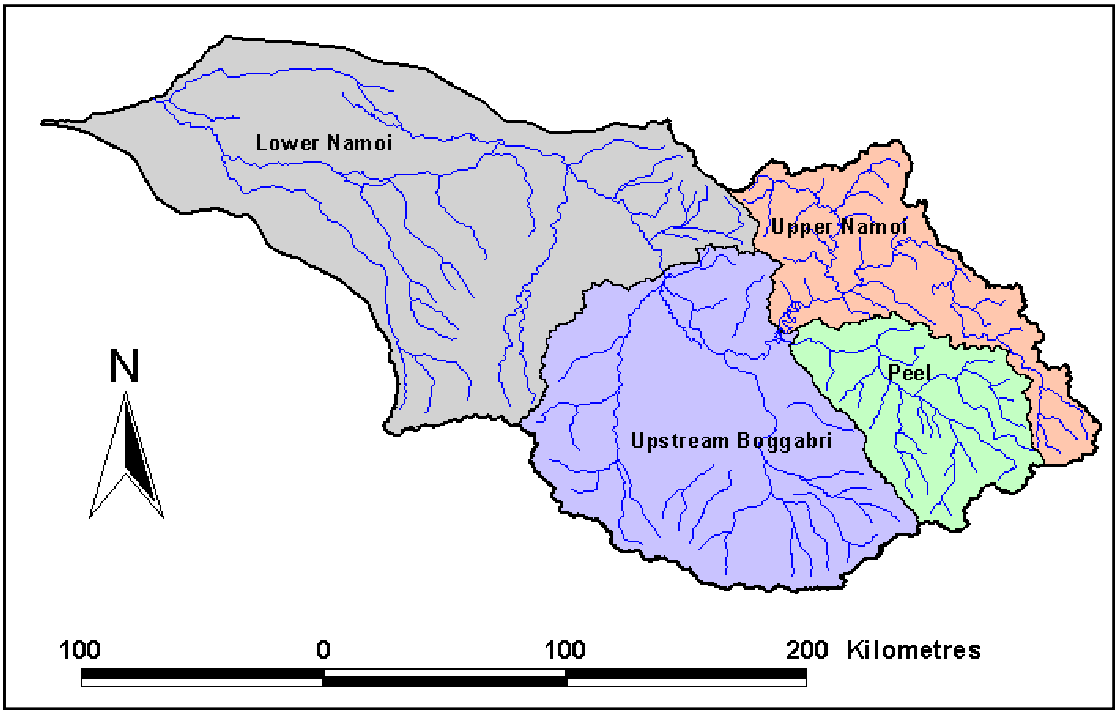


Figure 2.3 Major regions of Namoi & Peel Catchment

2.1.2. Stream network

2.1.2.1. Upper Namoi

The Namoi River above Keepit Dam includes catchment area in the Great Dividing Range. There are three major tributaries including the Manilla River (with Split Rock Dam at a capacity of about 397,000 ML), the Macdonald River and the Halls Creek catchment. There are also numerous smaller creeks. The rivers in these reaches flow within well-defined channels and have only limited floodplains. Keepit Dam with a capacity of 425,510 ML covers about 13% of the total Namoi-Peel catchment area.

2.1.2.2. Peel River

The Peel River joins the Namoi River between Keepit Dam and Gunnedah. The river starts in the Great Dividing Range above Tamworth and includes the major catchments of Upper Peel River (including Chaffey Dam at a capacity of about 61,830 ML), Cockburn River, and Goonoo Goonoo Creek. The upper reaches of the Peel River flow through narrow valleys to about the Cockburn River junction with the river broadening into wide alluvial floodplains below Tamworth. The Peel River catchment covers about 11% of the Namoi-Peel catchment area. A Tamworth town water supply dam is located on Dungowan Creek.

2.1.2.3. Upstream of Boggabri

Two major tributaries are located in this region:

- The Mooki River flows northwest from around Quirindi (Liverpool Range) and enters the Namoi River upstream of Gunnedah. The Mooki River catchment covers about 9% of the total Namoi-Peel catchment area.

- The Coxs River flow north-west from around Tambar Springs (Warrumbungle Range) and enters the Namoi River around Boggabri. The Coxs River catchment covers about 9% of the total Namoi-Peel catchment area.

2.1.2.4. Lower Namoi

- Mauls Creek catchment – an area located north of the Namoi River that is about 1% of the Namoi-Peel catchment area generates runoff entering the Namoi River between Boggabri and Narrabri.

- Pillegar Region – an area located to the south of the Namoi River that covers a large area including Bohena Creek, Bradine Creek plus many minor creeks. This area generally contributes little inflow during normal to dry periods, however, during wet times, significant flood inflows to the Namoi River between Wee Waa and Walgett can be generated from this region.

2.1.3. Hydrometeorology

2.1.3.1. Rainfall

Annual average rainfall varies over the Namoi Valley, from a maximum of 1200 mm over the high ground in the east to a minimum of less than 400 mm near the junction of Namoi and Barwon River (Figure 2.4). Rainfall varies throughout the year (Figure 2.4) with a higher average monthly rainfall in summer. Over the 112 years, the average monthly rainfall ranges from about 0.7 to 1.6 times the average. Over the benchmark climatic period, the catchment experienced an extended drought from 1979-1983, with a very dry year also in 1994(Figure 2.7).

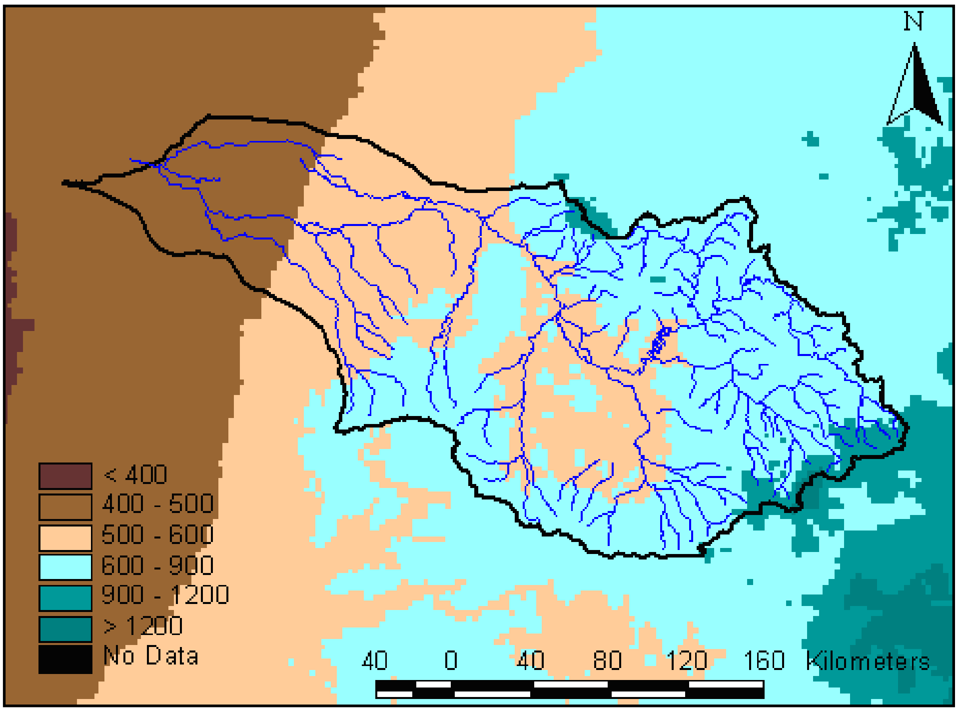


Figure 2.4. Average annual rainfall in Namoi-Peel catchment

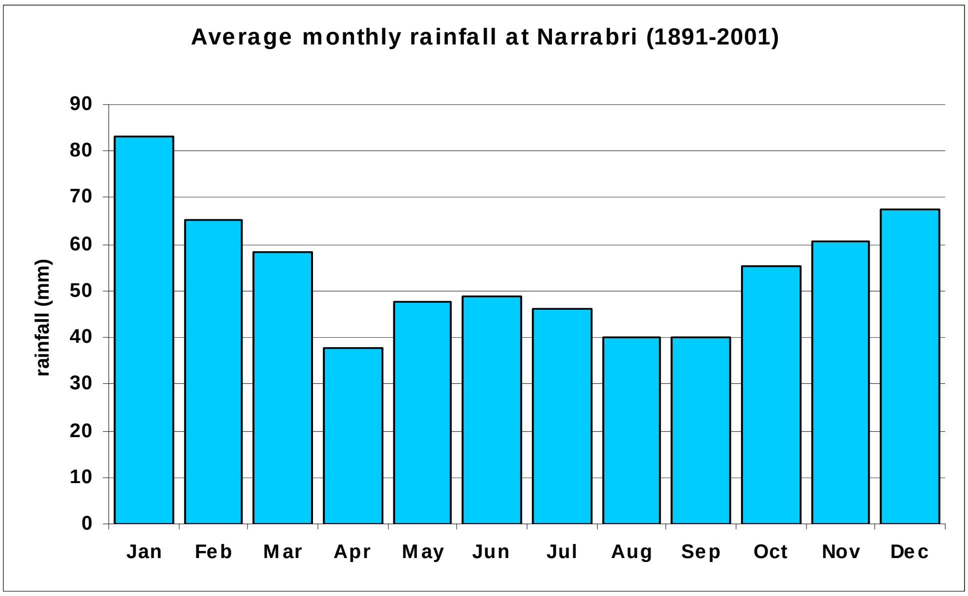


Figure 2.5. Average monthly rainfall at Narrabri 1891-2002.

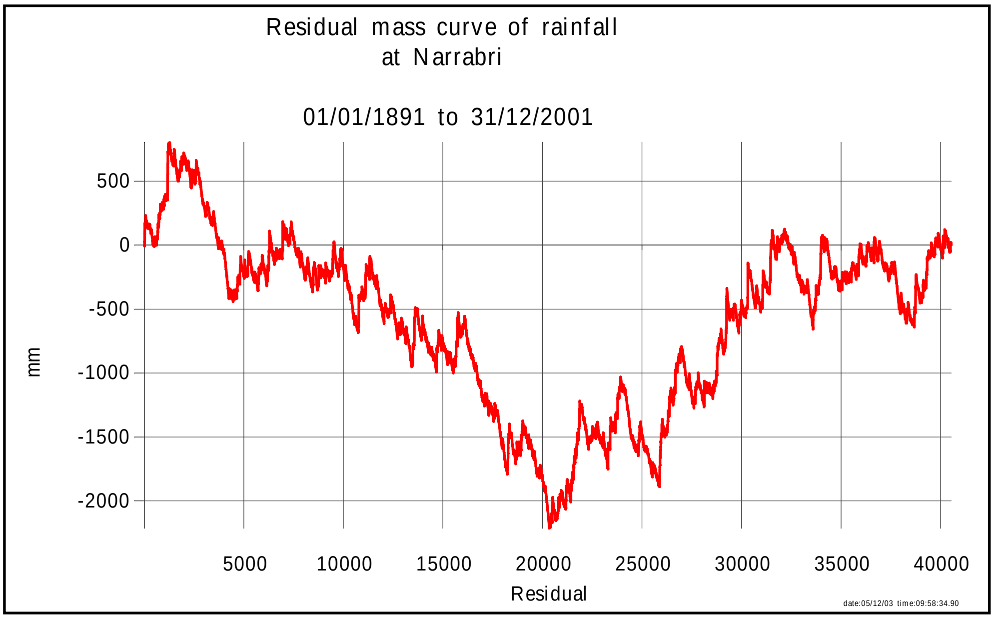


Figure 2.6. Residual mass curve at Narrabri

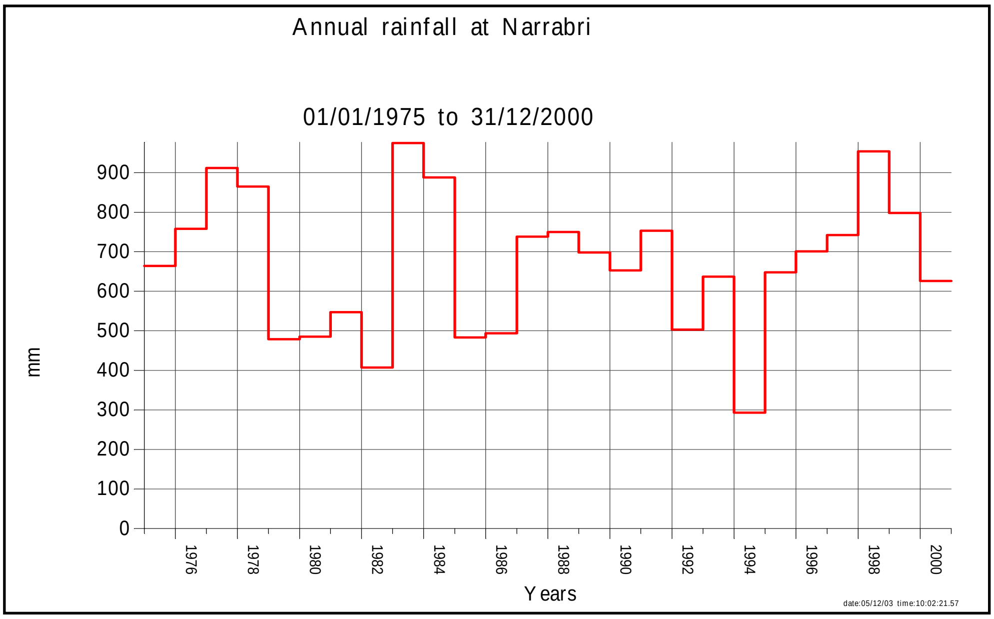


Figure 2.7. Annual rainfall at Narrabri 1975-2000

2.1.3.2. Evaporation

Pan evaporation in the Namoi-Peel catchment has a strong east-west gradient (Figure 2.8). Average Class A pan evaporation varies from around 1000 mm/year in the south-east, to over 2200 mm/year in the north-west. Pan evaporation is also strongly seasonal, varying from around 3 mm/d during June/July at Narrabri, to around 7 mm/d during December/January.

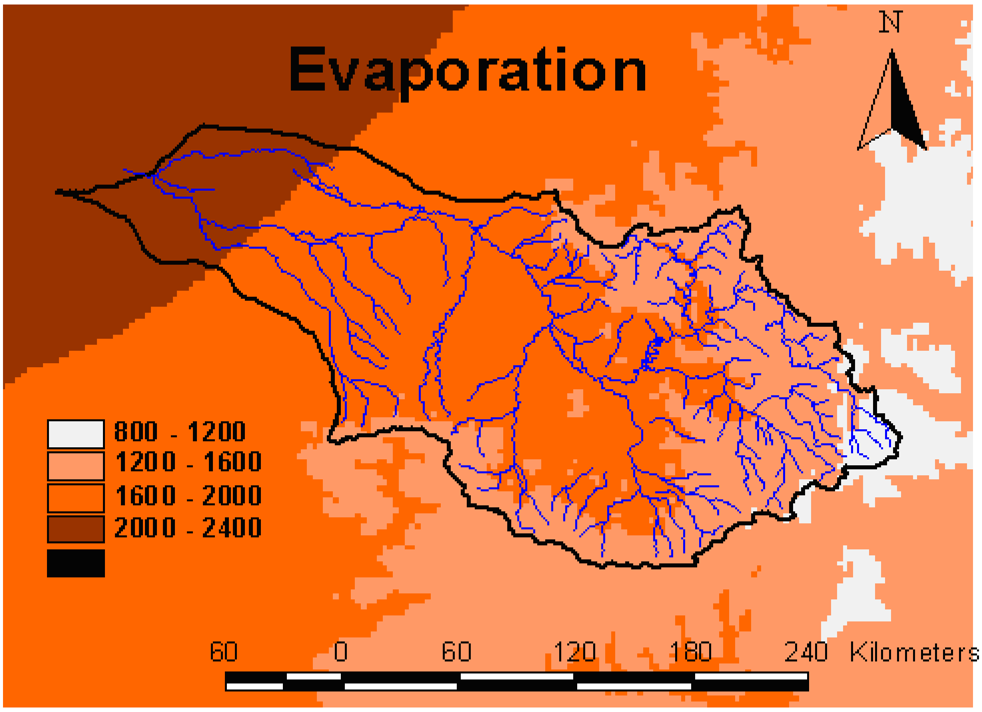


Figure 2.8. Average annual Class A Pan evaporation in Namoi-Peel valley (1973-1995)

2.1.3.3. Flow

The following table outlines the main tributary contribution to the to Namoi-Peel system.

Table 2.1 Average annual Namoi-Peel inflows from gauged streamflow stations (Baseline period 1975 to 2000)

Tributary and/or catchment	Average annual inflow (GL/year)	Sub-catchment (GL/year)
Split Rock Dam	73	
Macdonald River	248	
Peel River	274	
Chaffey Dam		48
Dungowan Dam		13
Gauged Tributaries (Duncans Ck, Cockburn River & Goonoo Goonoo Ck)		121
Mooki River	136	
Coxs Creek	95	
Maules Creek	24	

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 Namoi-Peel River system. 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. The interaction of surface water and groundwater can also result in salt leaving the river system by recharge to the groundwater system.

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 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 2.9). 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.

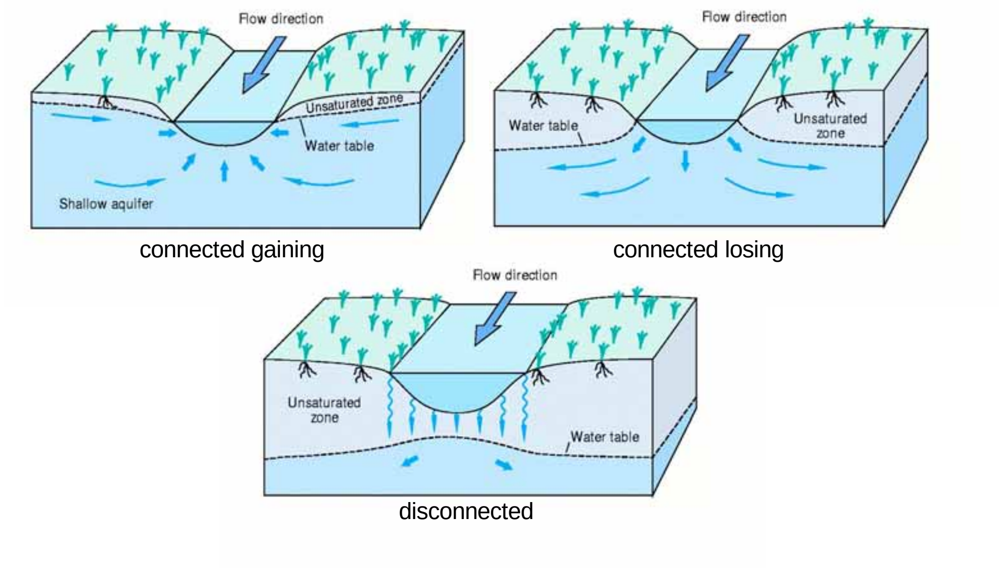


Figure 2.9. Types of river reach with respect to groundwater interaction

(*after Gates and Braaten, 2002*)

Generally, whether a river section is hydraulically connected has a geographic distribution (Figure 2.10). 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, and during periods of highly 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. This is the case for the Namoi River below Narrabri. However, most of the Namoi River between Narrabri and Keepit Dam, the upper Namoi sub-catchment and the Peel River are connected to the groundwater system in one way or the other. Figure 2.9 shows the general nature of the gaining or losing feature of these streams. Within each reach there is likely to be section of both gaining and losing groundwater.

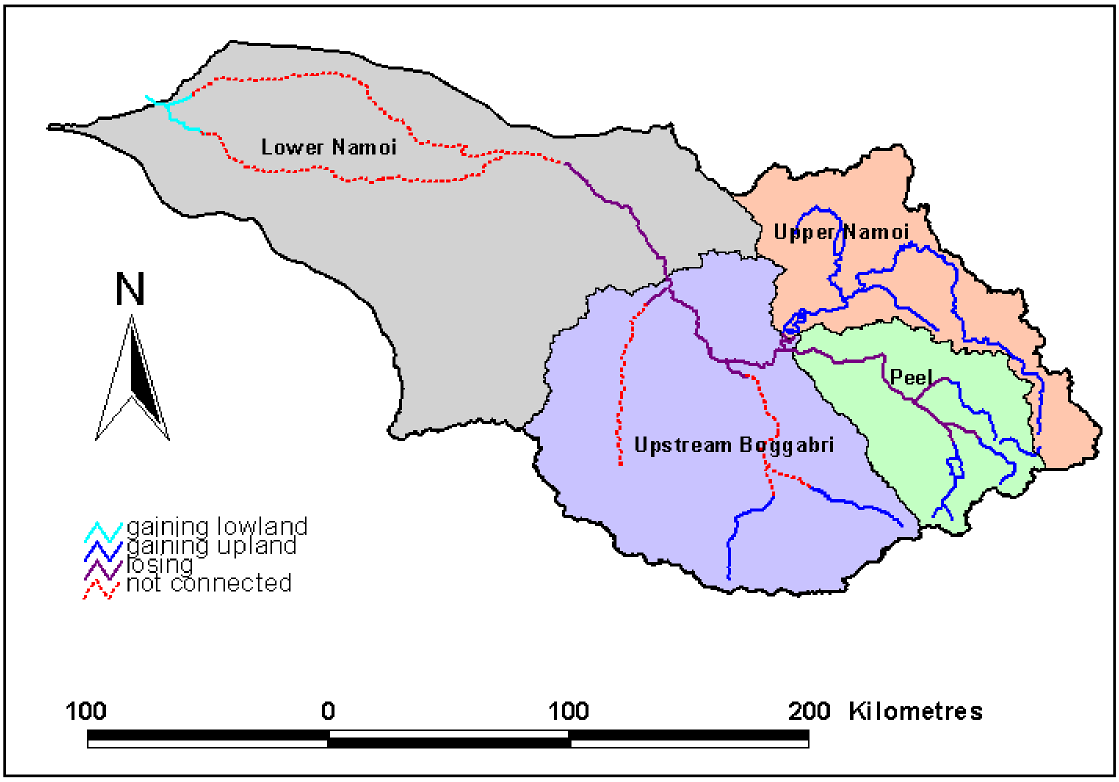


Figure 2.10. Hydraulic connection

2.1.5. Vegetation and land use

Table 2.2 and Figure 2.11 outline the land use for the Namoi Valley.

Table 2.2 Land use in the Namoi Valley

Land Use Description	Extent ('000 ha)	Extent (%)
Nature conservation	134	3
Minimal Use	183	4
Livestock grazing	2,598	62
Forestry	426	10
Dryland agriculture	745	18
Irrigated agriculture	96	2
Built environment	5	<1
Water bodies not otherwise classified	11	<1

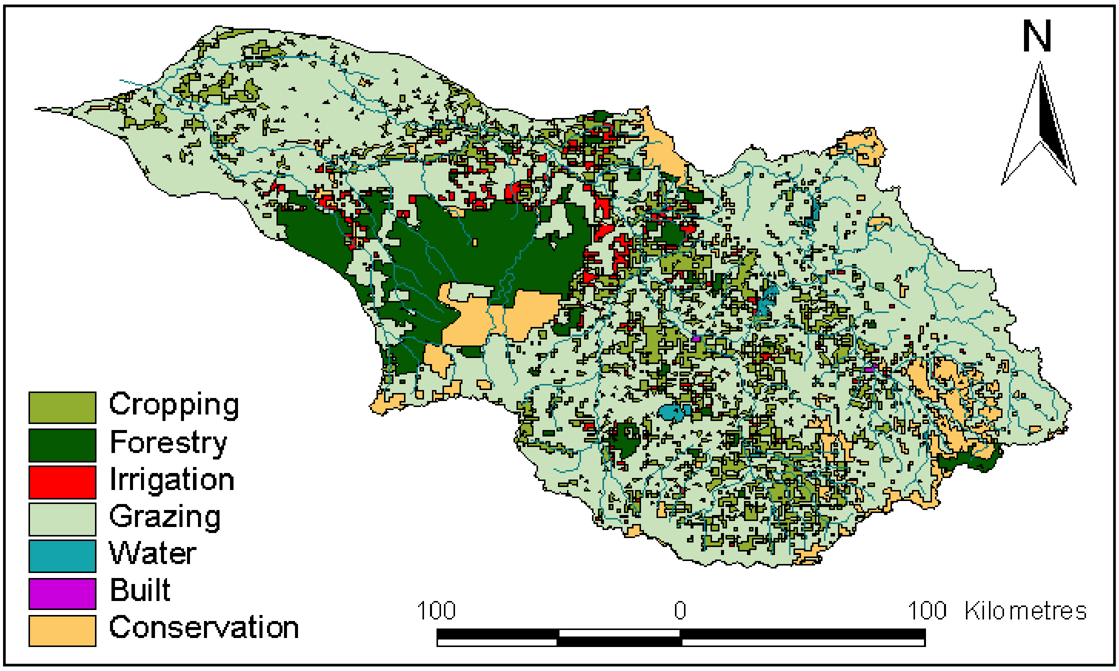


Figure 2.11 Namoi Valley Land Use

2.2. WATER RESOURCE MANAGEMENT

The Namoi River and Peel River system are operated separately from a water resource management perspective. The following outlines the major features of both systems.

2.2.1. Peel River system water resource management

The Peel River system is operated (or regulated) to meet the water resource needs of Peel River water users including general security and high security irrigators, stock and domestic users and Tamworth town water supply. There are two dams located within the catchment, Chaffey Dam (about 61,800 ML) and Dungowan Dam (about 6,300 ML). Dungowan Dam is owned and operated by Tamworth City Council in conjunction with their high security licensed river entitlement to meet the needs of Tamworth.

DWE operates Chaffey Dam under an annual accounting system to meet the day to day needs of water users. Where possible tributary flows are utilised to meet water user demands before dam releases are made. The two major water users in the system are Tamworth that has a entitlement to 16,400 ML and general security irrigators who have an annual entitlement to about 30,200 ML. During the sharing out of the water with Chaffey Dam, a reserve is maintained to ensure the security of high security water users.

When flow in the river is in excess of water user and environmental needs, supplementary water access is declared that allows irrigators to pump river water without their annual entitlement being debited. General security irrigators are allowed to use up to a maximum of 100% of their entitlement in any one water year. Minimum environmental flow conditions are maintained downstream of Chaffey Dam, Dungowan Dam and at Carol Gap. Excess water from the Peel Valley flow into the Namoi River and is utilised by Namoi water users where possible.

2.2.2. Namoi River system water resource management

The Namoi River system is operated (or regulated) to meet the needs of water users and the environment in the river from Split Rock Dam to the junction with the Barwon/Darling at Walgett. The water storages at Split Rock Dam (about 397,000 ML), Keepit Dam (about 425,000ML) plus re-regulation and/or diversion weirs at Mollee and Gunidgera are operated by DWE to meet user needs. Where possible the tributary inflows from the Peel River, Mooki River and Coxs Creek are utilised before dam releases are made.

The major water users in the Namoi River are general security irrigators with an annual entitlement of around 256,000 ML. About 9,000 ML of this entitlement is located between Split Rock and Keepit Dams. General security irrigators needs are met under a continuous accounting system where each irrigators operates their own individual account with the dams and can use the water resources as they wish. Irrigators are allowed to maintain up to 200% of their entitlement within their account at any one time and are allowed to use up to 100% of their entitlement within a water year.

Split Rock Dam and Keepit Dam are located in series with water transferred down from Split Rock Dam to Keepit Dam as required and within environmental conditions. Outlet capacity limitations for Keepit Dam may necessitate Split Rock Dam releases. Under the continuous accounting system, DWE maintains a reserve plus a working account (to cover transmission and operation losses) within the dams to ensure the security of water users.

When flows in the river are surplus to needs supplementary water access is declared when irrigation users can divert water from the river with debit to their account. The valley operates under a total supplementary cap of 110 GL per year. Because of the large volume of on-farm storages in the Namoi Valley and subsequent competition for supplementary water, DWE attempts to equally share supplementary water. The sharing of supplementary water plus limitation on diversions to the Gunidgera/Pian Creek system often results in a roster system to share supplementary water.

About 8 GL of high security entitlement exists within the valley including town water supply needs for Manilla and Walgett. Minimum flow requirements are in place downstream of Split Rock and Keepit Dams. Stock and domestic flow replenishment flow rules are also in operation for the Pian Creek system.

In 1998, environmental flow rules were introduced for the Namoi Valley that shared supplementary water. DWE, in consultation with water users, has introduced flow rate thresholds that determine supplementary water access. For each individual supplementary flow event, irrigators are only allowed to access 50% of the supplementary flow volume with the other 50% remaining in the river for environmental use.

2.3. SALINITY IN CATCHMENT

The Namoi River system (including the Peel River system) exports large quantities of salt to the Barwon/Darling River system. Current estimates suggest around 135,000 tonnes of salt is exported from the Namoi system. As shown in Figure 2.12, the salt load exported for the tributary streams upstream of Boggabri varies from 2-24 tonnes/km^2/year. The largest export rates occur for the catchments in the upper Peel River catchment where, for example, Goonoo Goonoo Creek exports about 18 tonnes/km^2/year and Chaffey Dam catchment 24 tonnes/km^2/year. The areal export rate, when multiplied by catchment area, gives an indication of mean annual salt load exported from the catchment. Table 2.3 details the mean annual salt load from the major catchments of the Namoi-Peel system.

Table 2.3. Average annual Namoi-Peel salt load inflows (Baseline period 1975 to 2000)

Catchment	Mean annual salt load ('000 tonnes/ year)
Chaffey Dam	9.7
Cockburn River	13.2
Goonoo Goonoo Creek	9.1
Peel River (total)	79.7
Namoi River above Keepit Dam	66.4
Mooki River	33.8

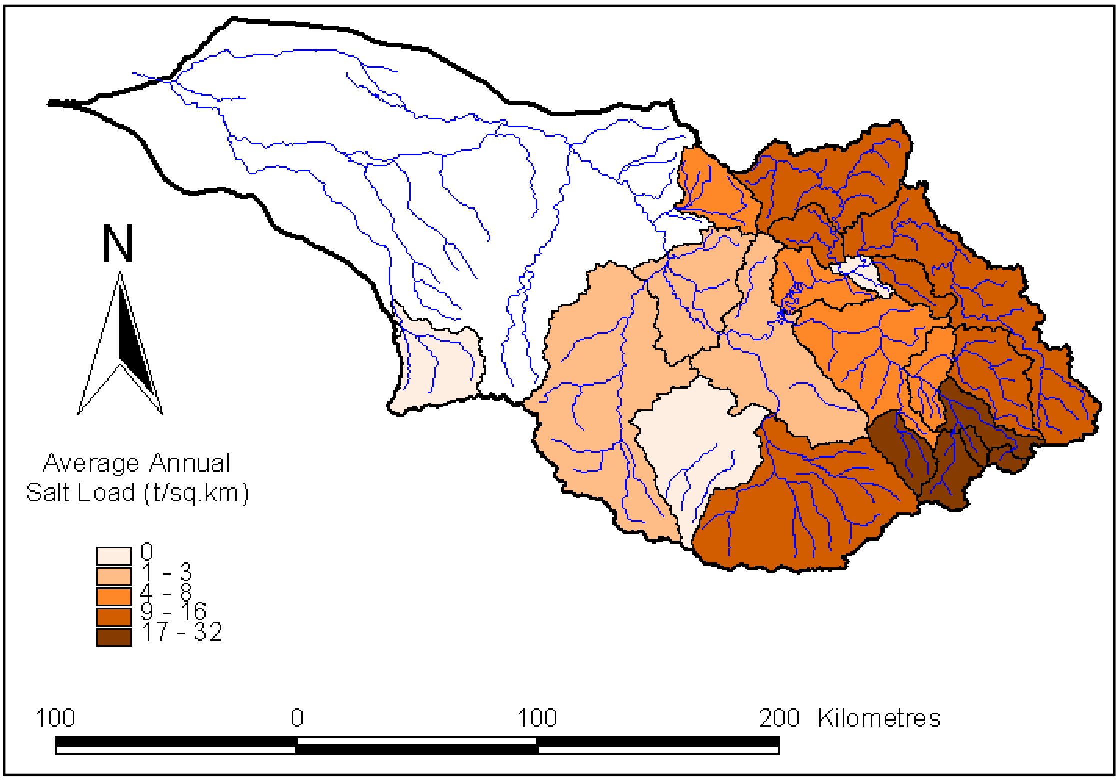


Figure 2.12 Average Salt load exports from the Namoi Valley

3. Salinity data

3.1. AVAILABLE DATA

All data for the Namoi-Peel catchment was extracted from the DWE databases and tabulated in Appendix A. The distribution and relative length of this data is shown in Figure 3.1 for discrete EC data stations, and Figure 3.2 for continuous EC data stations.

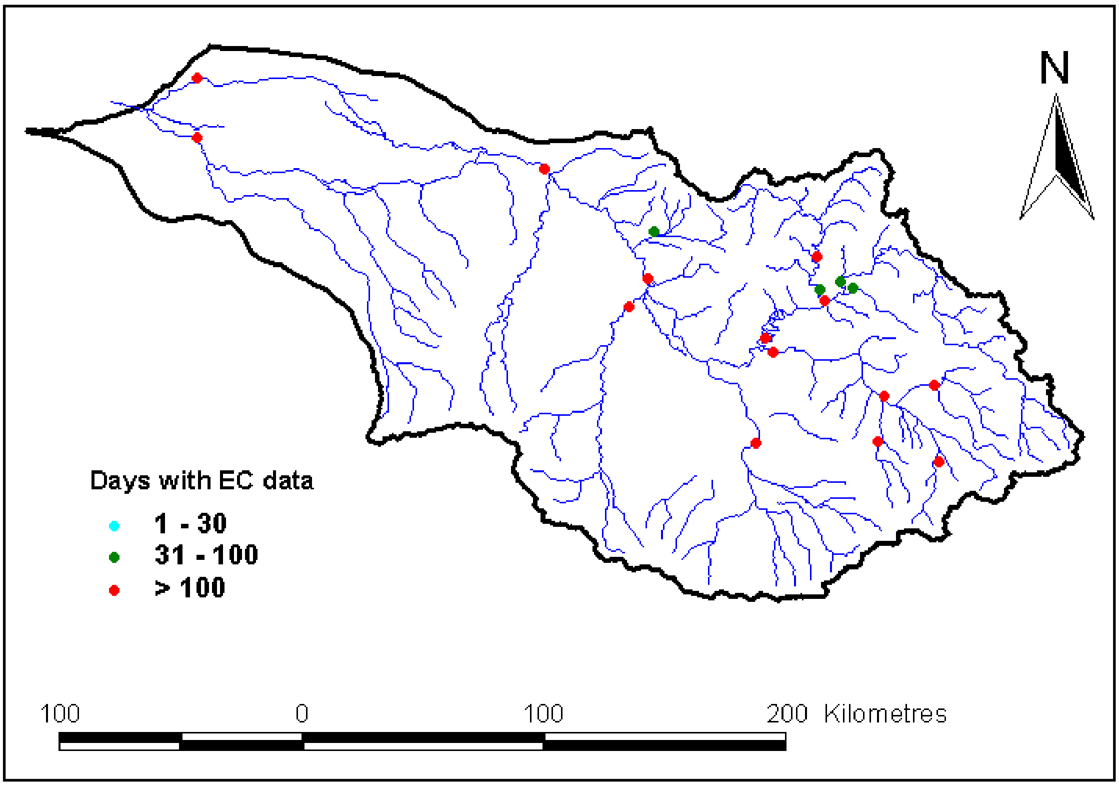


Figure 3.1. Location and record length size for discrete EC data stations

The legend used in Figure 3.1 and Figure 3.2 is 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.

A feature of the discrete data sets is that of the nineteen sites reported in Table 3.1 and Table 3.2 is that no sites have data less than thirty points and only four sites have data less than 100 points. Three of the sites with less than 100 points are located in the Upper Namoi catchment and one in the Lower Namoi. The other data sets look to give a good coverage across the whole catchment.

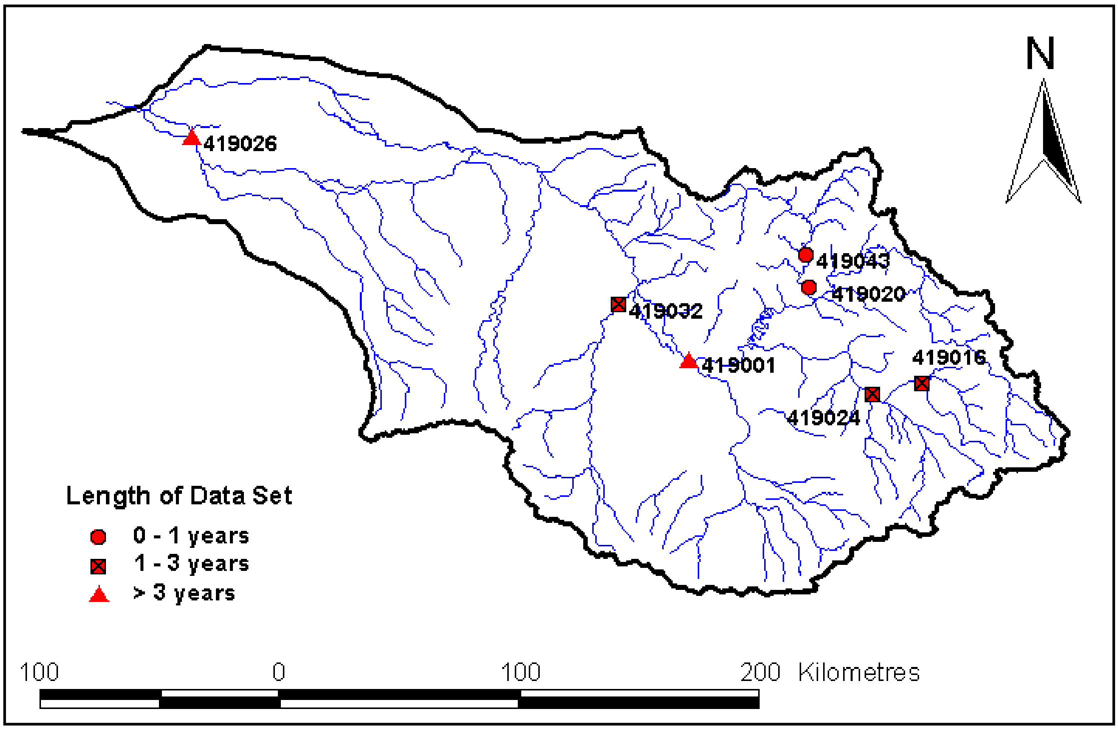


Figure 3.2. Location and record length for continuous EC data stations

The Namoi-Peel River System has an average coverage of continuous stations compared with most other NSW MDB valleys, and reflects on the level of salinity management activity in the catchment. Of the seven stations in total, two have less than one year of data and these are both on the Manilla. There are two longer term stations with more than five years of data on the Lower Namoi River below Keepit Dam and a further three stations with more than three years of data on major tributaries.

3.2. DATA USED FOR INFLOW ESTIMATES AND MODEL EVALUATION

The subset of 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 of the nineteen stations with discrete EC data and seven stations with continuous EC data were used for these purposes.

The stations at inflow points were used to estimate the parameters of the salt load relationships for the Salinity Audit, and may be used to re-estimate salt load inflows, depending on the outcomes of the model evaluation. This data was 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 inflow of inflow points (Figure 3.3) shows that Goonoo Goonoo Creek (Station No. 419035) and Mooki River (419027) contribute large quantities of high salinity water. The relatively high load contributed by the total Peel River catchment are reflected by the reading at Peel River at Carrol Gap (419006). Most of the other sites show median levels of salt load with only the Namoi River at North Cuerindi showing low levels.

The longitudinal overview of median salinities (Figure 3.4) shows some median higher values in both the Upper Namoi and Peel River catchments (greater than 450 EC). However, salinities in the Lower Namoi River below Keepit Dam are reasonable constant in the EC range of 250 to 300.

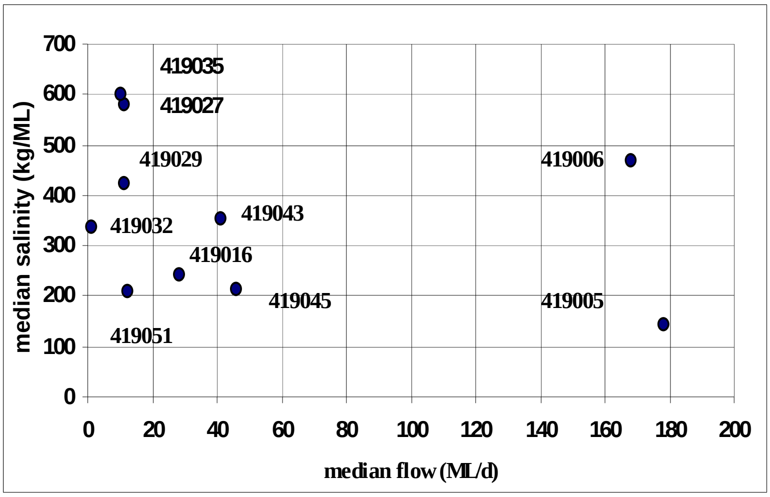


Figure 3.3. Median salinity versus median flow for inflow sites with discrete salinity data

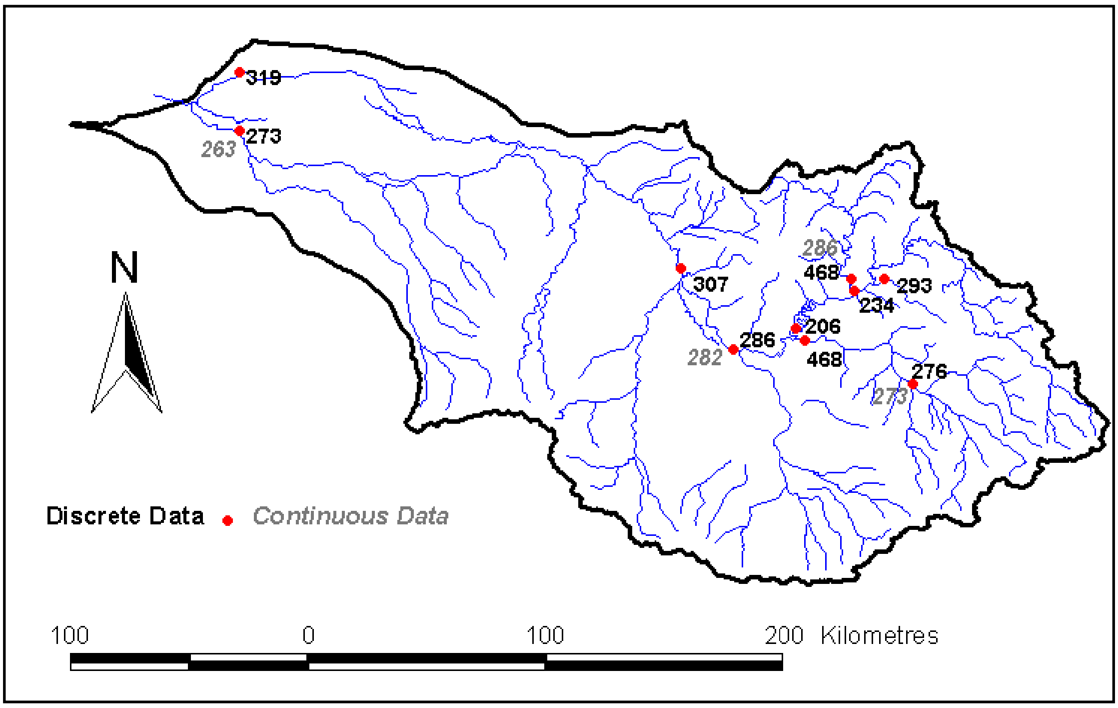


Figure 3.4. Median salinity along main stream

Table 3.1. Stations at inflow 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*	
419005	Namoi River at North Cuerindi	Inflow	0	0	0	71
419016	Cockburn River at Mulla Crossing	Inflow	0	5	0	119
419027	Mooki River at Breeza	Inflow	0	37	2	153
419029	Halls Creek at Ukolan	Inflow	0	44	0	76
419032	Coxs Creek at Boggabri	Inflow	1	111	0	123
419035	Goonoo Goonoo Creek at Timbumburi	Inflow	0	5	2	114
419043	Manilla River at D/S Split Rock Dam	Inflow	5	20	3	277
419045	Peel River at D/S Chaffey Dam	Inflow	12	3	1	315
419051	Maules Creek at Avoca East	Inflow	0	1	1	83

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*	
419001	Namoi River at Gunnedah	Evaluation	0	17	1	473
419006	Peel River at Carrol Gap	Evaluation	0	4	1	219
419007	Namoi River at Keepit	Evaluation	0	3	2	215
419012	Namoi River at Boggabri	Evaluation	0	16	0	118
419020	Manilla River at Brabri (Merriwee)	Evaluation	0	6	0	71
419022	Namoi River at Manilla Railway Bridge	Evaluation	0	26	0	142
419024	Peel River at Paradise Weir	Evaluation	0	1	0	286
419026	Namoi River at Goangra	Evaluation	0	8	0	195
419039	Namoi River at Mollee	Evaluation	0	5	1	167
419049	Pian Creek at Waminda	Evaluation	0	26	0	121

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*		
419001	Namoi River at Gunnedah	Evaluation	3	0	-	2342
419016	Cockburn River at Mulla Crossing	Inflow	16	0	-	935
419020	Manilla River at Brabri (Merriwee)	Evaluation	0	0	-	35
419024	Peel River at Paradise Weir	Evaluation	194	0	-	835
419026	Namoi River at Goangra	Evaluation	94	0	-	2385
419032	Coxs Creek at Boggabri	Inflow	1438	0	-	991
419043	Manilla River at D/S Split Rock Dam	Inflow	0	0	-	101

Table 3.4. Cumulative distribution statistics of screened EC data sets

Station Number	Station name	Data type	Data use	Salinity statistics kg/ML			Q_{50} ML/d
				C_{25}	C_{50}	C_{75}	
419001	Namoi River at Gunnedah	Continuous	Evaluation	435	282	217	637
419001	Namoi River at Gunnedah	Discrete	Evaluation	372	286	224	
419005	Namoi River at North Cuerindi	Discrete	Inflow	246	144	109	178
419006	Peel River at Carrol Gap	Discrete	Inflow	570	468	335	168
419007	Namoi River at Keepit	Discrete	Evaluation	251	206	175	165
419012	Namoi River at Boggabri	Discrete	Evaluation	372	307	243	543
419016	Cockburn River at Mulla Crossing	Continuous	Inflow	285	212	166	28
419016	Cockburn River at Mulla Crossing	Discrete	Inflow	303	241	190	
419020	Manilla River at Brabri (Merriwee)	Continuous	Evaluation	290	286	245	30
419020	Manilla River at Brabri (Merriwee)	Discrete	Evaluation	516	468	405	
419022	Namoi River at Manilla Railway Bridge	Discrete	Evaluation	341	234	147	286
419024	Peel River at Paradise Weir	Continuous	Evaluation	320	273	210	95
419024	Peel River at Paradise Weir	Discrete	Evaluation	317	276	234	
419026	Namoi River at Goangra	Continuous	Evaluation	330	263	209	209
419026	Namoi River at Goangra	Discrete	Evaluation	336	273	217	
419027	Mooki River at Breeza	Discrete	Inflow	721	582	412	11
419029	Halls Creek at Ukolan	Discrete	Inflow	501	425	309	11
419032	Coxs Creek at Boggabri	Continuous	Inflow	623	472	258	0
419032	Coxs Creek at Boggabri	Discrete	Inflow	568	339	179	
419035	Goonoo Goonoo Creek at Timbumburi	Discrete	Inflow	702	600	504	10
419039	Namoi River at Mollee	Discrete	Evaluation	366	293	240	740
419043	Manilla River at Split Rock Dam	Continuous	Inflow	241	239	241	41
419043	Manilla River at Split Rock Dam	Discrete	Inflow	471	356	286	
419045	Peel River at D/S Chaffey Dam	Discrete	Inflow	238	216	198	46
419049	Pian Creek at Waminda	Discrete	Evaluation	391	319	265	7
419051	Maules Creek at Avoca East	Discrete	Inflow	223	210	189	12

4. The Namoi & Peel IQQMs

4.1. QUANTITY MODEL

The Namoi and Peel IQQMs are two separate models. The Peel IQQM includes all tributaries inflows of the Peel River and the Peel River itself from Chaffey Dam down to the junction with the Namoi River. The Namoi IQQM includes Split Rock Dam, tributaries upstream of Keepit Dam, all tributaries downstream of Keepit Dam and the Namoi River itself from Keepit Dam down to the junction with the Barwon/Darling River. The flow at the end of the Peel IQQM becomes an inflow for the Namoi IQQM.

There are historical reasons why there are two models. DWE operates the Namoi and Peel River systems independently, and the models were developed accordingly. In addition both systems now operate under different accounting systems. The Peel River system utilises both Chaffey Dam and Dungowan Dam under an annual accounting system to meet significant Tamworth town water supply needs and the general security needs of Peel Valley irrigators. The Namoi Valley operates under a continuous accounting system that aims to meet the general security irrigators who have the majority of the entitlement in the valley. IQQM cannot operate with both annual and continuous accounting systems and would require significant enhancement to do so.

The historical reasons do not apply for the quality model. Actions in the Peel River are likely to change the quantity of water, and salt, entering the Namoi River. Currently the most appropriate way of representing quality in the Namoi and Peel River systems is with two separate models that consider the interaction between the systems.

A full description of the climatic and streamflow data, major features and calibration of Namoi IQQM is presented in the MDBC Cap Implementation Summary Report – Namoi Valley (Ribbons et al, 2003). Full details of the Peel IQQM are presented in the MDBC Cap Implementation – Peel Valley Report (Chowdhury et al 2004). The following gives a brief description of each model.

4.1.1. Peel system

The Peel IQQM configuration is shown schematically in Figure 4.1. The system includes eight inflow nodes in total, with five of these representing gauged tributary inflows. The ungauged tributary inflows below these were calibrated at three gauging stations, Peel River at Piallamore, Peel River at Paradise Weir and Peel River at Carrol Gap.

The water management features of significance in the Peel System IQQM are:

- Chaffey Dam (about 61,800 ML)
- Dungowan Dam (about 6,300 ML)
- Tamworth town water supply (entitlement of 16,400 ML and currently using about 10,000 ML/year). Tamworth receives its water supply by pipeline from Dungowan Dam and run of the river releases from Chaffey Dam.
- General security irrigators have entitlement to about 31,200 ML and their maximum use to date was about 15,000 ML.

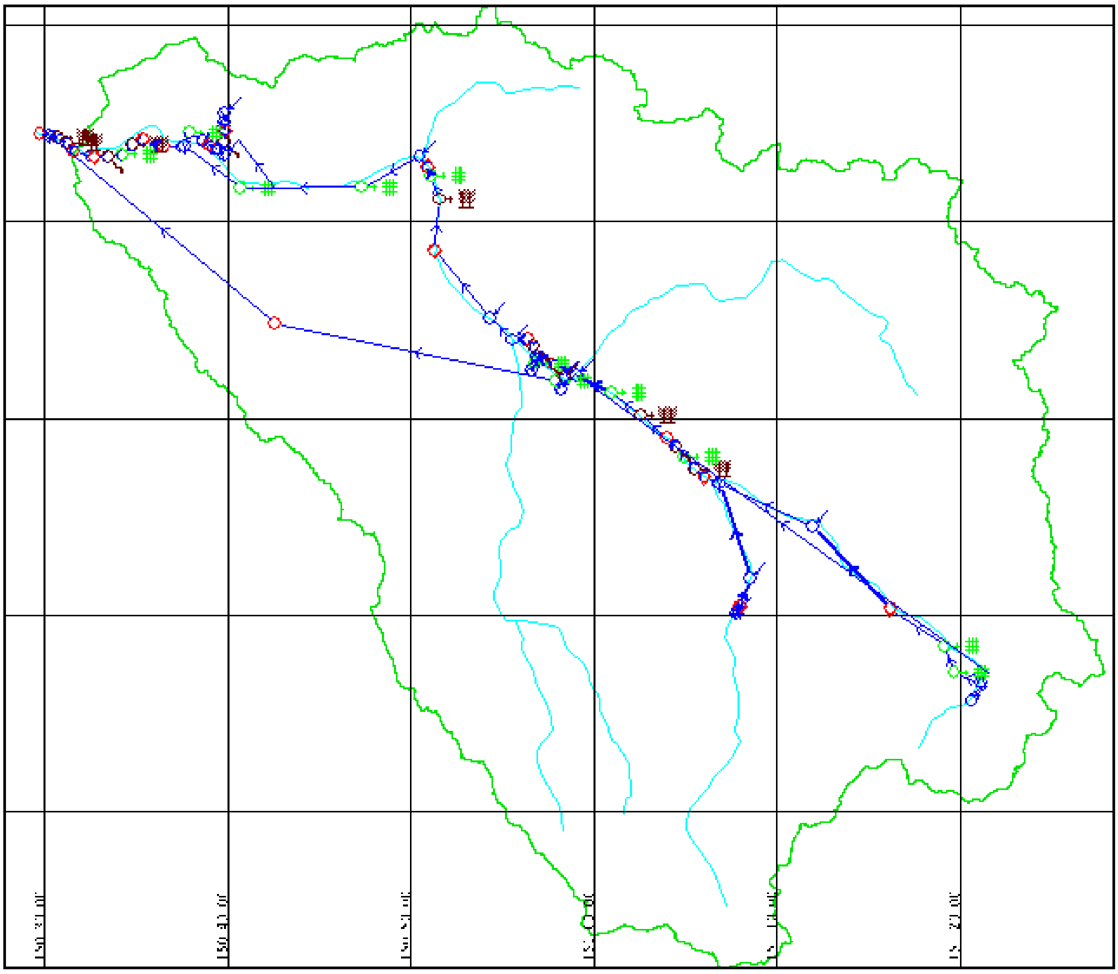


Figure 4.1. Schematic of Peel System IQQM

4.1.2. Namoi system

The Namoi IQQM is shown in Figure 4.2. The system includes eight gauged inflow tributaries and thirteen ungauged catchment inflows that were estimated by calibration of main stream gauges. The model includes thirteen main stream flow calibration reaches and twenty eight irrigators groupings to represent the spatial and/or functional distribution of irrigator extractions.

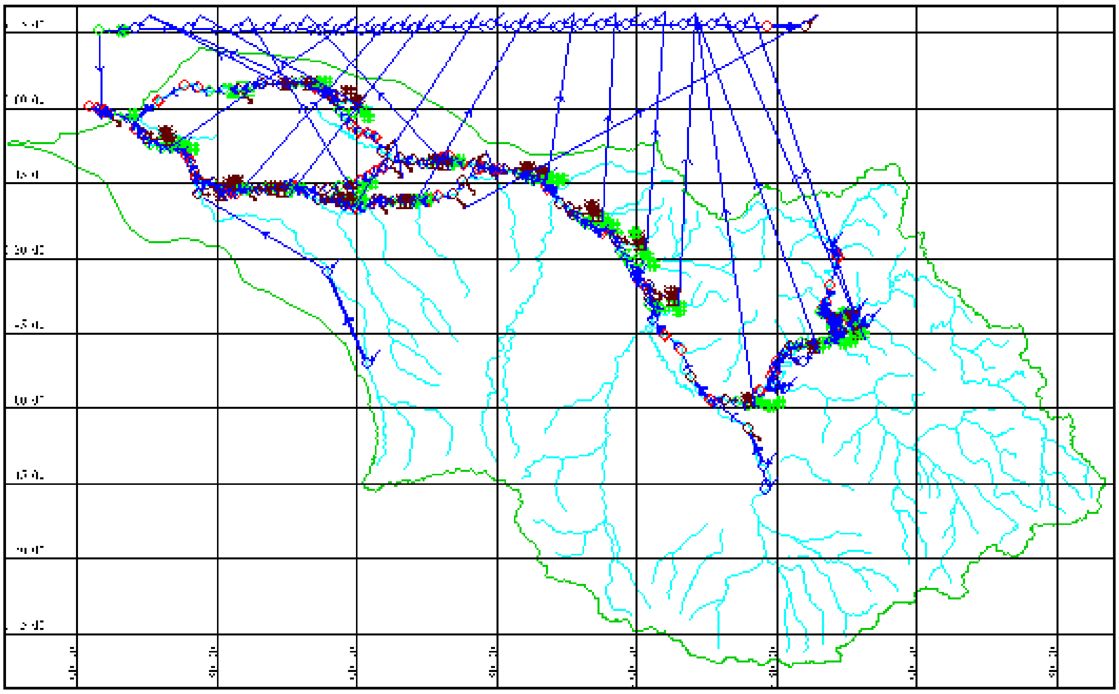


Figure 4.2. Schematic Namoi System IQQM

This figure is only meant to present an overview of the Namoi IQQM. The complexity of the Namoi IQQM, with over 200 nodes, is such that the detail cannot be presented in a single figure. 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 4.3 to Figure 4.6)
- storages (Figure 4.7)
- irrigation demands (Figure 4.8 to Figure 4.11), and
- instream and environmental nodes (Figure 4.12)

The features of the Namoi IQQM are discussed in Sections 4.1.3 to 4.1.6.

4.1.3. Inflows and calibration

Namoi IQQM has twenty-one inflow nodes along with thirteen calibration nodes to calibrate the flow along the main stream. The magnitude and distribution of these inflow and effluent nodes is shown in Figure 4.3 to Figure 4.6.

The two largest inflows in the Namoi System IQQM are those flows from the Manilla and Macdonald Rivers above Keepit Dam (about 20% of inflow) and the Peel River system (about 17% of inflow). Other major tributaries are the Mooki River (about 7% of total inflow) and the Coxs Creek (about 4% of total inflow).

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 Namoi Valley Cap calibration report (Ribbons C, Brown A and Chowdhury S, 2003). 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.

4.1.4. Storages

Two storages are modelled in the Namoi System IQQM, and their locations are shown along with their sizes in Figure 4.7. A re-regulation weir is also modelled at Mollee. The following briefly describe the operation of the dams.

Split Rock Dam releases water for:

- General security irrigators along the Manilla River upstream of Keepit Dam;
- Environmental releases in the Manilla River;
- Town water supply for Manilla (35 ML).
- Augmenting water in Keepit Dam to improve reliability for irrigators downstream of Keepit Dam.

Keepit Dam releases water for:

- General and high security irrigators along the Namoi River system including Gunidgera and Pian Creeks;
- Environmental and instream releases in the Namoi River;
- Town water supply for Walgett (2,271 ML/year).

Mollee Weir has a capacity of about 2,500 ML and is primary used for re-regulation purposes.

4.1.5. Extractive demands

Allocation of water to irrigators in the Namoi River System occurs under a volumetric allocation system, as with other regulated river systems. The total active licence entitlement in this river system is about 256 GL (about 9 GL is located between Split Rock Dam and Keepit Dam). High security entitlements in the Namoi Valley total about 8 GL. The majority of the licences are general security, for irrigating crops, with the dominant crop types being cotton grown in the lower reaches below Narrabri. Around 50,000 Ha of cotton is currently grown in the valley from regulated irrigators. The distribution of water usage for irrigation is shown in Figures 4.8 to Figure 4.11. .

4.1.5.1. Surplus water usage

Supplementary river water, in addition to that released specifically by Keepit Dam can also be extracted by licence holders, and is not debited against the licence holder's allocation for that year. This water originates as either higher than expected flows from tributaries, or as floods releases from Keepit, Split Rock and Chaffey Dams. Water extracted is typically stored in on-farm storages for later use. Environmental flow rules and flow thresholds that trigger have been put in place that limit access to these supplementary flows. The total volume that can be extracted by all users is restricted to 110 GL/year.

4.1.6. In-stream demands

In-stream demands are simulated at three locations in the Namoi System IQQM (Figure 4.12). The purpose of these particular nodes is described in Table 4.1.

Table 4.1. Function of in-stream demands in Namoi System IQQM

In-stream ordering node name	Purpose
Downstream of Split Rock Dam	Water is released from Split Rock Dam at a rate of 5 or 6 ML/day to meet downstream needs
Downstream of Keepit Dam	Water is released from Keepit Dam at a rate of 10 ML/day to meet downstream needs
Pian Creek stock and domestic replenishment	A 14,000 ML allowance is made for 2 stock & domestic replenishments of lower Pian Creek each year. The aim of these replenishments is to fill all the waterholes and billabongs down to the end of Pian Creek. These replenishments are usually met from surplus flows. If these surplus flows are insufficient, water is released from Keepit Dam at either the beginning or end of the irrigation season

4.1.7. Peer Review

There has not been any formal peer review of the quantity component of Namoi Rivers IQQM. The *Namoi River Valley IQQM Cap Implementation summary report (Ribbons et al 2003)* will be submitted to the MDBC for formal review in March 2004.

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.

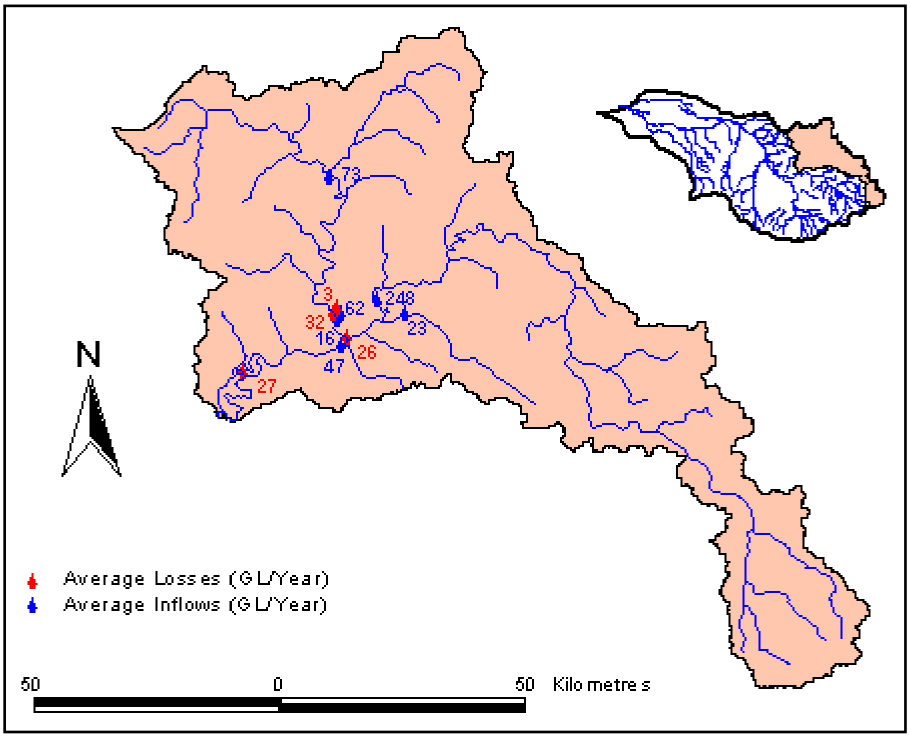


Figure 4.3. Distribution of modelled annual average (1975-2000) inflows and losses in Upper Namoi region of Namoi Valley.

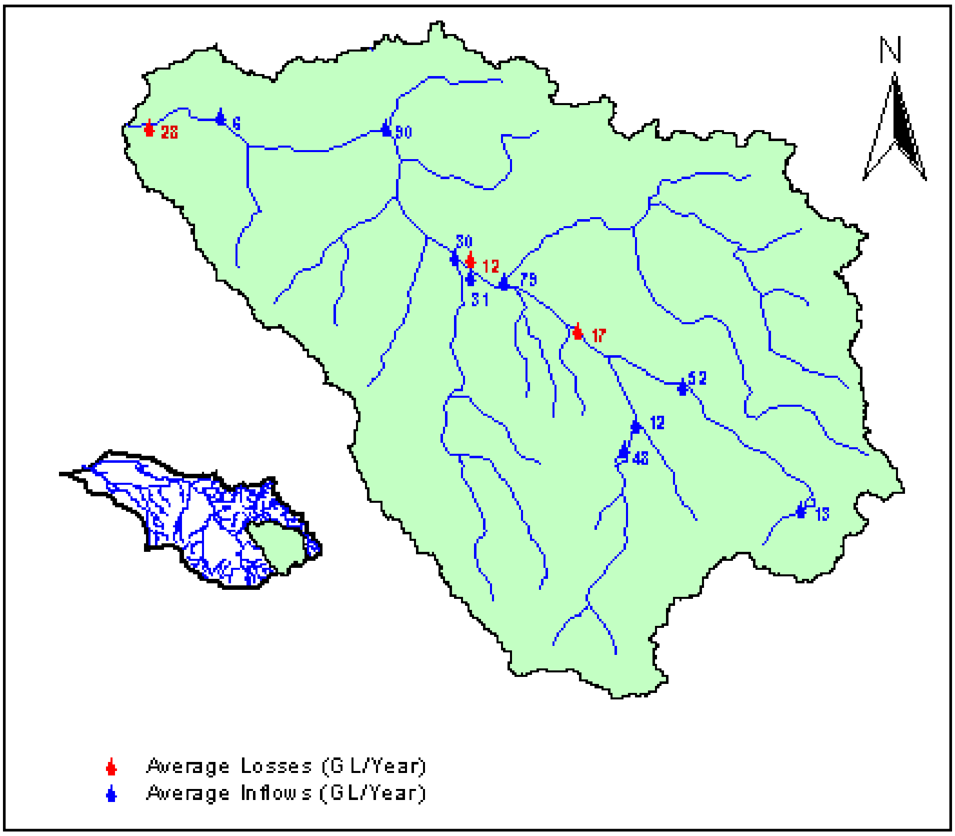


Figure 4.4. Distribution of modelled annual average (1975-2000) inflows and losses in Peel region of Namoi Valley

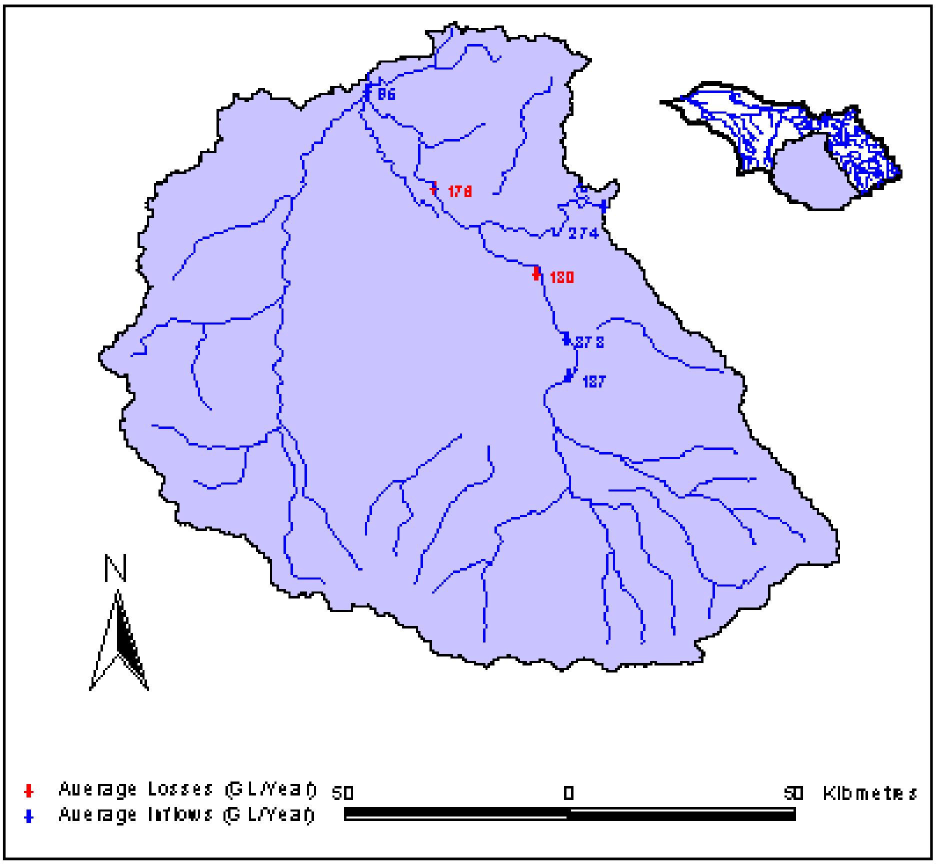


Figure 4.5. Distribution of modelled annual average (1975-2000) inflows and losses in Upper Boggabri region of Namoi Valley

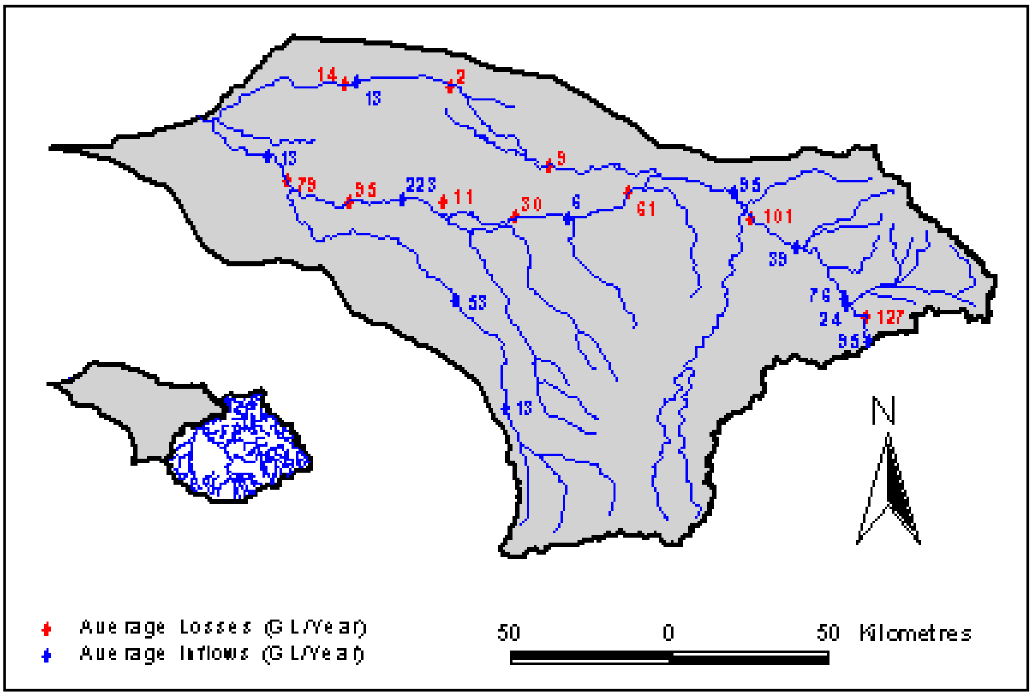


Figure 4.6. Distribution of modelled annual average (1975-2000) inflows and losses in Lower Namoi region of Namoi Valley

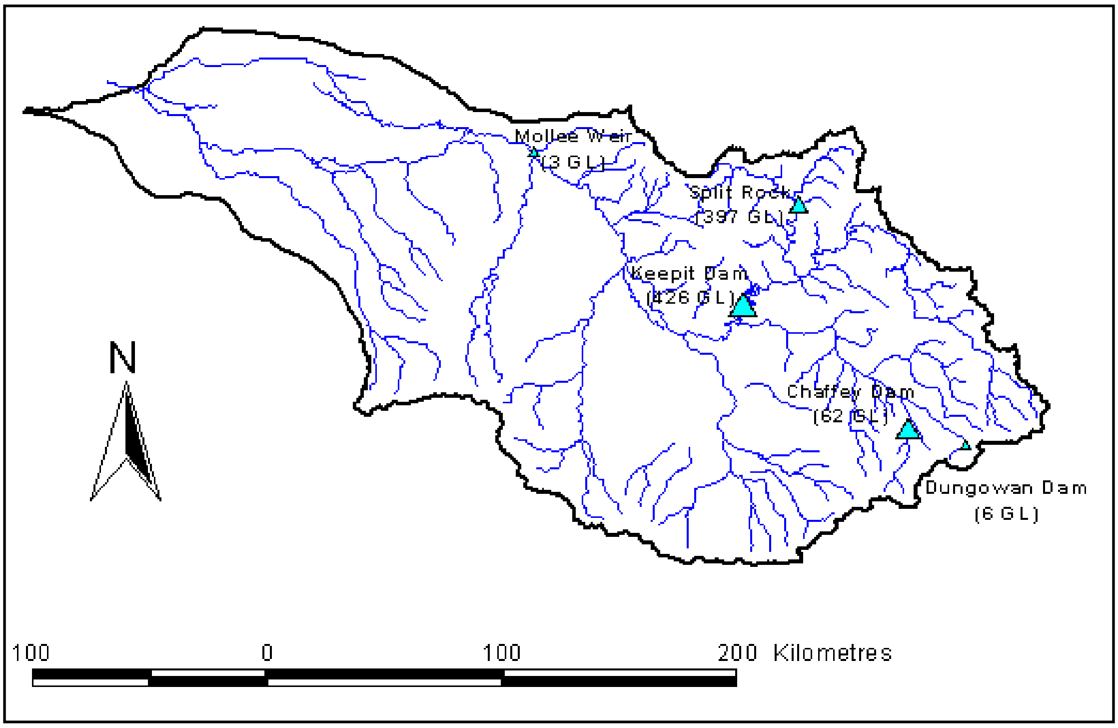


Figure 4.7. Modelled storage in Namoi-Peel System IQQM

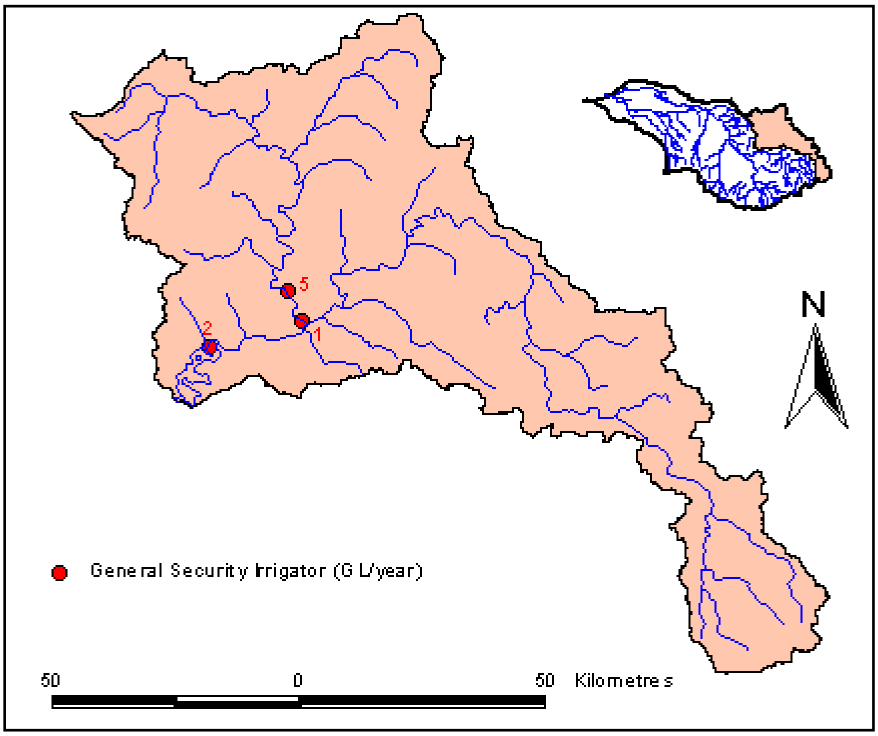


Figure 4.8. Modelled average annual irrigation diversions (GL/year; 1975-2000) for Upper Namoi region.

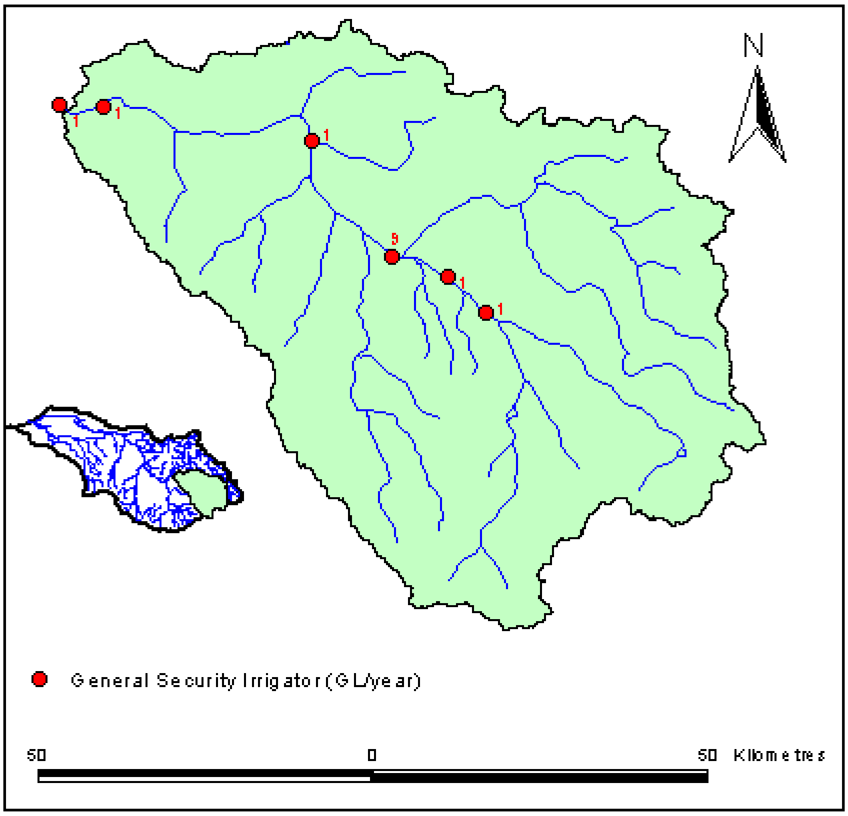


Figure 4.9. Modelled average annual irrigation diversions (GL/year, 1975-2000) for Peel Region

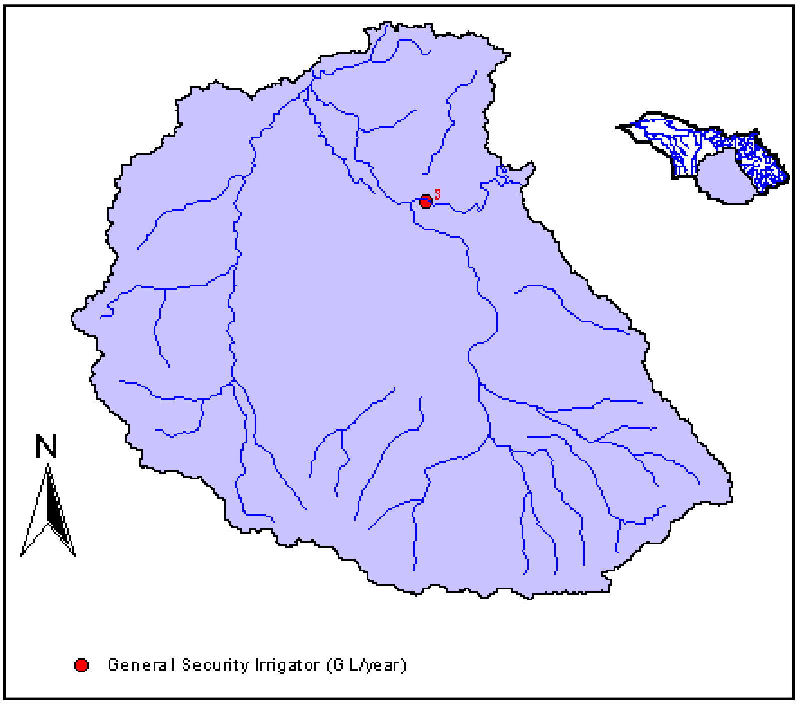


Figure 4.10. Modelled average annual irrigation diversions (GL/year, 1975-2000) for Upper Boggabri Region

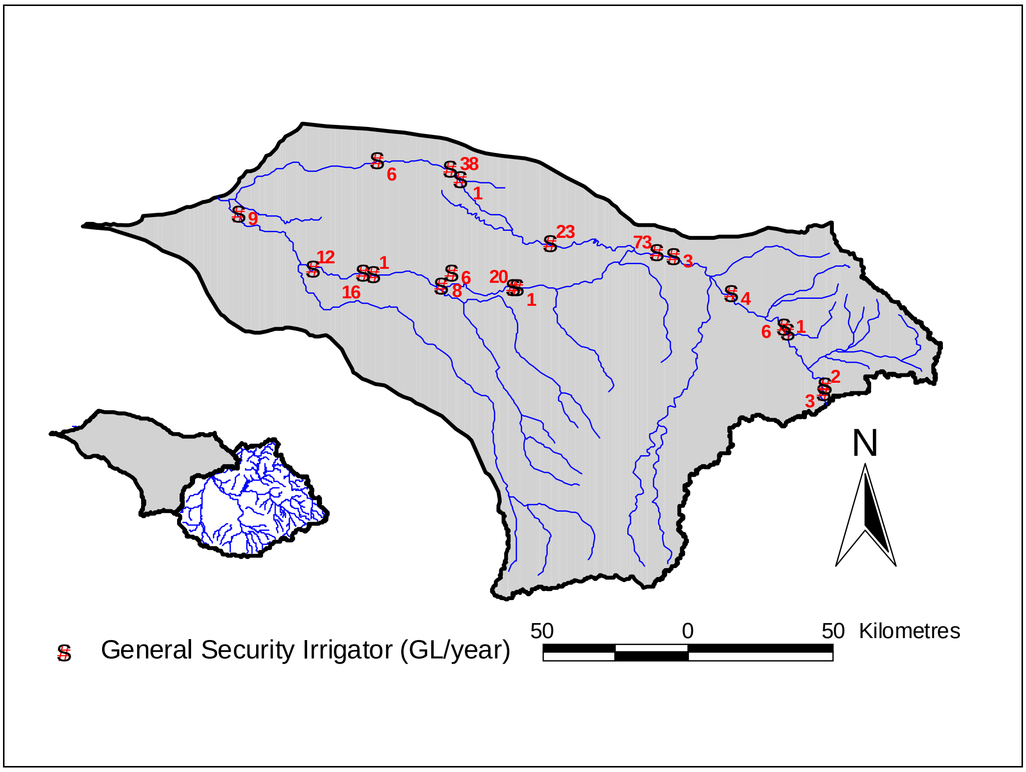


Figure 4.11. Modelled average annual irrigation diversions (GL/year, 1975-2000) for Lower Namoi Region

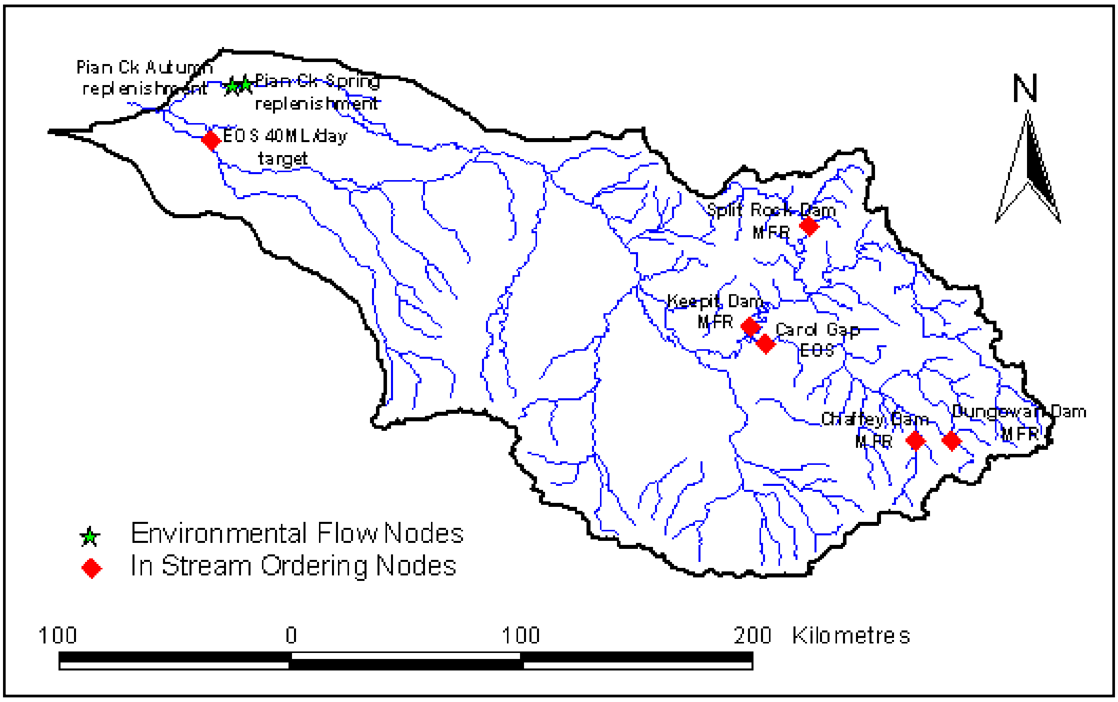


Figure 4.12. Distribution of nodes for ordering in-stream and environmental flow requirements

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 are shown in Table 4.2. The total error over the period of simulation is 0 ML, out of a total inflow of $63*10^6$ ML.

Table 4.2. Flow mass balance report for Namoi IQQM, 1993/4 Cap Scenario for 1975-2000.

Water balance component	Sum over simulation period (ML)
Inflows	63,210,925
Losses	53,897,231
Extractions	9,312,849
Storage change	-845
Error	0

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:

(i) did not change the magnitude of the quantity mass balance components from that of QA Test 1, and (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 4.3 show changes for the water balance components of the order of 0.003-0.02%. This result is of some concern and the cause of this is being investigated. The difference in flow volume is due to introduction of surface area in reaches with routing parameters in modelling salt movement. However, the differences are small enough that the remainder of the work can continue with some confidence that the software is working well enough. The salt mass balance report is shown at Table 4.4, and the results show that there are no numerical sources or sinks of salt introduced in the software.

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

Table 4.3. Flow mass balance comparison report for Namoi 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	63,210,925	63,231,205
Losses	53,897,231	53,892,455
Extractions	9,312,849	9,337,112
Storage change	-845	-1,642
Error	0	-4

Table 4.4. Salt mass balance report for Namoi 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 at the end of system was ($\mu \pm \sigma$) 100.0 ± 0.0 mg/L. The actual result was 100.0 ± 0.03 mg/L, indicating there were still some minor instabilities that need addressing in the code.

4.2.4. QA Test 4: Variable flow and constant concentration

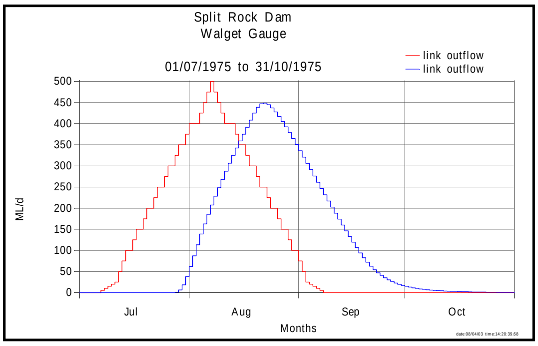
The purpose of QA Test 4 was to test the stability of the model under variable flow conditions, and to further test that there are no numerical sources or sinks in the model. The full set of inflows from QA Test 1 were used with a constant salinity concentration of 100 mg/L at all inflow nodes, and rainfall and evaporation set to zero.

The result aimed for at the end of system was (μ ± σ) 100.0 ± 0.0 mg/L. The actual result was 100.0 ± 2.3 mg/L, indicating there were still some minor instabilities that need addressing in the code.

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 with constant salinity concentration of 100 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 4.13. 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 exactly match; showing that salt load is routed through the system consistently with the flow. The concentration aimed for at the end of system was (μ ± σ) 100.0 ± 0.0 mg/L. This result was achieved.

(a)


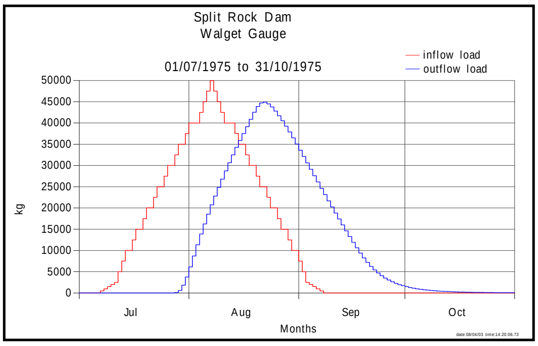
(b)


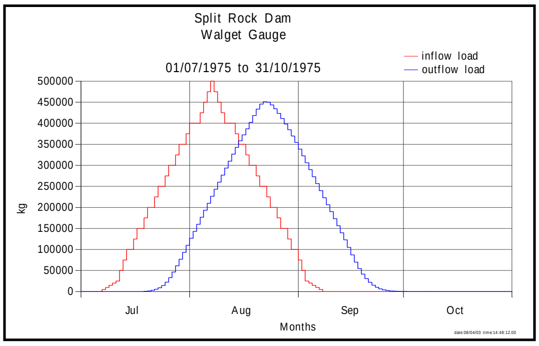
Figure 4.13. QA test 5 (a) Inflows and resultant EOS flows; (b) Salt load inflows and EOS salt loads

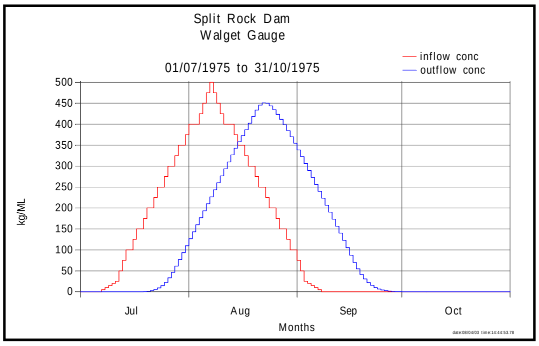
4.2.6. QA Test 6: Salt pulse with constant flow

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 varying 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 4.14. 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 exactly match, showing that salt load is routed through the system consistently with the flow.

Figure 4.14. QA test 6 (a) Salt load inflows and EOS salt loads; (b) Concentration inflows and EOS concentration

(a) 

(b) 

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 estimate and evaluation

5.1. INITIAL ESTIMATE

Salt loads were input to the model at all the inflow nodes. The initial estimates for the salt load inflows were based on the relationships documented in Table 5.7 of the Salinity Audit (Beale et al, 1999). These relationships are the basis of the 'first cut' models. The flow and salt load results from the 'first cut' model was firstly tested for consistency with the Salinity Audit results (Section B1). These results were then evaluated against in-stream concentration data, and if necessary, the salt inflow estimates were calibrated to improve the match with the concentration data.

The schematisations of the salt load inflows and balance points were shown in Figure 5.9 of the Salinity Audit. These are reproduced in this report showing the geographical form in Figure 5.1 and the catchment boundaries for inflow and balance points in Figure 5.2.

The salt load inflow relationships detailed in Table 5.9 of the Salinity Audit were modified in the following ways:

(i) Adapted to different IQQM network structure compared with Salinity Audit.

(ii) Replaced model form IIA with model form IID.

(iii) Modified for different EC→salinity conversion factor.

(iv) Concentration capped to highest observed.

(v) Accounting for different benchmark climatic condition Audit compared with BSMS.

The relationships finally adopted for the IQQM network structure, incorporating the Salinity Audit inflows arrived at after completing point (i) above, are listed in Table 5.1 for gauged catchments and Table 5.2 for the residual catchments.

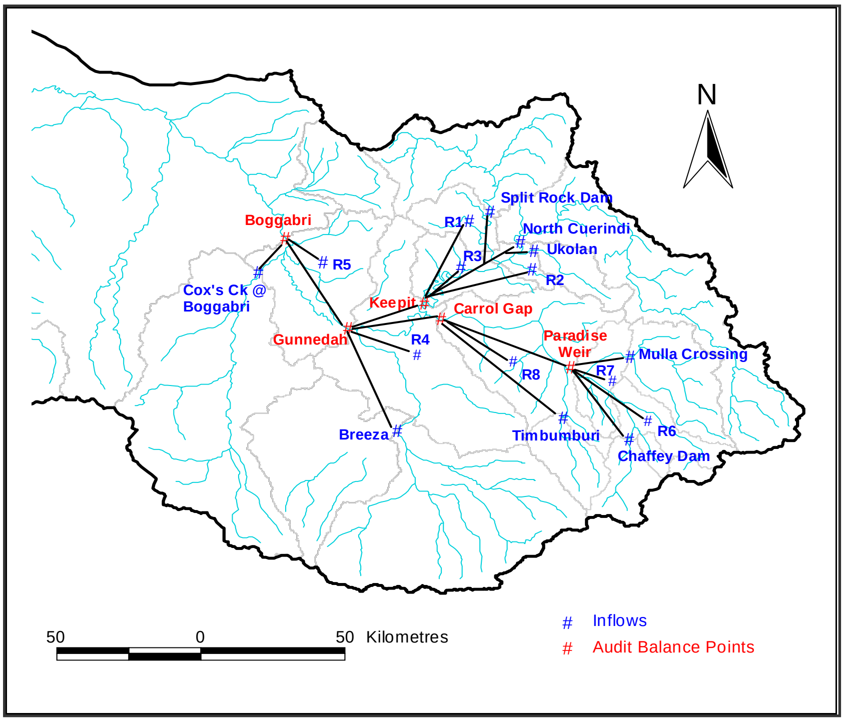


Figure 5.1. Geographic representation of 1999 Salinity Audit schematic of inflows and balance points

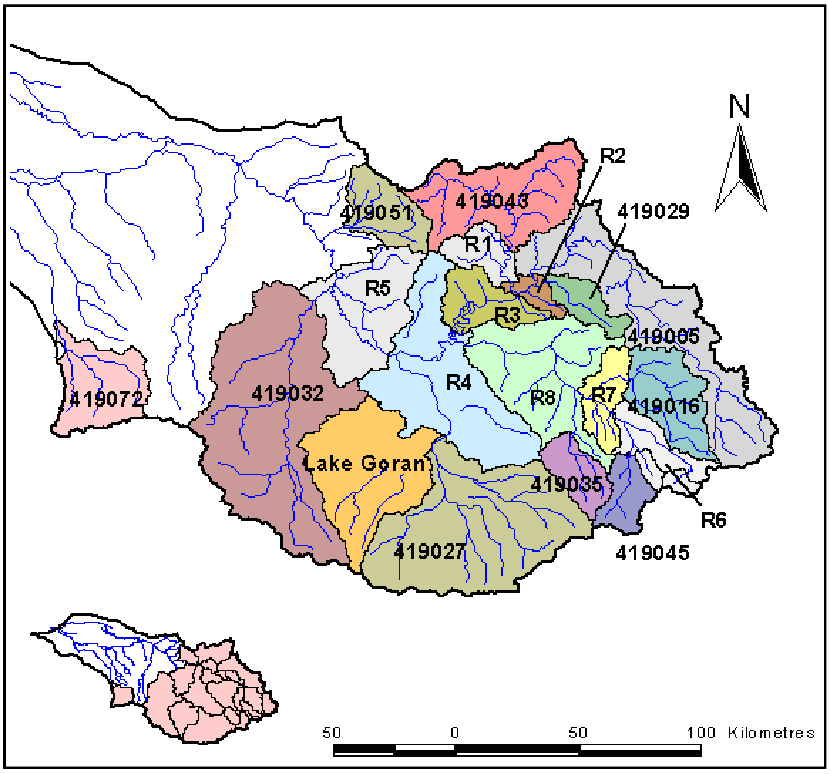


Figure 5.2. Inflow catchments used for 1999 Salinity Audit

Table 5.1. Salt inflow model parameters for gauged catchments

Subcatchment		IQQM inflow node number	Audit load flow model			
Gauge number	Station name		*Type*	*η*	*λ*	C_{max} *(mg/L)*
Peel System model						
419045	Peel River at Chaffey Dam	060	IIC	1.24	18.1	407
419036	Duncans Creek at Woolomin	062	IIC	1.42	14.2	407
419077	Dungowan Creek at Dungowan Dam	100	IIC	1.53	14.2	407
419016	Cockburn River at Mulla Crossing	67	IIC	14.4	9.86	469
419035	Goonoo Goonoo Creek at Timbumburi	74	IID	3.62	0.85	906
Namoi System model						
419043	Manilla River at Tarpoly (Split Rock Dam site)	001	IIC	-0.25	31.30	612
419029	Halls Creek at Ukolan	012	IIC	4.57	14.50	614
419005	Namoi River at North Cuerindi	011	IIC	8.59	8.59	675
419006	Peel River at Carrol Gap	025	IIC	39.9	20.6	870
419027	Mooki River at Breeza	028	IID	3.75	0.88	1139
419032	Coxs Creek at Boggabri	056	IIC	19.60	7.54	834
419051	Maules Creek at Avoca East	072	IIC	3.29	8.82	325

Note: Goonoo Goonoo Creek (419035) was changed from IIA as in the audit report to IID flow-load relationship. Mooki River (419027) was also changed from IIA to IID flow-load relationship.

Table 5.2. Salt inflow model parameters for residual catchments

Subcatchment		IQQM inflow node number	Audit load flow model			
Number	Description		*Type*	*η*	*λ*	C_{max} *(mg/L)*
Peel System model						
R6	Ungauged catchment into Peel River from Chaffey Dam to Piallamore	109	IIC	6.25	14.2	407
R7	Ungauged catchment into Peel River from Piallamore to Paradise Weir	051	IIC	4.7	7.2	450
R8	Ungauged catchment into Peel River from Paradise Weir to Carrol Gap	075	IIC	15.9	14.6	900
Namoi System model						
R1	Ungauged catchment into Manilla River from Split R dam to Brabri	005	IIC	4.60	7.20	612
R2	Ungauged catchment into Manilla RiveratBrabri to Namoi RatManilla Bridge	015	IIC	4.57	14.50	612
R3	Ungauged catchment into Namoi R at Manilla Bridge to Keepit Dam	019	IIC	6.50	10.10	612
R4	Ungauged catchment into Namoi R at Keepit Dam to Gunnedah	029	IIC	19.60	7.50	870
R5	Ungauged catchment into Namoi R at Gunnedah to Boggabri	057	IIC	19.60	7.50	834

5.2. EVALUATION METHOD

The salt transport models have to be developed to the point where they are fit for the intended purposes, which are:

(i) estimating a time series of flows and salt loads under baseline conditions at valley target locations for the benchmark climatic period; and

(ii) simulate the impact of salinity management interventions and other actions on salinity targets.

The extent to which the salt transport model is fit for purpose can be tested by comparing how well the model reproduces observed data of flow and concentration. A satisfactory performance, matching model results against observed data, provides some confidence that the model can reliably simulate scenarios that differ from the observed. Appropriate methods to measure performance have to be developed to be able to reach this conclusion. These performance measures need to be robust, and the use of multiple measures helps to ensure this. Inappropriate methods to calibrate a model, e.g., by setting parameter values outside reasonable ranges, may get a satisfactory result using one performance measure, but will probably fail others.

Appropriate performance measures have been developed, and results reported and peer reviewed for the quantity components of the model. These performance measures include matching basic statistical parameters such as mean and standard deviation, but also important characteristics such as the distribution of flows using exceedance curves. The flow calibration results can be studied in the Cap Implementation Report (Ribbons et al 2003).

Appropriate performance measures are being developed for salinity. Initially they will be similar to some of those used for flow calibration, but modified to account for the characteristics of salinity data.

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 5.3, and Equation 5.1. If either of the two simulated flows that mix are in error then that will result in an incorrect estimate of simulated concentration at the gauge locations (C_{obs}).

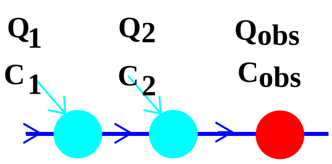


Figure 5.3. Calculating resultant concentration from two tributaries

$$C_{obs} = \frac{Q_1 \times C_1 + Q_2 \times C_2}{Q_1 + Q_2} \qquad (5.1)$$

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 Namoi-Peel System IQQM provides good estimates of flow for the parts of the model upstream of storages (where modelled). Downstream of storages observed flows depend a lot on regulation, i.e., how much water was released from the storage. No single configuration of the model estimates these releases well consistently over the period when data was collected, because levels of irrigation development and storage operation policies changed within this period.

A good match of the flows downstream of the storages was achieved by forcing the releases from the storages to observed releases. Exceptions to this are when diversions are a significant proportion of the flow in the river. Simulated diversions in the Namoi-Peel System 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 would not significantly effect simulated concentrations, because most of the inflows have already entered the Namoi-Peel Rivers (Figure 4.5) upstream of most of the diversions (Figure 4.11).

5.2.2. Selection of evaluation sites

The model was evaluated at seven sites along the main streams of the Namoi River System plus three sites on the Peel River. The basis for selecting these sites is discussed in Section 5.2.4. Time series plots comparing observed and simulated salinity are located at the end of this chapter (Figure 5.37 to Figure 5.53), and discussion of these results with performance measures are presented in the following sections.

Evaluation sites were selected based on available data and available relationships from the audit report. The last inflow point with audit relationship is Maules Creek at Avoca East (419051). The next gauging station along the Namoi River after Maules Creek with sufficient EC data is the Namoi River at Mollee (419039).

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

- Station 419026 Namoi River at Goangra.

Additional in-valley target sites defined in the Catchment Blueprint are:

- Station 419043: Manilla River at Tarpoly;
- Station 419022: Namoi River at Manilla Railway Bridge;
- Station 419007: Namoi River at Keepit;
- Station 419001: Namoi River at Gunnedah;
- Station 419012: Namoi River at Boggabri; and
- Station 419039: Namoi River at Mollee
- Station 419049: Pian Creek at Waminda
- Station 419045: Peel River at Chaffey Dam
- Station 419024: Peel River at Paradise Weir
- Station 419006: Peel River at Carrol Gap

These sites are shown in Figure 5.4, and the results presented in the following section.

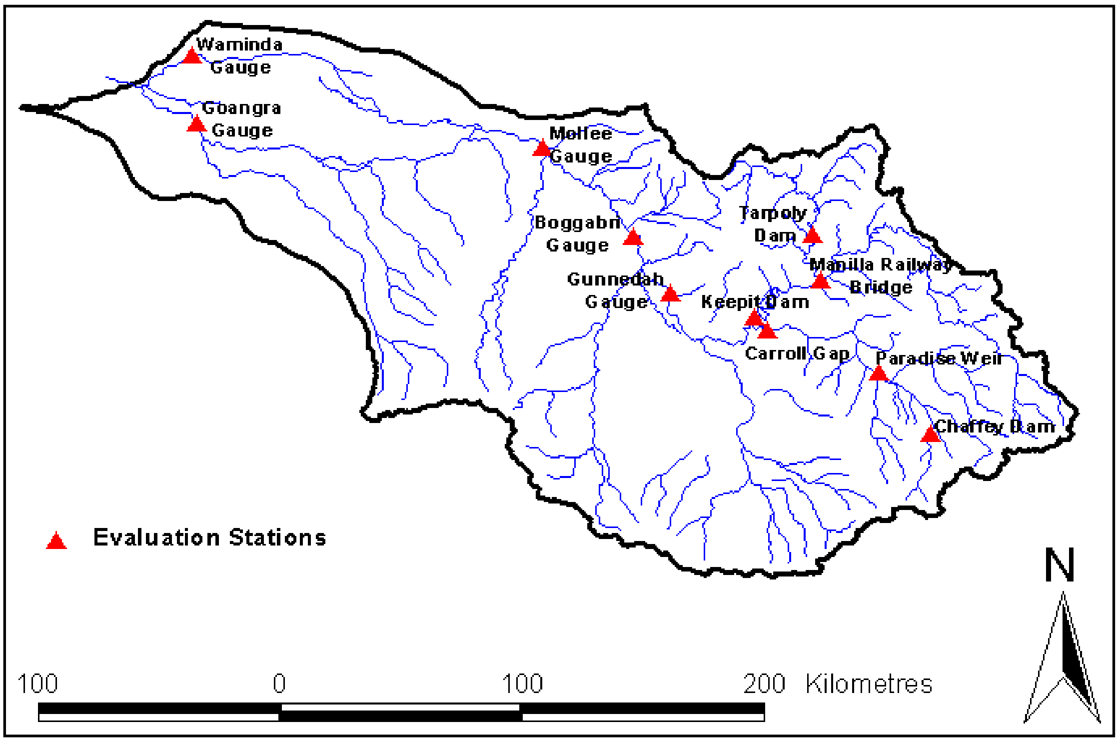


Figure 5.4. Location of evaluation sites

5.2.3. Data quality performance measures

A component of evaluating model results is to evaluate how representative the data is of the hydrologic conditions in the catchment. Observations of in-stream EC at a location vary considerably depending on many factors that all vary, including:

- 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
- underlying trend, if any.

How good a data set is depends on how well it samples all of these. Because these cannot all be individually quantified, performance measures for data quality include:

(v) how many data points there are;

(vi) what period the data represents;

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

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

Graphs of the full set of screened salinity data and observed flow at evaluation locations (Table 3.2) are shown in Figure 5.26 to Figure 5.36. Performance measures (i), (ii), and (iii) from above are reported for each of the evaluation sites. The flow ranges used in the reporting 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. Qualitative indicators of relative data quantity are discussed in Section 3. A good result for performance measure (iv) is a close approximation of the observed flow statistics, ie, the observations sample the flow variability.

5.2.4. Model result performance measures

5.2.4.1. Storages

Concentrations in storages do not vary in the same way as in streams. Storages accumulate salt load, and daily concentrations vary based on the previous days concentrations, in addition to changes in water and salt into and out of the storage (Equation 5.2). Except for times of very high inflows, the daily variation in salinity is very low.

Dry periods result in gradual changes of concentration because the volume of water in the storage is much larger than the tributary inflow volume. Salinities during these times typically increase because: (i) low flows have higher concentrations; and (ii) because evaporation decreases water volume without changing the salt load. Wet periods will usually result in abrupt changes in concentration because the volume of water in storage and the inflow are a similar size, and the high flows usually have relatively low concentrations. IQQM explicitly simulates all these processes.

$$C_t = \frac{(V_{t-1} \times C_{t-1}) - (V_{out} \times C_{t-1}) + (V_{in} \times C_{in})}{V_{t-1} - V_{out} + V_{in} + V_p - V_e} \qquad (5.2)$$

Where: C_t = Resultant concentration (mg/L)
V_{t-1} = Volume in storage on previous day (ML)
C_{t-1} = Concentration in storage on previous day (mg/L)
V_{out} = Volume released from storage (ML)
V_{in} = Tributary inflow volume (ML)
C_{in} = Concentration of tributary inflow (mg/L)
V_p = Volume added to storage by precipitation (ML)
V_e = Volume lost from storage by evaporation (ML)

Five performance measures were developed to evaluate the model results here, as follows:

(i) Pattern match (Equation 5.3), which measures how well the model reproduces the magnitude and direction of the change in concentration.

(ii) Mean match (Equation 5.4), which measures how well the model reproduces the mean concentration for the period of simulation.

(iii) Average error (Equation 5.5), which measures the average difference between simulated and observed.

(iv) Range comparison (Equation 5.6) which measures how well the model matches the range of results.

(v) Coefficient of determination (Equation 5.7), which measures the ratio of explained variation to total variation.

Where S_t and O_t are simulated and observed measures at time *t*. All these performance measures are dimensionless to allow for comparison between results at different sites. A perfect result for a performance measure (i to iv) is zero, and for performance measure (v) the perfect result is one.

$$P = \frac{\sum_i \left|(O_{i+1} - O_i) - (S_{i+1} - S_i)\right|}{(n-1) \times \sigma_s} \tag{5.3}$$

$$M = \left|\frac{\sum_i S_i}{\sum_i O_i}\right| - 1 \tag{5.4}$$

$$E = \frac{\left|\sum_i S_i - \sum_i O_i\right|}{\sum_i O_i} \tag{5.5}$$

$$G = \left|\frac{S_{max} - S_{min}}{O_{max} - O_{min}}\right| - 1 \tag{5.6}$$

$$R^2 = \frac{\sum_i (S_i - \overline{O})^2}{\sum_i (O_i - \overline{O})^2} \tag{5.7}$$

5.2.4.2. In-stream

Performance measures for comparing simulated and observed results for in-stream locations are reported within the three flow ranges defined in Section 5.2.3, as well as for the total flow range. For flow and concentration, the following are reported in tabular format for the observed and simulated data:

(i) mean;

(ii) standard deviation;

(iii) maximum; and

(iv) minimum.

In addition, the following are reported for concentration:

(ix) mean error (same formulation as Equation 5.5); and

(x) coefficient of determination (same formulation as Equation 5.7).

Lastly, mean simulated loads are compared with mean observed loads for each flow range. An example of these results is shown in Table 5.6.

5.3. EVALUATION OF MODELLING USING THE SALINITY AUDIT RELATIONSHIPS.

The following sections compare the model results (using the Salinity Audit salt load relationships) with observed flow and salinity at the evaluation sites. The Salinity Audit detailed information downstream to the Namoi River at Boggabri.

5.3.1. Split Rock Dam

Split Rock Dam is located at the top of the Manilla River. Flows from Split Rock Dam travel down the Manilla River and flow into Keepit Dam. Namoi IQQM has a single inflow node for Split Rock Dam that was based on Manilla River at Tarpoly (419043) prior to the dam being built in about 1987 and back-calculated inflows after the dam was built.

Storage levels and releases from Split Rock Dam were available from 1988. The salt inflow was calculated based on the flow -salt relationship from the audit report (see Table 5.1) with a maximum salinity of 612 mg/L.

The gauging station Manilla River at Tarpoly (419043) has salinity data from August 1976 at intervals of about once a week, with the exception of gaps fron 1991-1994 and from 1996-1997. After the construction of Split Rock Dam, the salinity ranges from about 208-347 mg/L. The evaluation period adopted was from January 1988 to September 2001.

The result of storage performance evaluation is shown in Table 5.3. The observed storage volume with observed salinity data is shown in Figure 5.26. The simulated storage salinity with observed is shown in Figure 5.37.

Table 5.3. Results of performance measures for observed versus simulated salinities in Split Rock Dam using Salinity Audit relationships

Performance measure	Result
Pattern match	0.54
Mean match	0.38
Average error	0.38
Range match	1.07
R^2	0.06

5.3.2. Gauging Station 419043: Manilla River at Tarpoly

The evaluation period adopted was from January 1988 to September 2001. The data was not representative of all the flow ranges and months (Table 5.5). There was no data in the summer period at low flows and not much data in the winter at high flows (Table 5.4)

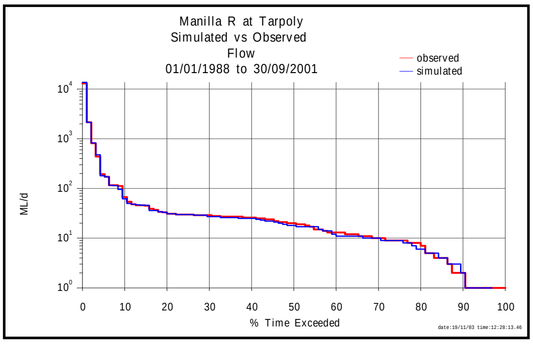
The results for the simulation using the Salinity Audit relationships show that the observed flow distribution is being maintained (Figure 5.5.a) as would be expected with forced releases from Split Rock Dam. The simulated salinity distribution is higher than that in the observed salinity distribution as shown in Figure 5.5 b, resulting to higher simulated salt loads than observed.

Table 5.4. Distribution of flow with discrete EC across flow ranges and months for Gauging Station 419043: Manilla River at Tarpoly

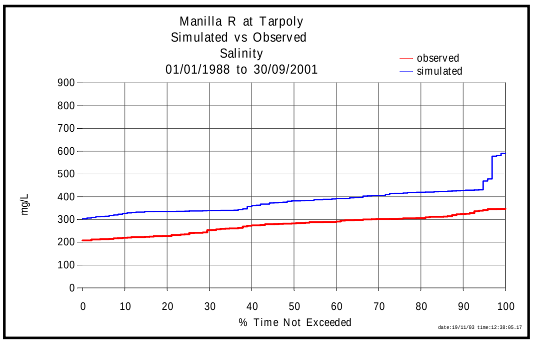
Flow range	Period	Number Points	Number of months with data											
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Low	1988-2001	28	0	0	0	0	2	2	3	2	2	0	1	1
Medium		52	5	4	3	5	5	3	2	3	4	2	2	1
High		15	2	2	2	0	0	0	0	0	2	1	2	2
All		95	7	6	5	5	6	5	5	5	7	3	5	4

Table 5.5. Comparison of statistics within flow ranges of all observed flows versus observed flows on days with discrete EC data during evaluation period for Gauging Station 419043: Manilla River at Tarpoly

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	7	2	1	10
	With EC obs	4	3	1	10
Medium	*All*	24	8	10	41
	With EC obs	23	8	10	38
High	*All*	367	1140	41	26070
	With EC obs	1158	3311	45	12960
ALL	*All*	89	528	1	26070
	With EC obs	197	1344	1	12960



(a)



(b)

Figure 5.5. Gauging Station 419043: Manilla River at Tarpoly; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity

Table 5.6. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419043: Manilla River at Tarpoly

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	4	3	1	10	307	29	208	347			1
	Simulated	5	3	1	10	364	54	335	591	58	0.01	2
Medium	Observed	23	8	10	38	271	34	215	346			6
	Simulated	23	8	10	38	382	59	302	581	111	0.06	9
High	Observed	1158	3311	45	12960	235	25	208	289			256
	Simulated	1158	3311	44	12961	407	17	382	425	172	0.24	456
All	Observed	197	1344	1	12960	276	39	208	347			44
	Simulated	197	1345	1	12961	381	55	302	591	105	0.06	77

5.3.3. Gauging Station 419022: Namoi River at Manilla Railway Bridge

The gauging station Namoi River at Manilla Railway Bridge has data collected since August 1973 at intervals of about once every 6 weeks, with the exception of a gap in 1992-1993 and from 1998-1999. After the construction of Split Rock Dam the salinity ranges from about 60-447 mg/L. The data is available at least once in most months except April and June at high flows. Table 5.7, Table 5.8 and Figure 5.27 shows the observed flow and salinity data. Most of the data was collected in the low to medium flow range with a spread across all months.

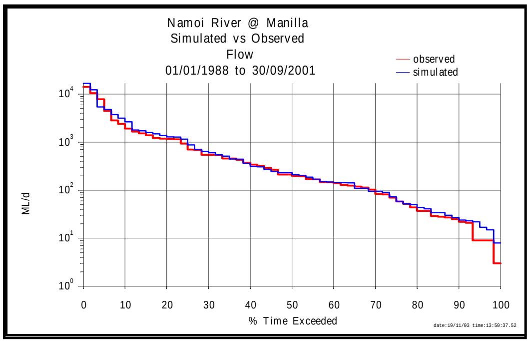
The evaluation period adopted was from January 1988 to September 2001. The simulated flows match the distribution of the observed flows well, which is to be expected as the model was calibrated to get this result. The simulated salinity data was capped at 675 mg/L since the simulated salinity gets too high at low flows. The simulated salinity at low flows is a lot higher than the observed. Over all the simulated salinity is higher than observed. Table 5.9, Figure 5.6 and Figure 5.38 shows the simulated and observed salinity data. The simulated salinity distribution shown in Figure 5.6 b is higher than the observed salinity data significantly over estimating salinity in low flows.

Table 5.7. Distribution of flow with discrete EC across flow ranges and months for Gauging Station 419022: Namoi River at Manilla Railway Bridge

Flow range	Period	Number Points	Number of months with data											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Low	1988-2001	15	1	1	2	1	3	1	1	1	1	1	1	1
Medium		28	2	2	1	3	2	4	4	3	2	1	3	1
High		17	2	2	1	0	1	0	1	1	2	2	1	2
All		60	5	5	4	4	6	5	6	5	5	4	5	4

Table 5.8. Comparison of statistics within flow ranges of all observed flows versus observed flows on days with discrete EC data during evaluation period for Gauging Station 419022: Namoi River at Manilla Railway Bridge

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	32	14	1	58
	With EC obs	27	17	3	58
Medium	*All*	234	161	59	696
	With EC obs	252	161	70	617
High	*All*	2973	6012	700	124428
	With EC obs	3308	3946	704	14160
ALL	*All*	740	2910	1	124428
	With EC obs	1062	2504	3	14160

(a) 

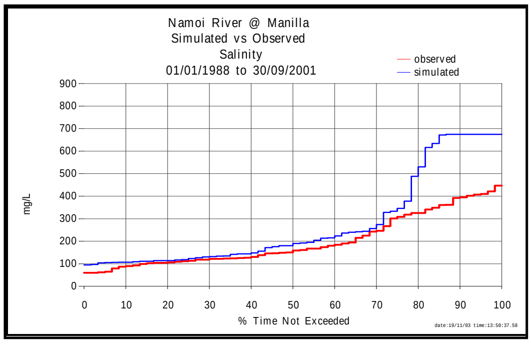
(b) 

Figure 5.6. Gauging Station 419022: Namoi River at Manilla Railway Bridge; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity

Table 5.9. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419022: Namoi River at Manilla Railway Bridge

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*	27	17	3	58	353	69	215	447			9
	Simulated	33	18	8	73	581	132	333	675	229	0.39	18
Medium	*Observed*	252	161	70	617	177	71	90	349			38
	Simulated	257	166	50	640	211	104	130	675	59	0.08	44
High	*Observed*	3308	3946	704	14160	99	29	60	167			257
	Simulated	3652	4383	707	16777	111	8	95	127	23	0.33	378
All	*Observed*	1062	2504	3	14160	199	113	60	447			93
	Simulated	1163	2779	8	16777	275	207	95	675	91	0.71	132

5.3.4. Keepit Dam

Keepit Dam storage volume and releases were available from July 1974. EC data from Gauging Station 419007: Namoi River d/s Keepit Dam was available from 1970. The benchmark period from May 1975 to April 2000 was used in the evaluation period. The observed salinity ranges from just over 100 mg/L (after periods of high inflows relative to storage volume) to over 420 mg/L (after an extended period of low inflows and presumably high evaporation relative to storage volume. The observed storage volume with observed salinity data is shown in Figure 5.28. The simulated storage salinity with observed is shown Figure 5.39.

Table 5.10. Results of performance measures for simulated versus observed concentrations at Keepit Dam using Salinity Audit Relationships

Performance measure	Result
Pattern match	0.34
Mean match	0.20
Average error	0.22
Range match	0.46
R^2	0.64

5.3.5. Gauging Station 419007: Namoi River at Keepit

The discrete data was available from 1970 to date. The benchmark period used for evaluation was from May 1975 to April 2000. The detail the statistics for the observed data are shown in Table 5.11 and Table 5.12. Most data points are in the medium flow range and in the summer period.

Table 5.11. Distribution of flow with discrete EC across flow ranges and months for Gauging Station 419007: Namoi River at Keepit

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	19	0	0	1	1	3	1	4	2	2	1	3	0
Medium		101	4	5	9	11	9	5	5	6	10	6	8	7
High		30	5	6	2	0	0	2	0	0	3	2	2	2
All		150	9	12	12	12	12	8	8	7	15	9	12	9

Table 5.12. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC* data during evaluation period for Gauging Station 419007: Namoi River at Keepit

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	3	3	0	8
	With EC obs	5	2	0	8
Medium	*All*	355	374	9	1352
	With EC obs	353	369	9	1298
High	*All*	3269	4888	1353	110796
	With EC obs	3287	5704	1394	33221
ALL	*All*	857	2509	0	110796
	With EC obs	896	2806	0	33221

Table 5.13 and Figure 5.7 show the simulated verses observed flow and salinity distribution. The flows match perfectly (forced flows) however the salinity concentration and salt loads are lower then observed.

(a) (b)

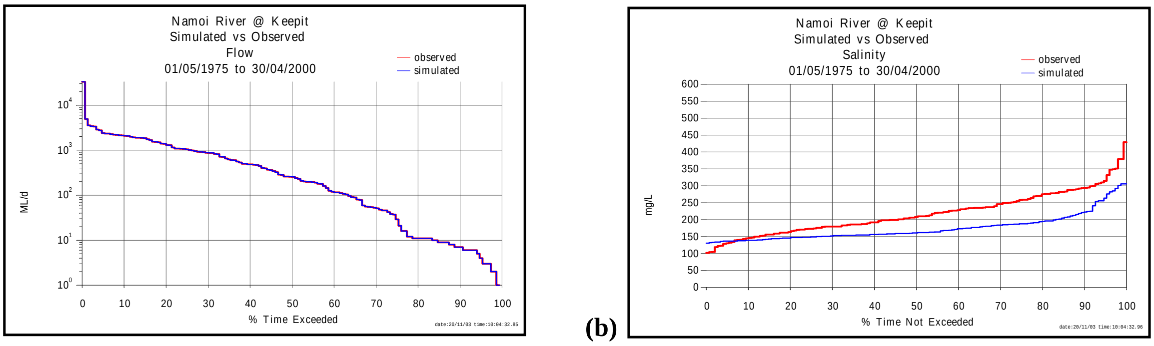


Figure 5.7. Gauging Station 419007: Namoi River at Keepit; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity

Table 5.13. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419007: Namoi River at Keepit

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*	5	2	1	8	241	39	176	299	60	0.58	1
	Simulated	5	2	1	8	181	23	154	225			1
Medium	*Observed*	353	369	9	1298	223	64	119	429	48	0.70	71
	Simulated	353	369	9	1298	178	43	132	306			59
High	*Observed*	3,287	5,704	1,394	33,221	182	45	102	282	35	0.22	540
	Simulated	3,287	5,704	1,394	33,221	159	18	131	190			495
All	*Observed*	902	2,815	1	33,221	217	61	102	429	47	0.65	157
	Simulated	902	2,815	1	33,221	174	38	131	306			140

5.3.6. Gauging Station 419001: Namoi River at Gunnedah

The discrete data was available from 1970 to 2000. The evaluation period was from May 1975 to April 2000. The time series observed flow and concentration data is shown in Figure 5.29. The observed and simulated salinity is shown in Figure 5.40. Most of the observed EC data lies in the medium flow range with good distribution across the year (Table 5.14). The statistics in Table 5.15 show that the observed EC data is fairly representative of the flow range in which it was collected.

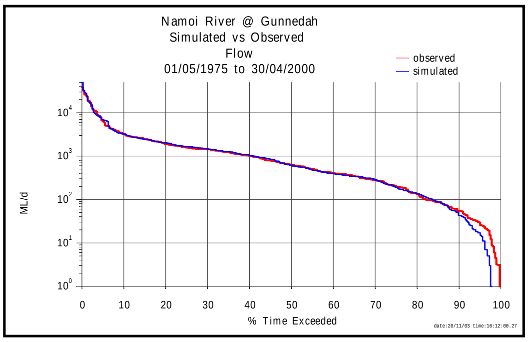
Table 5.14. Distribution of flow with discrete EC across flow ranges and months for Gauging Station 419001: Namoi River at Gunnedah

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	80	1	2	6	8	6	7	3	5	3	1	3	3
Medium		211	12	15	14	7	7	4	12	5	11	17	16	17
High		74	7	7	2	0	0	2	2	3	4	4	4	2
All		365	15	19	16	15	13	14	17	13	16	19	19	17

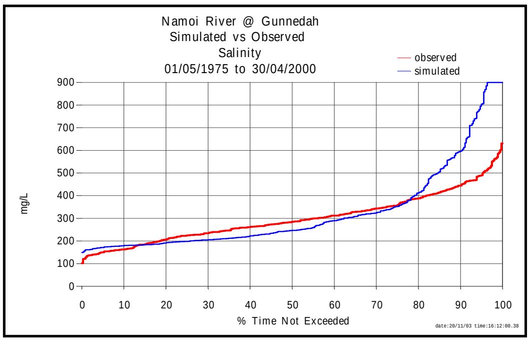
Table 5.16 and Figure 5.8 compare simulated with observed flow and salinity distribution. The flow distribution matches well however model salinity and salt loads underestimates in the low to medium flow range.

Table 5.15. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC* data during evaluation period for Gauging Station 419001: Namoi River at Gunnedah

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	71	50	0	155
	With EC obs	64	41	1	148
Medium	*All*	768	496	155	1873
	With EC obs	797	496	155	1867
High	*All*	7348	14464	1874	191392
	With EC obs	6405	7442	1922	38729
ALL	*All*	1945	7025	0	191392
	With EC obs	1773	4099	1	38729



(a)



(b)

Figure 5.8. Gauging Station 419001: Namoi River at Gunnedah; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.16. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419001: Namoi River at Gunnedah

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*	70	39	6	148	411	91	186	592	237	0.01	29
	Simulated	69	48	1	183	632	179	268	900			37
Medium	*Observed*	797	496	155	1867	295	85	102	631	64	0.24	215
	Simulated	841	650	110	6203	263	65	169	488			192
High	*Observed*	6405	7442	1922	38729	198	52	121	372	41	0.17	1141
	Simulated	6541	8387	1769	50017	183	15	153	226			1133
All	*Observed*	1813	4137	6	38729	298	105	102	631	94	0.38	369
	Simulated	1867	4527	1	50017	321	186	153	900			356

5.3.7. Gauging Station 419012: Namoi River at Boggabri

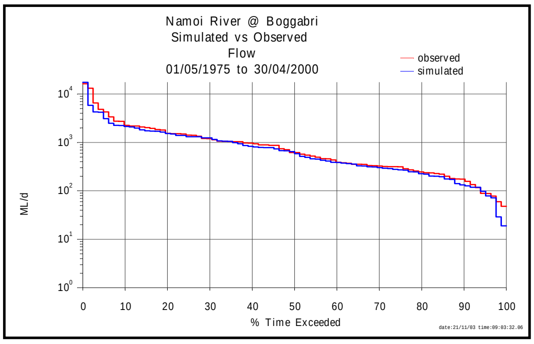
The discrete data was available from 1970 to 1991. The salinity data was not well represented in the low and high flow ranges as shown in Table 5.17 and Table 5.18. The benchmark evaluation period was from May 1975 to April 2000. The time series observed flow and salinity data is shown in Figure 5.30. The observed and simulated salinity is shown in Figure 5.41. The observed flows and salt loads are below observed values as shown in Figure 5.9 and Table 5.19.

Table 5.17. Distribution of flow with discrete EC across flow ranges and months for Gauging Station 419012: Namoi River at Boggabri

Flow range	Period	Number Points	Number of months with data											
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Low	1975-1991	11	0	0	1	2	1	2	0	1	0	0	1	0
Medium		58	5	2	8	4	4	4	3	5	4	9	2	6
High		13	2	2	0	0	0	1	0	2	2	1	1	0
All		82	8	5	10	6	6	7	3	7	6	11	4	6

Table 5.18. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC* data during evaluation period for Gauging Station 419012: Namoi River at Boggabri

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	75	57	0	171
	With EC obs	125	45	52	171
Medium	*All*	786	494	171	1922
	With EC obs	726	459	183	1832
High	*All*	8605	17528	1922	234731
	With EC obs	4019	3673	2000	15336
ALL	*All*	2207	8477	0	234731
	With EC obs	1167	1934	52	15336



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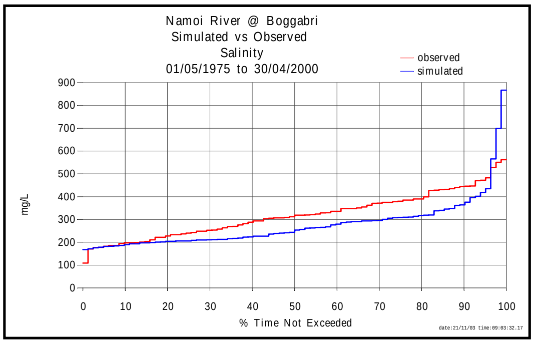


(b)

Figure 5.9. Gauging Station 419012: Namoi River at Boggabri; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.19. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419012: Namoi River at Boggabri

Flow range	Data set	Distributions								C_o versus C_s		Mean load (t/d)
		Flow (ML/d)				Salinity (mg/L)				*Avg. error (mg/L)*	R^2	
		Mean	*S.D*	*Min*	*Max*	*Mean*	*S.D*	*Min*	*Max*			
Low	*Observed*	119	49	52	171	381	43	309	435	138	0.11	45
	Simulated	88	43	15	133	468	202	288	866			34
Medium	*Observed*	675	457	214	1832	334	94	186	562	76	0.43	204
	Simulated	673	553	175	3090	269	52	198	395			163
High	*Observed*	4206	3968	2021	15336	232	84	171	470	52	0.26	895
	Simulated	3949	4628	1643	17359	184	11	168	207			719
All	*Observed*	1173	2082	52	15336	324	96	171	562	80	0.24	295
	Simulated	1125	2239	15	17359	282	114	168	866			236

5.3.8. Gauging Station 419039: Namoi River at Mollee

The discrete data was available from 1976 to 2002 and there was more data at this station than at Boggabri. The data appears to be uniformly distributed across the flow ranges, and throughout the year (Table 5.20 and Table 5.21), and the statistics of the flows on the days with salinity data match the statistics for the whole flow record.

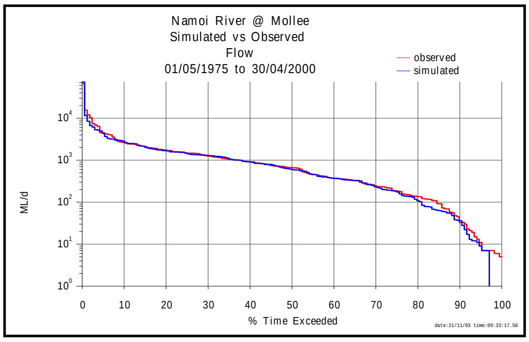
The simulated flow distribution at Mollee match the observed flow distribution except at very low flows (Figure 5.10a). However, the simulated salinity underestimates the observed salinity. The time series observed flow and salinity is shown in Figure 5.31. The observed and simulated salinity is shown in Figure 5.50 .

Table 5.20. Distribution of flow with discrete EC across flow ranges and months for Gauging Station 419039: Namoi River at Mollee

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	44	0	1	5	7	6	6	4	3	2	0	2	2
Medium		97	10	8	8	5	4	3	6	7	8	12	8	9
High		26	4	3	1	1	0	2	2	2	3	3	2	0
All		167	15	12	14	14	11	11	12	12	13	16	12	11

Table 5.21. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC data* during evaluation period for Gauging Station 419039: Namoi River at Mollee

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	95	62	4	200
	With EC obs	78	61	5	187
Medium	*All*	876	531	201	2080
	With EC obs	892	527	215	2031
High	*All*	9162	16706	2081	185707
	With EC obs	6922	12224	2197	64558
ALL	*All*	2375	8217	4	185707
	With EC obs	1616	5292	5	64558

(a)


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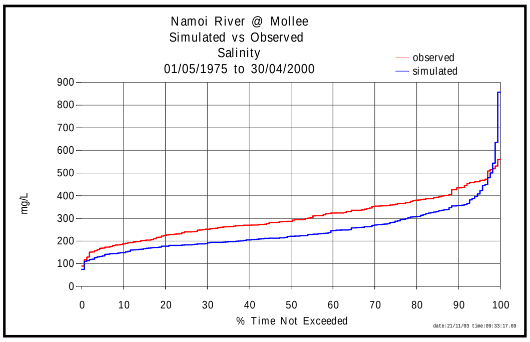


Figure 5.10. Gauging Station 419039: Namoi River at Mollee; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.22. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419039: Namoi River at Mollee

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*	81	61	5	187	355	78	187	561	96	0.29	27
	Simulated	97	96	0	330	308	144	109	858			28
Medium	*Observed*	892	527	215	2031	298	89	117	519	90	0.18	247
	Simulated	877	589	59	3006	227	64	130	478			172
High	*Observed*	7103	12441	2197	64558	235	73	90	453	81	0.04	1267
	Simulated	6643	13925	1543	72538	156	29	73	201			790
All	*Observed*	1650	5368	5	64558	302	92	90	561	90	0.27	350
	Simulated	1574	5826	0	72538	236	99	73	858			232

5.3.9. Gauging Station 419026: Namoi River at Goangra

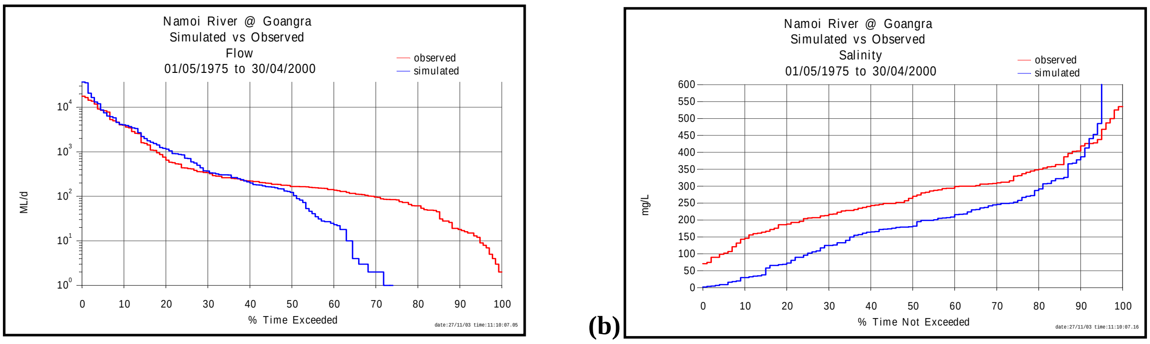
The discrete data are available from 1970 to 2002. There were no audit flow-load relationships for residual inflows downstream of Boggabri. The assumed inflow salinity from residual catchments was set at zero until calibration can be done. Table 5.23 and Table 5.24 show that most of the data was reasonably well distributed across the year and collected mostly during medium flows. The model is over estimating salt loads in the low to medium flow range and underestimating salt loads in the high flow range.

Table 5.23. Distribution of flow with discrete EC across flow ranges and months for Gauging Station 419026: Namoi River at Goangra

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	23	2	3	2	3	3	1	3	0	1	1	1	2
Medium		90	10	11	4	8	7	7	7	7	5	6	9	9
High		22	1	2	2	1	1	1	3	2	2	2	2	2
All		135	12	15	9	12	12	9	13	9	8	9	12	13

Table 5.24. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC data* during evaluation period for Station 419026: Namoi River at Goangra

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	22	17	0	55
	With EC obs	23	17	1	54
Medium	*All*	308	279	55	1311
	With EC obs	252	213	56	1095
High	*All*	8145	11216	1313	109261
	With EC obs	6795	4937	1498	18163
ALL	*All*	1817	5933	0	109261
	With EC obs	1279	3134	1	18163



(a) (b)

Figure 5.11. Gauging Station 419026: Namoi River at Goangra; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.25. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419026: Namoi River at Goangra

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*	15	9	1	30	333	117	146	525			5
	Simulated	252	548	1	1984	309	292	4	900	181	0.35	35
Medium	*Observed*	287	234	49	1095	274	93	90	535			76
	Simulated	897	4570	0	36654	231	172	7	900	139	0.01	91
High	*Observed*	6795	4937	1498	18163	220	95	71	468			1281
	Simulated	7542	8048	852	35214	108	61	2	201	112	0.26	598
All	*Observed*	1681	3559	1	18163	271	101	71	535			331
	Simulated	2268	5920	0	36654	215	186	2	900	139	0.10	195

5.3.10. Gauging Station 419049: Pian Creek at Waminda

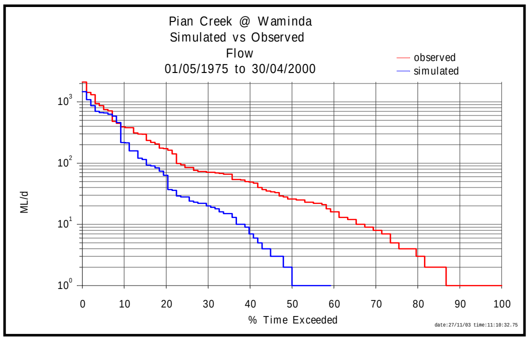
The discrete data are available from 1976 to 2002. There were no audit flow-load relationships for residual inflows downstream of Boggabri. The assumed inflow salinity for the residual catchments was set at zero until calibration can be done. Most of the data collected was during medium flows with data well spread across the year (Table 5.26 and Table 5.27). The model results significantly underestimate the salt loads compared to observed data.

Table 5.26. Distribution of flow with discrete EC across flow ranges and months for Station 419049: Pian Creek at Waminda

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	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium		74	7	7	6	7	9	4	9	1	4	4	9	7
High		24	2	1	1	0	1	2	2	3	4	2	2	2
All		98	8	8	8	7	10	6	11	4	8	6	11	9

Table 5.27. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC data* during evaluation period for Gauging Station 419049: Pian Creek at Waminda

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	0	0	0	0
	With EC obs	0	0	0	0
Medium	*All*	21	24	0	94
	With EC obs	25	26	1	91
High	*All*	1274	3908	94	35809
	With EC obs	543	512	94	2104
ALL	*All*	267	1820	0	35809
	With EC obs	152	336	1	2104

(a)


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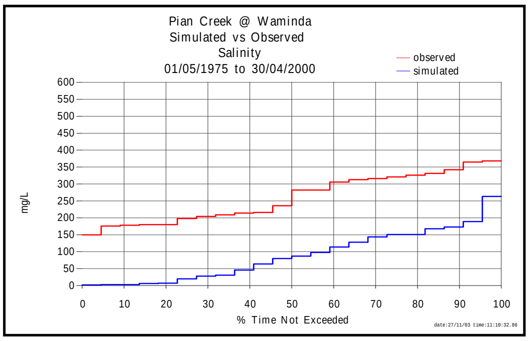


Figure 5.12. Gauging Station 419049: Pian Creek at Waminda; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.28. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419049: Pian Creek at Waminda

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	na	na	na	na	na	na	na	na	na	na	0
	Simulated	na	na	na	na	na	na	na	na	na	na	0
Medium	Observed	25	16	1	52	309	62	209	368	197	0.07	8
	Simulated	83	162	0	460	112	93	6	263			13
High	Observed	573	436	146	1462	230	59	150	321	154	0.20	118
	Simulated	421	478	1	1472	76	62	2	173			43
All	Observed	374	436	1	1462	259	71	150	368	170	0.03	78
	Simulated	298	422	0	1472	89	75	2	263			32

5.3.11. Chaffey Dam

Storage levels and releases from Chaffey Dam were available from 1979. Back calculation inflows were estimated using observed flows at the Gauging Station Peel River at Chaffey Dam (419045). The period for model evaluation was July 1979 to June 2000. The observed storage volume and salinity is shown in Figure 5.34. The simulated salinity using the audit flow-salt relationship with observed salinity is shown in Figure 5.42.

Table 5.29. Results of performance measures for simulated versus observed concentrations at Chaffey Dam using Salinity Audit Relationships

Performance measure	Result
Pattern match	0.41
Mean match	0.03
Average error	0.08
Range match	0.39
R^2	0.36

5.3.12. Gauging Station 419045: Peel River d/s Chaffey Dam

Storage releases from Chaffey Dam were available from 1979. Back calculation inflows were estimated using observed flows at the Gauging Station Peel River at Chaffey Dam (419045). The period for model evaluation was July 1979 to June 2000. The majority of salinity data was collected during medium flow events and good spread of data points through out the year (Table 5.30 and Table 5.31). The model frequency of salinity matches the observed well (Figure 5.13 and Table 5.32).

Table 5.30. Distribution of flow with discrete EC across flow ranges and months for Gauging Station 419045: Peel River d/s Chaffey Dam

Flow range	Period	Number Points	Number of months with data											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Low	1979-2000	18	0	0	0	1	2	2	1	1	0	1	0	1
Medium		141	9	9	8	8	6	4	1	4	1	4	6	5
High		70	2	2	0	1	1	1	3	4	3	3	2	2
All		229	10	9	8	9	8	5	3	8	4	6	8	7

Table 5.31. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC data* during evaluation period for Gauging Station 419045: Peel River d/s Chaffey Dam

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	2	2	0	6
	With EC obs	3	1	1	6
Medium	*All*	46	28	6	112
	With EC obs	46	23	7	106
High	*All*	419	858	112	17290
	With EC obs	554	577	112	2891
ALL	*All*	112	415	0	17290
	With EC obs	198	397	1	2891

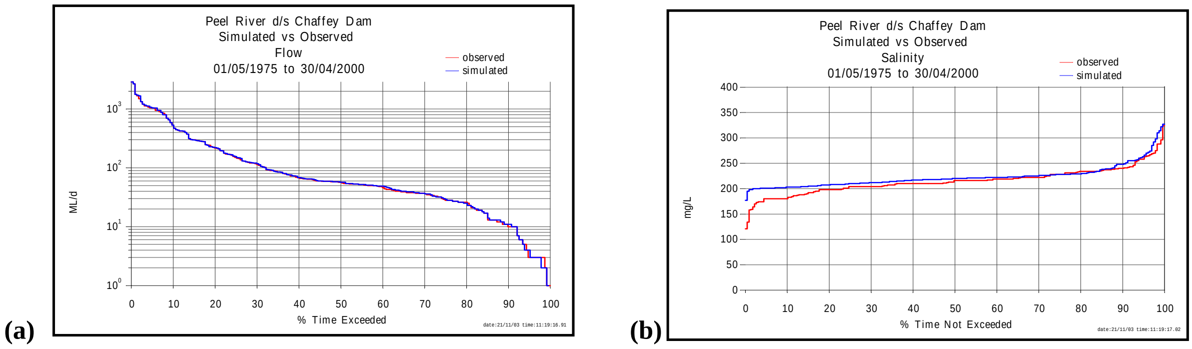


Figure 5.13. Station 419045: Peel River d/s Chaffey Dam; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.32. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419045: Peel River d/s Chaffey Dam

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*	3	1	1	6	230	26	184	296	30	0.01	1
	Simulated	3	2	0	6	234	26	176	293			1
Medium	*Observed*	46	23	7	106	220	21	174	324	16	0.34	10
	Simulated	46	23	7	106	227	23	195	331			10
High	*Observed*	554	577	112	2891	198	25	121	269	19	0.48	109
	Simulated	554	577	113	2890	213	16	200	287			116
All	*Observed*	198	397	1	2891	214	25	121	324	18	0.34	40
	Simulated	198	397	0	2890	223	22	176	331			42

5.3.13. Gauging Station 419024: Peel River at Paradise Weir

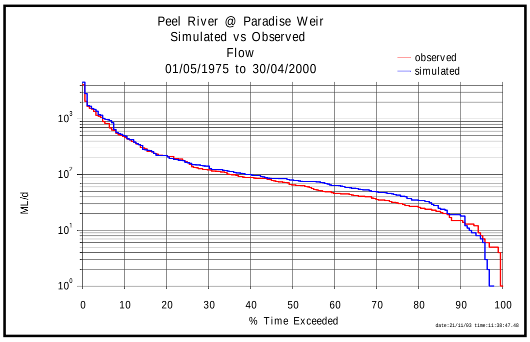
Observed EC data was available from 1970 to 2002. The evaluation period was from July 1979 to June 2000. Figure 5.35 shows the observed flow and salinity data. Most data was collected during periods of low and medium flow and was well distributed across the year (Table 5.33 and Table 5.34). The distribution of modelled flows and salinity match well (Table 5.35 and Figure 5.14).

Table 5.33. Distribution of flow with discrete EC across flow ranges and months for Gauging Station 419024: Peel River at Paradise Weir

Flow range	Period	Number Points	Number of months with data											
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Low	1979-2000	44	2	4	3	4	4	5	1	2	3	0	4	5
Medium		123	9	7	7	5	4	5	7	6	4	6	8	10
High		25	1	2	0	0	1	0	1	3	5	3	4	1
All		192	10	11	11	9	9	10	9	10	12	7	13	13

Table 5.34. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC data* during evaluation period for Gauging Station 419024: Peel River at Paradise Weir

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	15	9	0	28
	With EC obs	17	8	4	27
Medium	*All*	109	81	28	364
	With EC obs	104	77	28	352
High	*All*	1816	3527	364	72492
	With EC obs	967	798	381	4147
ALL	*All*	430	1722	0	72492
	With EC obs	197	418	4	4147

(a)


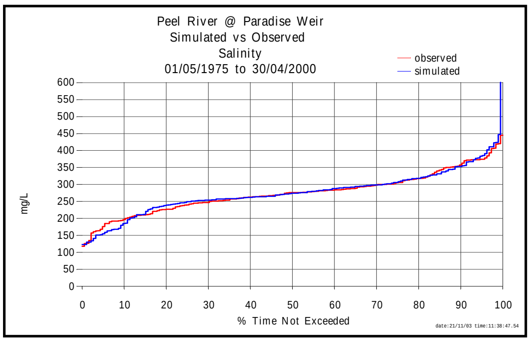
(b)


Figure 5.14. Gauging Station 419024: Peel River at Paradise Weir; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.35. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419024: Peel River at Paradise Weir

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*	17	8	4	27	323	44	253	419	35	0.32	5
	Simulated	36	26	1	106	313	43	262	447			11
Medium	*Observed*	105	77	28	352	275	49	118	445	43	0.17	27
	Simulated	109	85	1	532	286	57	164	620			28
High	*Observed*	967	798	381	4147	195	50	126	378	40	0.02	175
	Simulated	1086	941	274	4566	171	34	123	253			165
All	*Observed*	200	421	4	4147	275	60	118	445	41	0.39	42
	Simulated	223	484	1	4566	277	67	123	620			43

5.3.14. Gauging Station 419006: Peel River at Carrol Gap

Observed EC data was available from 1970 to 2002. The evaluation period was from July 1979 to June 2000. Figure 5.36 show the observed flows and salinity data collected. Most of the data was collected during periods of low to medium flow and was well distributed across the year (Table 5.36 and Table 5.37). The distribution of flow and salinity shows the model over estimated salinity during low flow and under estimates during higher flows (Figure 5.15 and Table 5.38).

Table 5.36. Distribution of flow with discrete EC across flow ranges and months for Gauging Station 419006: Peel River at Carrol Gap

Flow range	Period	Number Points	Number of months with data											
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Low	1979-2000	31	2	1	4	6	3	2	1	1	3	2	3	2
Medium		72	6	8	7	3	6	8	11	4	3	5	5	4
High		21	1	1	1	0	1	2	1	1	5	4	1	2
All		124	9	9	12	10	10	12	13	6	11	10	9	8

Table 5.37. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC data* during evaluation period for Gauging Station 419006: Peel River at Carrol Gap

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	18	13	0	40
	With EC obs	21	12	1	39
Medium	*All*	161	107	40	476
	With EC obs	150	104	42	463
High	*All*	2522	5811	476	98576
	With EC obs	1165	624	484	2486
ALL	*All*	609	2782	0	98576
	With EC obs	289	480	1	2486

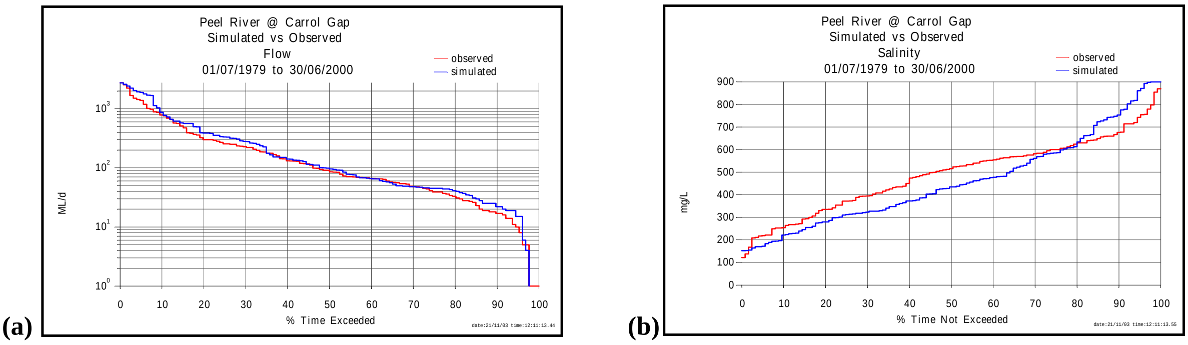


Figure 5.15. Gauging Station 419006: Peel River at Carrol Gap; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.38. Comparison of statistics within flow ranges of flow, salinity and load for Gauging Station 419006: Peel River at Carrol Gap

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*	21	12	1	39	638	130	294	870	220	0.05	13
	Simulated	45	21	15	94	506	147	327	816			22
Medium	*Observed*	150	104	42	463	488	108	253	678	111	0.39	65
	Simulated	178	170	4	772	490	186	164	898			62
High	*Observed*	1165	624	484	2486	262	78	122	408	55	0.41	291
	Simulated	1345	805	332	2740	221	55	152	327			263
All	*Observed*	295	484	1	2486	485	162	122	870	127	0.34	92
	Simulated	348	581	4	2740	447	191	152	898			87

5.3.15. Discussion of results from evaluation of results from simulation with Salinity Audit relationships

Observed EC data points were most representative of medium flows. The statistics of the flows from observed EC data was considered representative of the long term flow statistics from May 1975 to April 2000. There was limited EC data available for very high flows, as can be seen from the maximum value for all days compared to the maximum when only EC data was available.

5.3.15.1. Upper Namoi Catchment

On days with discrete EC data, the simulated mean salinity is over by 35 % at Split Rock Dam and by about 55% at Manilla. The mean flow increased from 197 ML/d at Tarpoly (419043) to 1062 ML/d at Manilla (419022). The mean observed salinity decreased from 276 mg/L to 199 mg/L and the mean salt load increased from 44 t/d to 93 t/d. The simulated salt load increased from 77 t/d to 134 t/d. At the end of this river section the model over estimates flow by about 9%, overestimates salinity by about 38% and consequently over estimates salt load by about 42%.

5.3.15.2. Lower Namoi Catchment

Downstream of Keepit Dam along the Namoi River, the mean flow increased from 896 ML/d to 1945 ML/d at Gunnedah due to significant inflow from Peel River (419006). The simulated flow was over by about 3% while the simulated salt load was under by about 4% from the observed salt load.

At Boggabri, the mean simulated salt load was under by 20% of the observed salt load.

Downstream of Boggabri, there are many residuals with unknown salt inflows. For these residuals, The input salinity was assumed to be zero. This resulted to dilution of water, hence a very low simulated salinity at Goangra. The simulated salt load was under by 40% compared to the observed salt load. At Waminda the simulated salt load was under by 60%.

5.3.15.3. Peel River Catchment

On days with EC data, the simulated mean salinity was over by 4% at Chaffey Dam and by about 18% at Piallamore (419015). At Paradise Weir (419024), the simulated flow was over by about 10% than observed. The simulated salinity and salt load were about the same as observed during days with EC data.

At Carrol Gap (419006), the simulated flow was about 17% more than observed and salinity 8% less than observed. The simulated salt load at Carrol Gap (419006) was only about 5% lower than the observed salt load.

5.4. SALINITY MODEL CALIBRATION

5.4.1. Methods (General)

The model calibration re-estimated the salt inflow relationships with the intention of matching the statistical characteristics of the observed data along the mainstream.

5.4.1.1. headwater catchments

Salt load inflows for headwater catchments were estimated using all available salinity data. Two methods were used to estimate these inflows:

(i) flow versus salt load relationship, using the IID form of the relationship;

(ii) flow versus concentration look-up tables (LUT), based on ordinates from exceedance curves

$$SL = e^{\eta} Q^{\lambda} \qquad (5.8)$$

The flow versus concentration LUT is based on the assumption that flow is inversely related to concentration (Equation 5.9). 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.

$$C \propto \frac{1}{Q} \qquad (5.9)$$

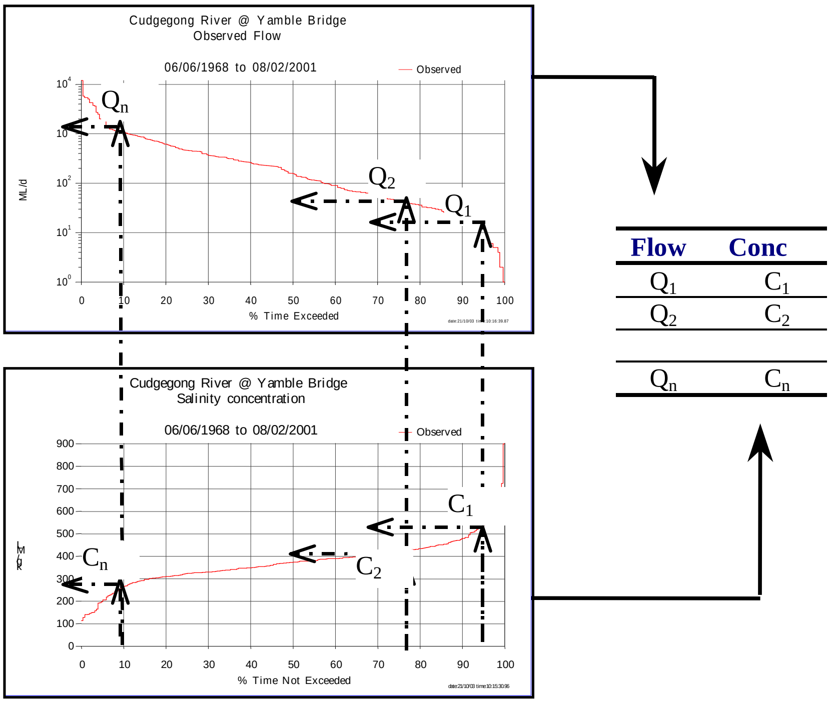


Figure 5.16. Derivation of flow versus concentration LUT from exceedance curves

5.4.1.2. Residual catchments

The salt inflows from residual catchments were calibrated using a procedure as illustrated in Figure 5.17. A target salt load at the calibration point was estimated using the power form of the salt load versus flow relationship (Equation 5.8). The model was run, and the salt loads that the residual catchments need to contribute were calculated from the difference between the results of this simulation and the target salt load calculated in Step 1. Using these results and the flow at the residual catchments, an intial estimate of the flow-concentration LUT is made. This LUT is revised methodically to match the 20th, 50th and 80th percentiles of the exceedance curve of salinities at the calibration point.

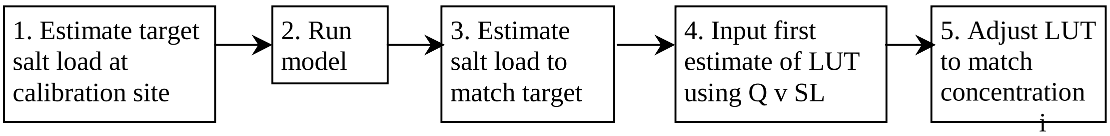


Figure 5.17. Procedure to calibrate salt inflows from residual catchments

5.4.2. Split Rock Dam

To derive the inflow salinity, observed EC data prior to the construction of Split Rock Dam (from 1976 to 1987) were used to produce an initial flow verses salinity table. This was revised to obtain the observed salinity downstream of the dam from January 1988. The time series observed and simulated salinity from the calibration is shown in Figure 5.45.

Table 5.39. Calibrated flow versus salinity relationship for Split Rock Dam inflows

Flow (ML/d)	Concentration (mg/L)
1	500
5	520
13	460
25	410
40	390
60	370
95	340
167	300
335	245
696	200
2929	150
1.00E+37	150

Table 5.40. Results of performance measures for simulated versus observed salinities in Split Rock Dam using calibrated relationship

Performance measure	Result
Pattern match	0.58
Mean match	0.04
Average error	0.13
Range match	0.93
R^2	0.17

5.4.3. Gauging Station 412022: Namoi River at Manilla Railway Bridge

The flow verses salinity relationships at inflows from Split Rock Dam to Manilla Railway Bridge were revised to match the salinity duration plot of observed salinity (Figure 5.18 and Table 5.45). The resulting flow verses salinity for the corresponding inflow points are listed in the following tables. The time series observed and simulated salinity is shown in Figure 5.46.

Table 5.41. Calibrated flow versus salinity relationship used for inflows in residual catchment R1

Flow (ML/d)	Concentration (mg/L)
1	400
35	400
120	300
556	200
2334	150
1.00E+37	150

The median inflow was 35 ML/d. There is a loss node downstream of Residual R1 inflow that loses flow less than 20 ML/d.

Namoi River at North Cuerindi (419005) has data from 1976 to 1990. It is the biggest inflow upstream of Keepit Dam. The resulting flow verses salinity tables at inflow points are listed in Table 5.42, Table 5.43 and Table 5.44.

Table 5.42. Calibrated flow versus salinity relationship used for inflows from Station 419005: Namoi River at North Cuerindi

Flow (ML/d)	Concentration (mg/L)
1	675
3	444
4	420
26	282
50	240
80	180
181	144
284	129
390	118
600	99
1,154	88
1,220	84
4,200	80
$1*10^{37}$	80

Table 5.43. Calibrated flow versus salinity relationship used for inflows 419029: Halls Creek at Ukolan

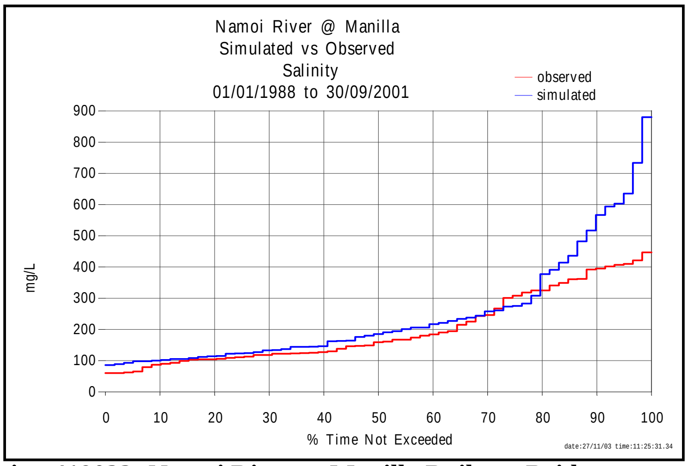
Flow (ML/d)	Concentration (mg/L)
1	614
2	553
3	526
4	486
18	450
25	384
39	318
53	300
107	245
363	170
833	164
952	135
$1*10^{37}$	135

Table 5.44. Calibrated flow versus salinity relationship used for inflows in residual catchment R2

Flow (ML/d)	Concentration (mg/L)
1	500
2	500
7	450
33	300
80	245
164	170
638	164
7,094	135
$1*10^{37}$	135

The median inflow for ungauged residual catchment R2 is 7 ML/d.

Figure 5.18. Non-exceedance curve for observed versus simulated salinity for calibrated model at Gauging



Station 419022: Namoi River at Manilla Railway Bridge

Table 5.45. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 419022: Namoi River at Manilla Railway Bridge

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*	353	69	215	447	154	0.34	9
	Simulated	500	172	273	880			14
Medium	*Observed*	178	73	90	349			38
	Simulated	192	43	124	275	38	0.67	45
High	*Observed*	99	29	60	167			257
	Simulated	108	13	86	133	21	0.39	356
All	*Observed*	199	114	60	447			93
	Simulated	246	178	86	880	63	0.75	127

5.4.4. Keepit Dam

The EC data for Namoi River d/s Keepit (419007) was used as a guide to salinity levels in Keepit Dam. The data was available from February 1970 with gaps from 1994 to 1997. The calibration period was from May 1975 to April 2000 (the benchmark period). There was a residual inflow (R3) between Manilla Railway Bridge and Keepit Dam that had to be calibrated (Table 5.46). The median inflow for ungauged residual catchment R3 was 20 ML/d. The time series observed and simulated salinity is shown in Figure 5.47. The results of the calibration are presented in Table 5.47.

Table 5.46. Calibrated flow versus salinity relationship for inflows in residual catchment R3

Flow (ML/d)	Concentration (mg/L)
1	900
2	900
4	800
6	600
10	500
96	400
2,000	250
$1*10^{37}$	250

The salinity inflows to Keepit Dam were estimated in three steps.

Step 1 for pre Split Rock Dam conditions - A system file was set up from Split Rock Dam to Keepit Dam without Split Rock Dam and run from July 1974 to December 1988. Inflows to Split Rock Dam were observed inflows. Inflow salinity was derived from the flow salinity table using observed flow and salinity at 419043. Gauged inflows and residuals were calibrated using observed salinity at Manilla Railway Bridge (419022). At Keepit Dam, the simulated storage was not exactly equal to observed storage because the simulated inflow was not exactly equal to observed inflow and the simulated salinity was not equal to observed salinity at Keepit Dam. Residual R3 was calibrated to match the observed salinity at Keepit Dam.

Step 2 Post Split Rock Dam - A system file was set up from Split Rock Dam to Keepit Dam with Split Rock Dam included and run from January 1988 to December 2000. To match the observed Split Rock Dam storage volume and flows d/s Split Rock Dam, back calculated inflows were used. The simulated inflow salinity to Split Rock Dam was revised to match the observed simulated salinity downstream at stream gauging station 419043. The simulated salinity at Keepit Dam was compared with observed to validate the derived flow versus salinity table estimated for residual inflow R3.

Step 3 Combining Pre and Post Split Rock Dam - The simulated salinity upstream Keepit Dam (pre-Split Rock Dam) was merged with simulated salinity upstream Keepit Dam (post Split Rock Dam). The observed Keepit Dam inflows and merged simulated Keepit Dam inflow salinity was run from July 1974 to December 2000 and the simulated salinity downstream of the dam was compared with observed salinity at gauging station 419043. If they were not similar, an iterative process was used back through Step 1 to revise the flow salinity relationship at residual R3.

Table 5.47. Results of performance measures for simulated versus observed salinities in Keepit Dam using calibrated relationship

Performance measure	Result
Pattern match	0.34
Mean match	0.04
Average error	0.12
Range match	0.02
R^2	0.76

5.4.5. Gauging Station 419007: Namoi River at Keepit

Observed EC data downstream of Keepit Dam (Figure 5.28) was generally available throughout the benchmark period (1975 to 2000). Some data was missing during the dry period in 1994-95. The simulated salinity shown in Figure 5.39, using the salinity audit relationships was lower than that in the observed salinity. The salinity inflows from tributaries upstream of Keepit Dam were revised to try and match the observed salinity behaviour at Keepit Dam shown in Figure 5.47. The resulting good salinity distribution achieved at the end of the calibration is shown in Figure 5.19 and Table 5.48.

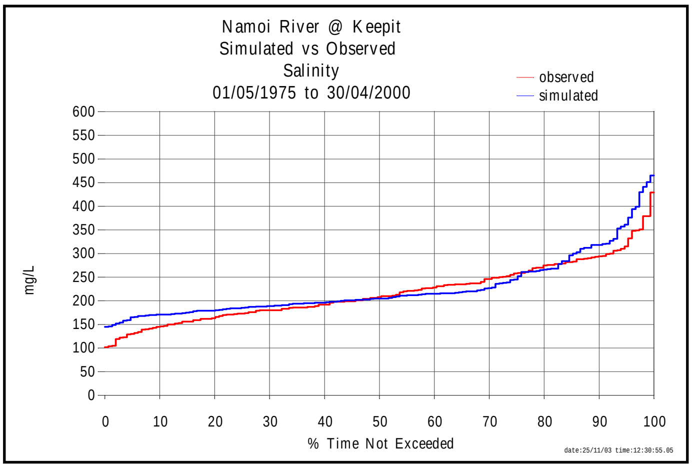


Figure 5.19. Non-exceedance curve for observed versus simulated salinity for calibrated model at Gauging Station 419007: Namoi River at Keepit

Table 5.48. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 419007: Namoi River at Keepit

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*	241	39	176	299	24	0.80	1
	Simulated	219	36	158	284			1
Medium	*Observed*	223	64	119	429	27	0.81	71
	Simulated	236	73	154	465			77
High	*Observed*	182	45	102	282	26	0.67	540
	Simulated	199	30	145	268			600
All	*Observed*	217	61	102	429	27	0.76	157
	Simulated	226	64	145	465			173

5.4.6. Gauging Station 419001: Namoi River at Gunnedah

Gauged inflows from Keepit Dam to Gunnedah include inflows from the Peel River and the Mooki River. The Peel River contributes the largest tributary inflow to the Namoi River. The calibrated flow salinity relationships are shown in the following tables. The simulated salinity at Gunnedah is higher than observed and this mostly results from the simulated low flow being lower than observed.

Observed EC data for the Namoi River at Gunnedah (419001) was available throughout the benchmark period and included high salinity readings during the dry periods. The simulated salinity using audit inflow relationships (Figure 5.40) and that using the calibrated relationships (Figure 5.20) both show similar behaviour up to the 80% non exceedance compared to the observed salinity. Table 5.49, Table 5.50 and Table 5.51 show the calibrated tributary salinity relationships.

Table 5.49. Calculated flow versus salinity relationship for inflows from Station 419006: Peel River at Carrol Gap

Flow (ML/d)	Concentration (mg/L)
1	870
12	870
20	640
48	600
65	550
139	500
218	430
484	300
876	260
1479	220
2485	120
1.00E+37	120

Table 5.50. Calculated flow versus salinity relationship for inflows from Station 419027: Mooki River at Breeza

Flow (ML/d)	Concentration (mg/L)
1	1092
2	895
5	789
7	684
9	612
16	582
21	546
48	470
120	384
358	298
1260	259
6764	204
1.00E+37	204

Table 5.51. Calculated flow versus salinity relationship for inflows in residual catchment R4

Flow (ML/d)	Concentration (mg/L)
1	600
27	600
105	400
432	300
16701	200
1.00E+37	200

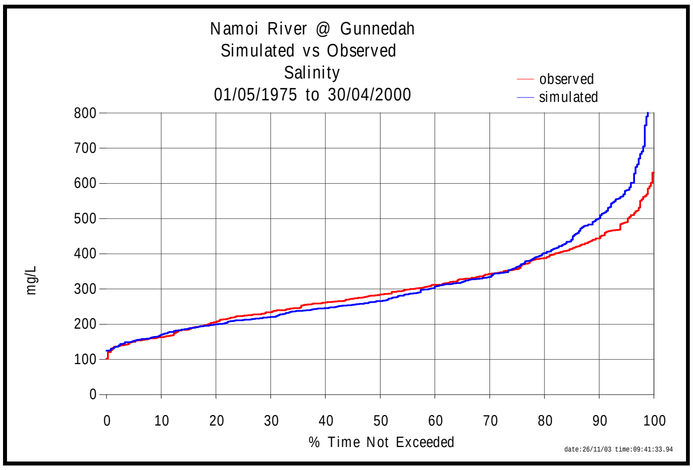


Figure 5.20. Non-exceedance curve for observed versus simulated salinity for calibrated model at Gauging Station 419001: Namoi River at Gunnedah

Table 5.52. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 419001: Namoi River at Gunnedah

Flow range	Data set	Distributions Salinity (mg/L) Mean	S.D	Min	Max	C_o versus C_s Mean error (mg/L)	R^2	Mean load (t/d)
Low	*Observed*	411	91	186	592	144	0.01	29
	Simulated	536	127	290	900			34
Medium	*Observed*	295	85	102	631	49	0.37	215
	Simulated	304	70	172	533			228
High	*Observed*	198	52	121	372	31	0.48	1141
	Simulated	204	28	153	280			1251
All	*Observed*	298	105	102	631	64	0.48	369
	Simulated	330	136	153	900			401

5.4.7. Gauging Station 419012: Namoi River at Boggabri

Observed EC data for Namoi River at Boggabri (419012), shown in Figure 5.30, are available only up to 1991. Gauged inflow between Gunnedah and Boggabri included Coxs Creek. The salinity verses flow relationship for Coxs Creek was derived from observed data. The residual ungauged catchment

(R5) flow-salinity relationship was then derived to match the salinity distribution at Boggabri (Table 5.66 and Figure 5.21). The calibrated model produced salt loads closer to the observed data than the model using audit inflows.

Table 5.53. Calculated flow versus salinity relationship for inflows from Station 419032: Coxs Creek at Boggabri

Flow (ML/d)	Concentration (mg/L)
1	834
2	702
3	606
7	551
15	458
21	339
35	279
136	201
399	163
1221	121
2885	102
11860	82
1.00E+37	82

Table 5.54. Calculated flow versus salinity relationship for inflows in residual catchment R5

Flow (ML/d)	Concentration (mg/L)
1	834
3	650
7	600
21	450
35	300
399	200
11860	100
1.00E+37	100

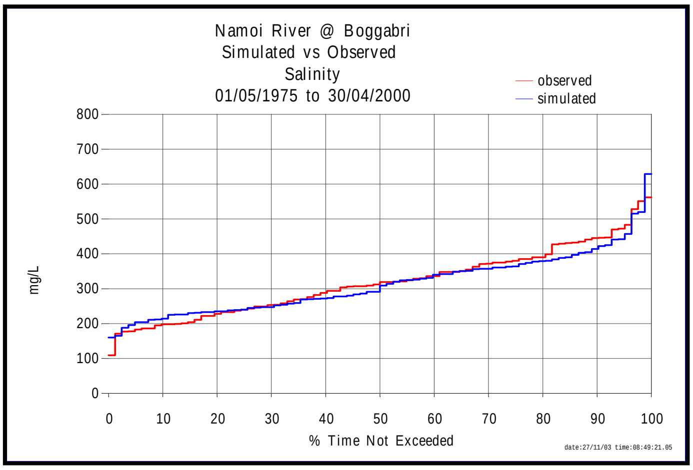


Figure 5.21. Non-exceedance curve for observed versus simulated salinity for calibrated model at Gauging Station 419012: Namoi River at Boggabri

Table 5.55. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 419012: Namoi River at Boggabri

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*	381	43	309	435	83	0.07	45
	Simulated	442	93	350	629			38
Medium	*Observed*	334	94	186	562	53	0.41	204
	Simulated	323	63	196	457			195
High	*Observed*	232	84	171	470	40	0.21	895
	Simulated	209	32	160	272			744
All	*Observed*	324	96	171	562	55	0.42	295
	Simulated	320	90	160	629			263

5.4.8. Gauging Station 419039: Namoi River at Mollee

Gauged inflow from Boggabri to Mollee includes Maules Creek (419051). The residual inflows include residual inflow to Narrabri (R6) and residual inflow from Narrabri to Mollee (R7). There was no EC data for Namoi River at Narrabri. EC data for Maules Ck was available from 1976 to 1991 and was used to estimate the flow verses salinity relationship for this creek. The calibrated salinity behaviour matches that of the observed salinity very well and is shown in Figure 5.22 and Table 5.59.

Table 5.56. Calculated flow versus salinity relationship for inflows from Station 419051: Maules Creek at Avoca East

Flow (ML/d)	Concentration (mg/L)
2	325
5	233
8	225
11	222
14	216
16	210
21	204
28	193
40	180
89	168
263	153
1799	101
1.00E+37	101

Table 5.57. Calculated flow versus salinity relationship for inflows in residual catchment R6.

Flow (ML/d)	Concentration (mg/L)
1	400
12	400
27	300
73	200
5000	100
1.00E+37	100

Table 5.58. Calculated flow versus salinity relationship for inflows in residual catchment R7

Flow (ML/d)	Concentration (mg/L)
2	300
43	200
2000	100
1.00E+37	100

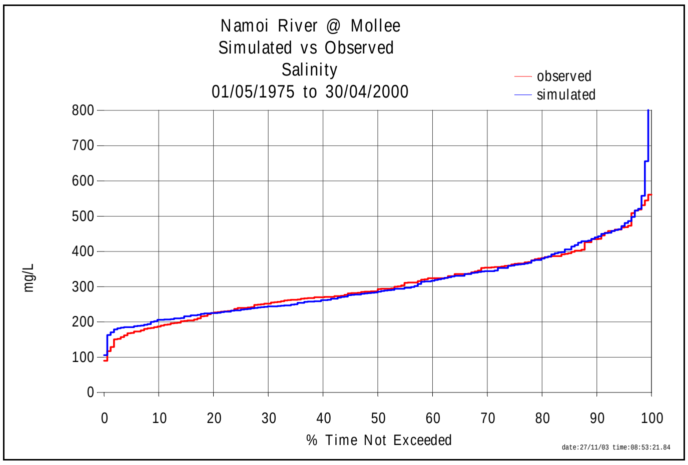


Figure 5.22. Non-exceedance curve for observed versus simulated salinity for calibrated model at Gauging Station 419039: Namoi River at Mollee

Table 5.59. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Gauging Station 419039: Namoi River at Mollee

Flow range	Data set	Distributions Salinity (mg/L)				C_o versus C_s		Mean load (t/d)
		Mean	*S.D*	*Min*	*Max*	*Mean error (mg/L)*	R^2	
Low	*Observed*	360	83	187	561	69	0.49	27
	Simulated	409	107	250	837			38
Medium	*Observed*	298	89	117	519	58	0.29	247
	Simulated	291	68	163	521			229
High	*Observed*	235	73	90	453	45	0.51	1267
	Simulated	202	29	106	244			1059
All	*Observed*	304	94	90	561	59	0.44	348
	Simulated	307	101	106	837			308

5.4.9. Gauging Station 419026: Namoi River at Goangra

Downstream of Mollee there no gauged inflows to derived flow verses salinity relationships for all residuals (R8 to R13). For the 20% exceedance flow and lower, a salinity of 200 mg/L was assumed and for the 1% exceedance flow and higher, a salinity of 100 mg/L was assumed. The salinity value was linearly interpolated between the 20% and 1% exceedance. Table 5.60 shows the residual flows with corresponding salinity. For example in Table 5.60 for residual R8, the 20% flow is 19 ML/d and flows less than this value were assigned a salinity of 200 mg/L. Also the 1% flow was 6000 ML/d and flows greater than this were assigned a salinity of 100 mg/L.

Table 5.60. Flows versus salinity for inflows in residual catchments R8 to R13

Node Number	Residual	Flow at which 200 mg/L salinity occurs (ML/d)	Flow at which 100 mg/L salinity occurs (ML/d)
96	R8	19	6000
113	R9	7	1000
110	R10 & R11	45	5000
124	R12	58	5000
125	Baradine Ck	73	5000
131	R13	14	5000

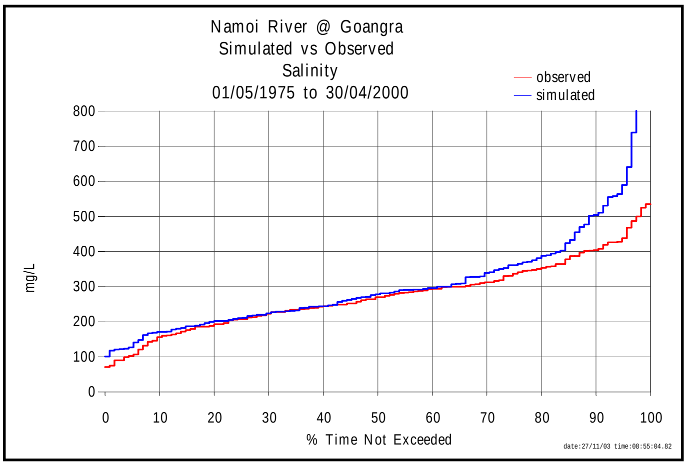


Figure 5.23. Non-exceedance curve for observed versus simulated salinity for calibrated model at Gauging Station 419026: Namoi River at Goangra

The simulated high salinity is due to routing in links with storage volumes affected by evaporation, rainfall and surface area. There is also a difference in the observed and simulated flow especially at low flow range as shown in Figure 5.11.

Table 5.61. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Gauging Station 419026: Namoi River at Goangra

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*	319	116	146	525	109	0.18	5
	Simulated	377	156	189	739			65
Medium	*Observed*	279	90	90	535	109	0.04	69
	Simulated	333	151	141	900			155
High	*Observed*	220	95	71	468	62	0.50	1281
	Simulated	172	38	101	232			1094
All	*Observed*	273	98	71	535	100	0.13	292
	Simulated	309	153	101	900			322

5.4.10. Gauging Station 419049: Pian Creek at Waminda

There were no gauged tributaries for this system and the following salinities were assumed the Pian Creek residual, R16 & 17. The 20% exceedance flow of 14 ML/d was assigned a salinity of 300 mg/L and for a flow of 1000 ML/d and higher, a salinity of 200 mg/L was assumed.

The 80% exceedance flow was the assumed threshold for low flows (zero). Pian Creek has zero flow for about 25% of the calibration period. Hence, there are no comparisons at low flows. The salinity on days with zero flow were not considered, hence no zero salinity.

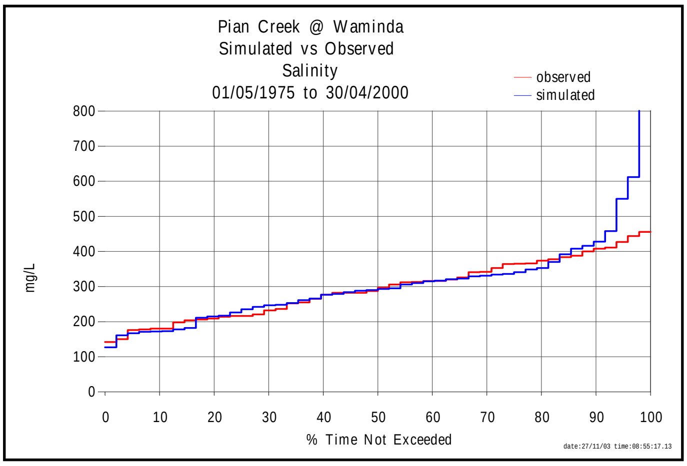


Figure 5.24. Non-exceedance curve for observed versus simulated salinity for calibrated model at Gauging Station 419049: Pian Creek at Waminda

Table 5.62. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 419049: Pian Creek at Waminda

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*	0	0	0	0	n/a	n/a	n/a
	Simulated	0	0	0	0			n/a
Medium	*Observed*	331	76	206	456	89	0.16	12
	Simulated	346	136	178	836			19
High	*Observed*	239	62	142	353	50	0.31	102
	Simulated	250	80	127	416			90
All	*Observed*	293	83	142	456	73	0.30	50
	Simulated	306	125	127	836			49

5.4.11. Gauging Station 419006: Peel River at Carrol Gap

From Chaffey to Paradise Weir, the Cockburn River (419016) is the only tributary inflow with EC data. The EC data are available only up to March 1990 with only 46 points within the calibration period from July 1979 to June 2000. The audit IIC linear relationships were maintained at all inflows upstream of Paradise Weir (419024) because they produced similar salinity distribution as that observed at Paradise Weir.

Below Paradise Weir there is gauged tributary inflow from Goonoo Goonoo Creek. The audit IID salinity relationship was initially used for Goonoo Goonoo Creek (419035), however, it revised to match the observed salinity. The residual R8 flow verses salinity relationship was initially taken from Goonoo Creek (419035) and revised to match the observed salinity at Carrol Gap.

The observed EC data at Peel River at Carrol Gap (419006) and shown in Figure 5.36 was available from 1979. The simulated salinity using audit inflow relationships (Figure 5.44), and simulated salinity using the calibrated relationships in (Figure 5.53) showed different behaviour compared with the observed salinity especially from 1994-95 which is a dry period. At Paradise Weir (Figure 5.52) the simulated salinity was about 300 mg/L, which is similar to observed. During that period, the observed salinity in Carrol Gap was about 700 mg/L that is higher than observed. Overall, the calibrated run produced lower salt loads than that in the audit as shown in Table 5.66.

Table 5.63. Calculated flow versus salinity relationship for inflows from Station 419035: Goonoo Goonoo Creek at Timbumburi

Flow (ML/d)	Concentration (mg/L)
1	906
3	750
6	700
8	670
12	650
21	600
26	550
41	456
81	393
303	348
6407	122
$1*10^{37}$	122

Table 5.64. Calculated flow versus salinity relationship for inflows in residual catchment R8

Flow (ML/d)	Concentration (mg/L)
1	800
108	800
291	500
633	300
3,645	122
$1*10^{37}$	122

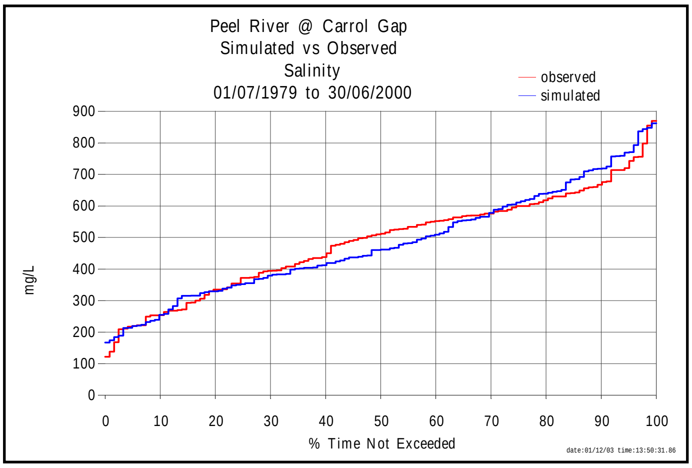


Figure 5.25. Non-exceedance curve for observed versus simulated salinity for calibrated model at Gauging Station 419006: Peel River at Carrol Gap

Table 5.65. Calculated Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Gauging Station 419006: Peel River at Carrol Gap

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*	638	130	294	870	223	0.07	13
	Simulated	497	142	324	793			21
Medium	*Observed*	488	108	253	678	111	0.31	65
	Simulated	530	163	174	862			75
High	*Observed*	262	78	122	408	59	0.37	291
	Simulated	288	88	167	427			330
All	*Observed*	485	162	122	870	129	0.24	92
	Simulated	480	172	167	862			106

5.5. VALIDATION OF MODEL

5.5.1. Continuous salinity records

The results for the calibration were further assessed by comparing the simulations with continuous data reported in Table 3.3. The full time series of simulated versus observed concentrations are shown at Figure 5.54 and Figure 5.55 for the evaluation sites where data was available. A full statistical assessment is not possible at this stage, because:

- methods have not been developed yet;
- the continuous data record is short, and is not representative of the benchmark climate period; and
- there are discrepancies between discrete and continuous data.

Nevertheless, the data is useful to assess that the model is modelling the salinity behaviour correctly.

The results generally show the simulated salinity matching the observed salinity at Gunnedah well for both timing and magnitude. However, the observed salinity at Goangra (end of the system) is not matched very well by the simulated results. These type of results are also seen when comparing observed discrete data with the model results. Some of the models failure to reproduce salinity levels can be attributed to the models failure to match the flow volumes.

5.5.2. Comparison of calibrated salt loads with Salinity Audit salt loads

Table 5.66 shows the average annual salt loads using the salinity audit relationship, the modified relationships (see Appendix B) and the results from the calibrated model.

5.5.3. Peel River System

The audit salt inflows using audit relationships were maintained upstream of the Peel River at Paradise Weir. The simulated mean salinity and mean salt loads are similar to observed salinity. Downstream of Paradise Weir, the Goonoo Goonoo Creek salinity inflow was revised to match observed salinity. The residual flow verses salinity table was calibrated to match the observed salinity and salt loads at Carrol Gap. This resulted in an increase in the residual salt load by 50% (13,200 to 19,400 t/year). The model also includes a groundwater salt inflow contribution that is not included in the table (5,300 t/year). The average annual salt loads at Carrol Gap increased by 10% but still lower than the audit by 20%. A mass balance check from Paradise Weir indicates that the simulated salt load at Carrol Gap appears about right. In comparison to that in the audit, there seems to be unaccounted salt inflow to get the reported salt load of 79,700 t/year.

5.5.4. Namoi River System

At the Namoi River at Keepit, the calibrated annual salt load is lower by 16% than that in the audit. The calibrated salt inflow from Peel River is lower by 30% than that in the audit. The residual was calibrated to match the salinity and salt load at Gunnedah. The calibrated salt load at Boggabri is lower by 10% than that in the audit. Because the audit did not present any results downstream of Boggabri this section does not include any comment on salt loads below Boggabri.

Table 5.66. Comparison of average annual salt loads with Salinity Audit, and Audit as modified

Audit inflow / balance point		Mean salt load ('000 t/year)		
Number	**Name**	*Audit*	*Audit edited*	*Calibrated*
Peel System model				
419045	Peel River at Chaffey Dam	*9.7*	9.9	9.9
R6	Ungauged catchment into Peel River from Chaffey Dam to Piallamore	*13.2*	11.0	11.0
419016	Cockburn River at Mulla Crossing	*13.7*	11.4	11.4
R7	Ungauged catchment into Peel River from Piallamore to Paradise Weir	*2.0*	1.1	1.1
419024	Peel River at Paradise Weir	*37.9*	30.6	30.6
419035	Goonoo Goonoo Creek at Timbumburi	*9.1*	9.5	9.0
R8	Ungauged catchment into Peel River from Paradise Weir to Carrol Gap	*12.0*	13.2	19.4
419006	Peel River at Carrol Gap	*79.7*	57.4	63.0
Namoi System model				
419043	Manilla River at Tarpoly (Split R dam)	*19.7*	24.7	15.6
R1	Ungauged catchment into Manilla River from Split R dam to Brabri	*3.2*	3.7	8.0
R2	Ungauged catchment into Manilla RiveratBrabri to Namoi RatManilla Bridge		3.5	3.4
419029	Halls Creek at Ukolan	*6.3*	4.8	5.0
419005	Namoi River at North Cuerindi	*25.7*	25.9	23.1
R3	Ungauged catchment into Namoi R at Manilla Bridge to Keepit Dam	*4.1*	2.2	10.6
419007	Namoi River at Keepit	*66.4*	53.6	57.0
419006	Peel River at Carrol Gap	*79.7*	73.3	53.2
419027	Mooki River at Breeza	*33.8*	40.5	32.2
R4	Ungauged catchment into Namoi R at Keepit Dam to Gunnedah	*8.3*	13.7	54.3
419001	Namoi River at Gunnedah	*161.5*	148.1	160.8
R5	Ungauged catchment into Namoi R at Gunnedah to Boggabri	*3.0*	9.4	13.0
419032	Coxs Creek at Boggabri	*9.8*	9.4	9.6
419012	Namoi River at Boggabri	*178.6*	146.1	160.2
419051	Maules Creek at Avoca East	*3.1*	3.1	3.4

5.6. MODEL SUITABILITY FOR PURPOSE

The salt transport models have two key purposes under the BSMS. The first is that it can produce a time series of flows, salinities, and salt loads for the Baseline Condition and the Benchmark Climate period. The second is that it can estimate the in-stream flow and salinity effects of land based salinity management actions. Management actions could include landuse change, crop management, as well as the in-stream flow and salinity effects of changes to water sharing and utilisation, such as that of the Water Sharing Plans.

5.6.1. Baseline

The Namoi IQQM is a robust and reliable water balance model of the Namoi River. 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 ungauged 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 the ungauged catchments, modelling of the salinity through the major dams in the system. These issues were not a limitation for the previous water sharing work, but may effect reliability of results for the salt balance at this site.

The result of the comparison for salinity and salt loads from the tables in Section 5.4 are summarised in Table 5.67. 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.

The mean concentrations at the evaluation points, in each flow range, were matched within ±10% for only one of the sites (Keepit Dam). However at five of the eight evaluation sites the overall match was within ±10% (Keepit Dam, Boggabri, Mollee, Waminda and Carol Gap). The remaining two sites match by ±20% (Gunnedah and Goangra). The worst results (for all sites) were seen when matching concentrations in the low flow range.

The match of simulated salt loads to observed data was within ±10% for two sites (Gunnedah and Waminda). The matches at Keepit Dam, Gunnedah, Boggabri and was within ±10% for the medium flow ranges. Generally, all the evaluation points had poor matches in the low flow range.

In summary, the model appears to simulate the salinity behaviour in the river system reasonably well. Over all the best that could be interpreted from these model results is that the model is able to simulate salt loads within the ±20% range and concentrations within the ±10% range. The model is better at simulating salinity concentrations and salt loads within the middle reaches of the river system (Gunnedah to Mollee) with the accuracy reducing further down the river.

Table 5.67. Summary of comparisons of simulated versus observed salt loads

Target Site		**concentration match**				**salt load match**			
Number	Name	*Low*	*Medium*	*High*	*All*	*Low*	*Medium*	*High*	*All*
		Legend: 1 < ±10%;				**2 < ±20%;**		**3= > ±20%**	
419022	Manilla Railway Bridge	3	1	1	3	3	2	3	3
419007	Keepit Dam	1	1	1	1	1	1	2	2
419001	Gunnedah	3	1	1	2	2	1	1	1
419012	Boggabri	2	1	1	1	2	1	2	2
419039	Mollee	2	1	2	1	3	1	2	2
419026	Goangra	2	2	3	2	3	3	2	2
419049	Waminda	na	1	1	1	na	3	2	1
419006	Carol Gap	3	2	2	1	3	2	2	2

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 water sharing scenarios on salinity can be simulated with a reserved degree of confidence that must take into consideration the confidence limits of the model.

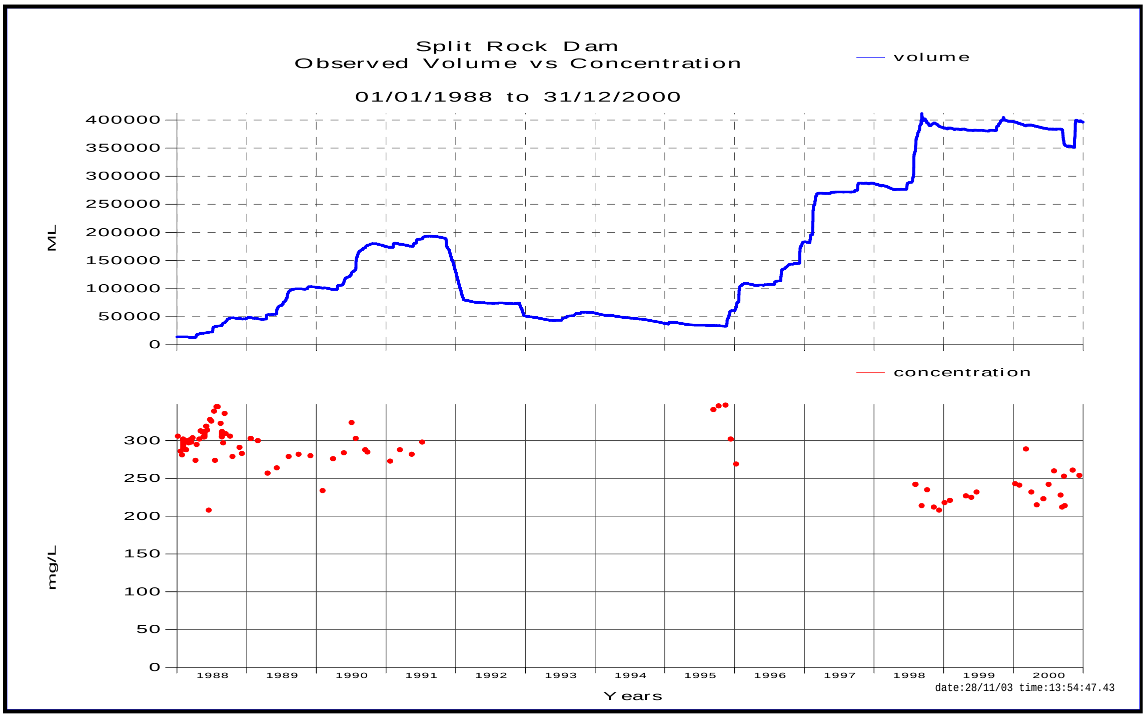


Figure 5.26. Split Rock Dam storage volume and concentration data

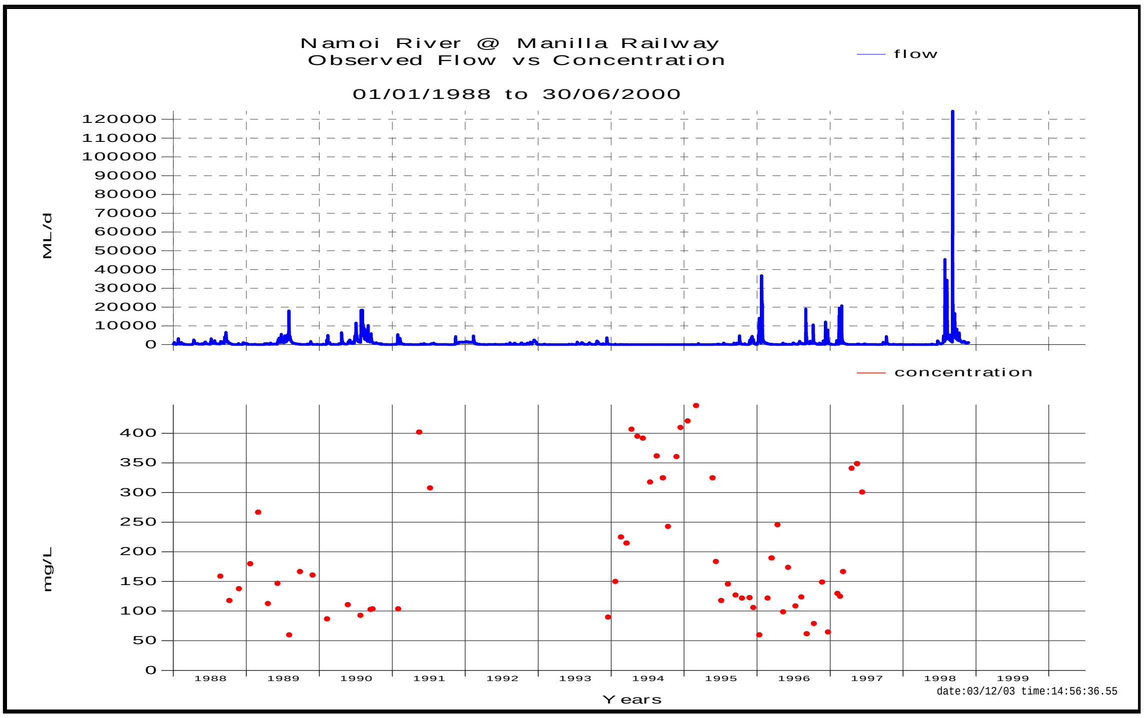


Figure 5.27. Gauging Station 419022: Namoi River at Manilla Railway Bridgeflow and concentration data

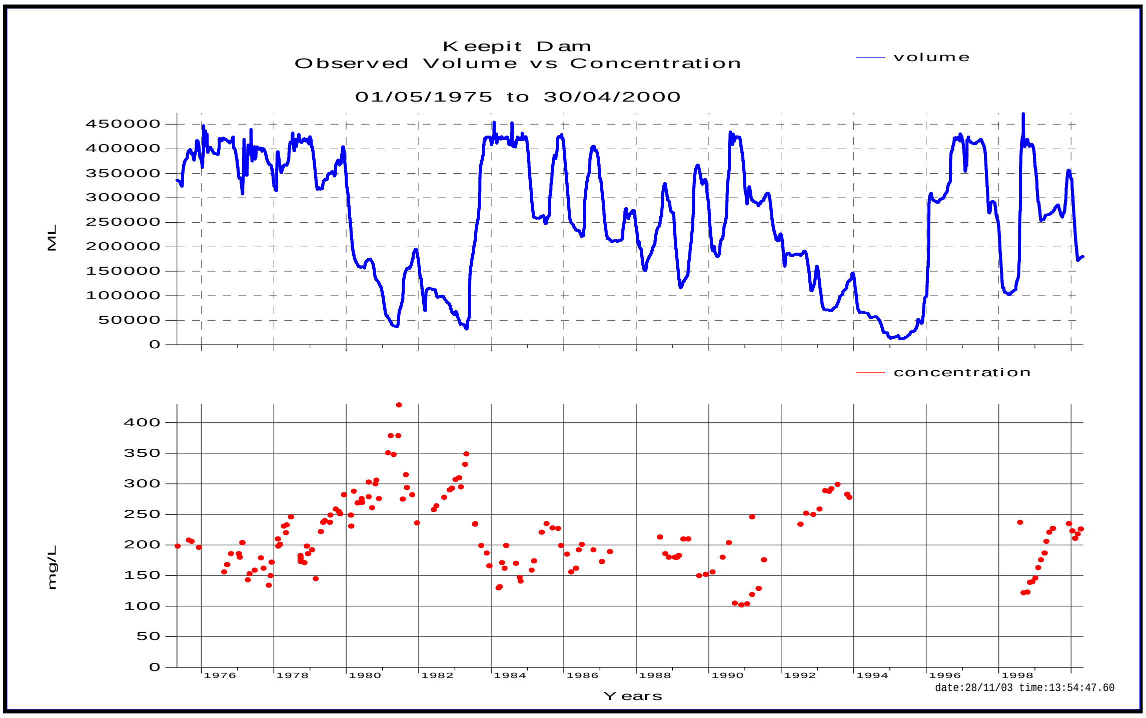


Figure 5.28. Keepit Dam storage volume and concentration data

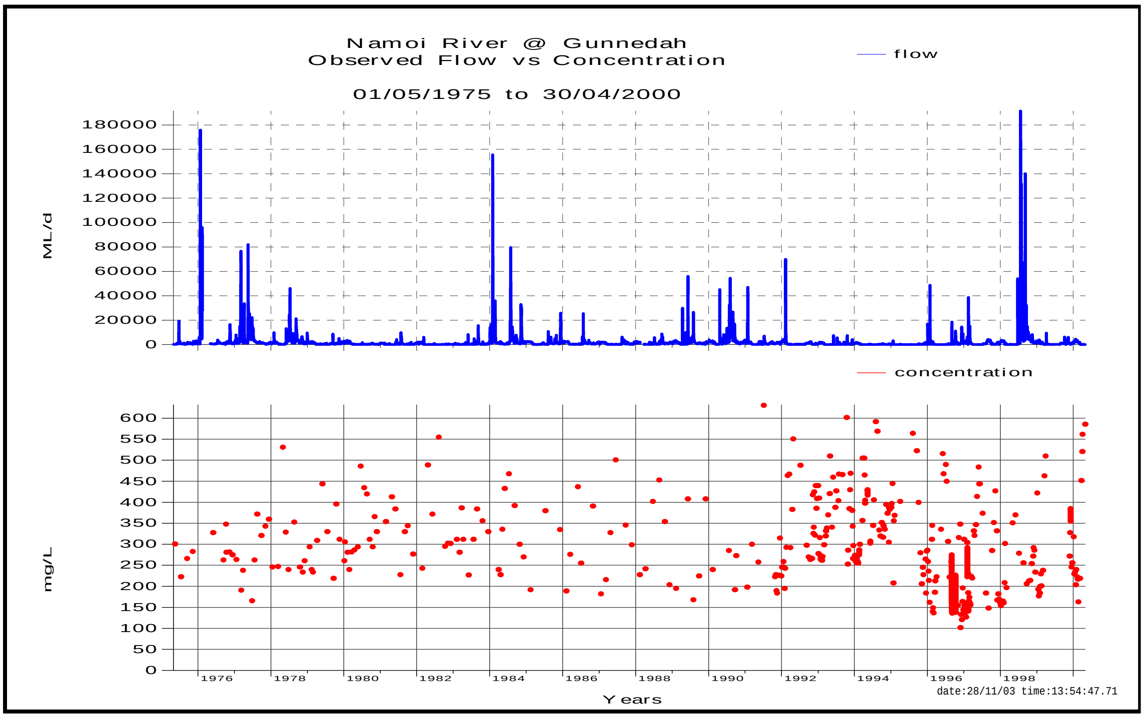


Figure 5.29. Gauging tation 419001: Namoi River at Gunnedah flow and concentration data

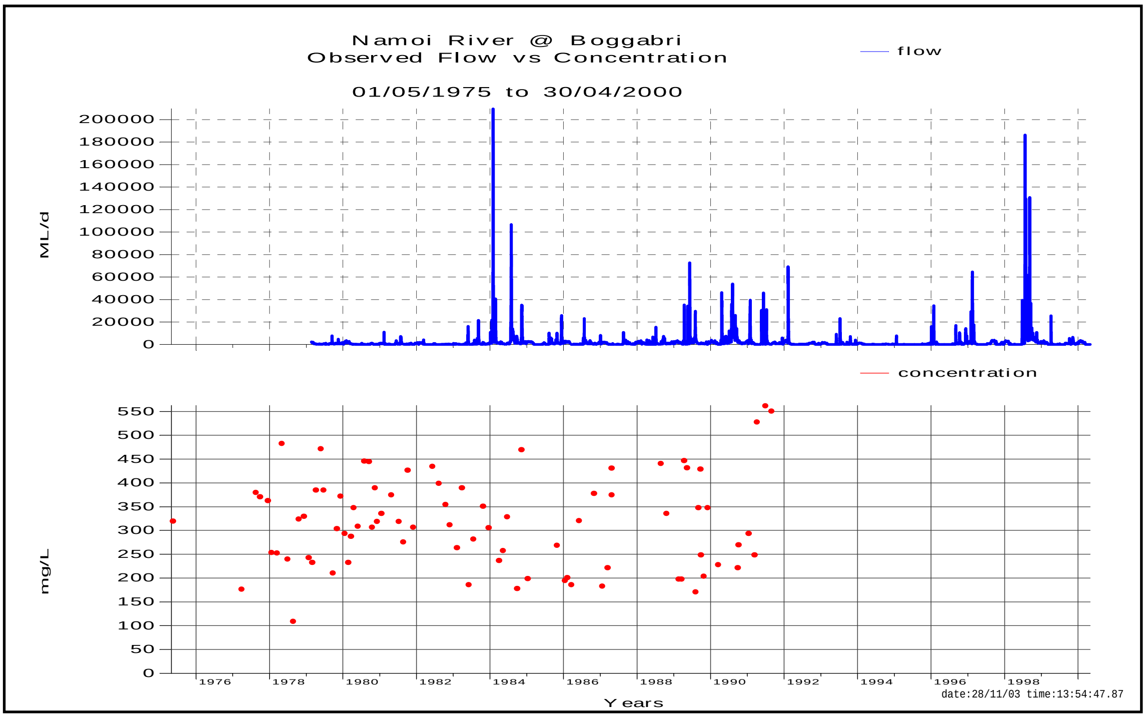


Figure 5.30. Gauging Station 419012: Namoi River at Boggabri flow and concentration data

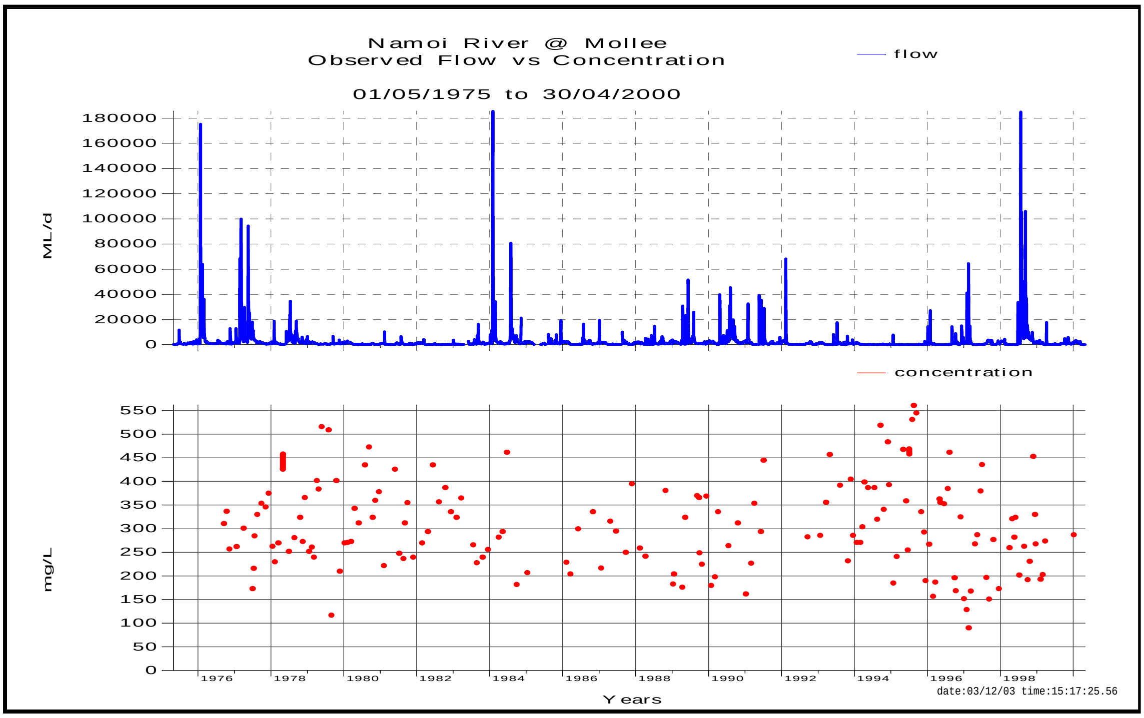


Figure 5.31. Gauging Station 419039: Namoi River at Mollee flow and concentration data

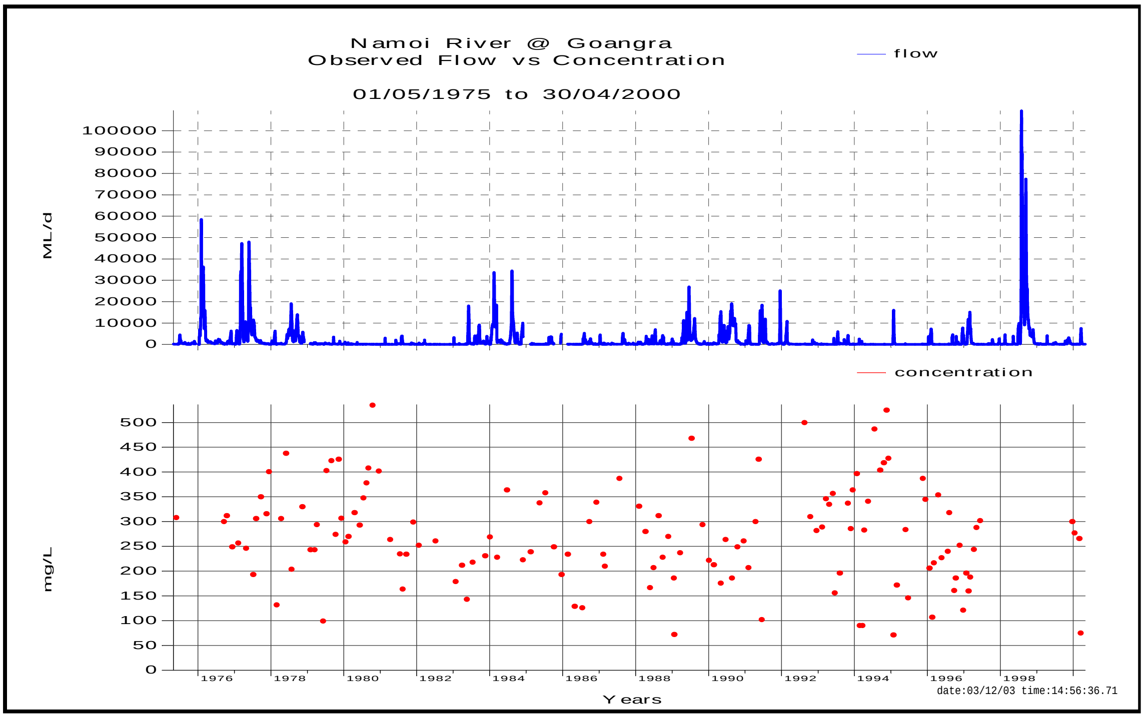


Figure 5.32. Gauging Station 419026: Namoi River at Goangra flow and concentration data

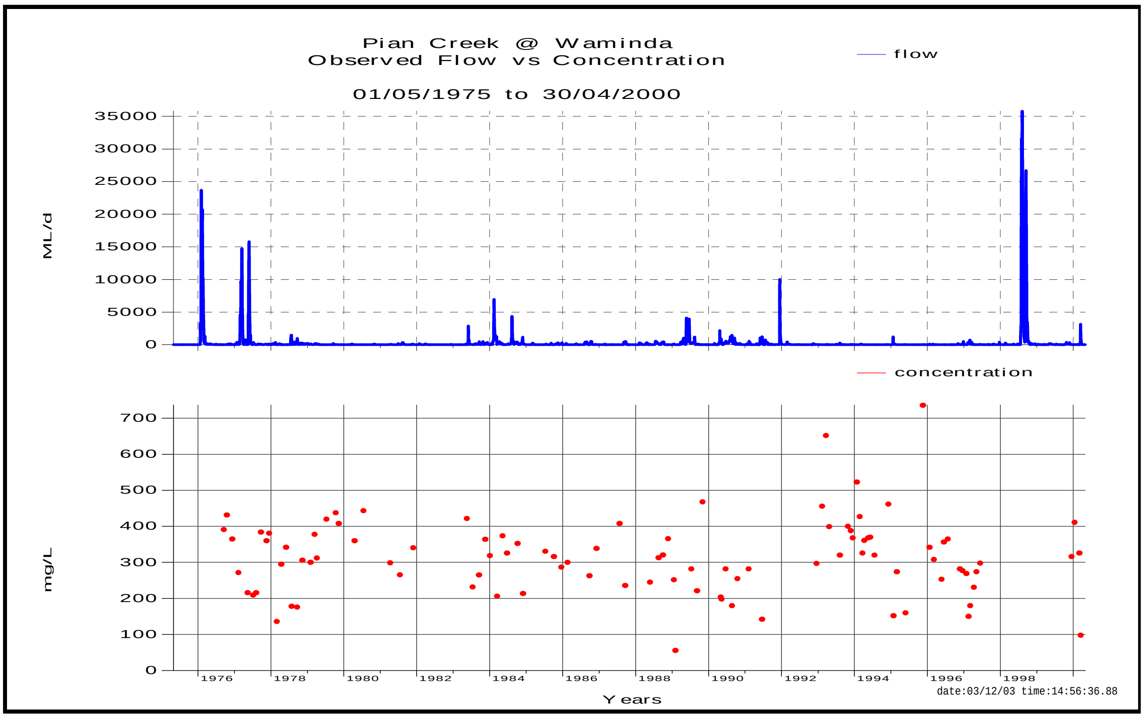


Figure 5.33. Gauging Station 419049: Pian Creek at Waminda flow and concentration data

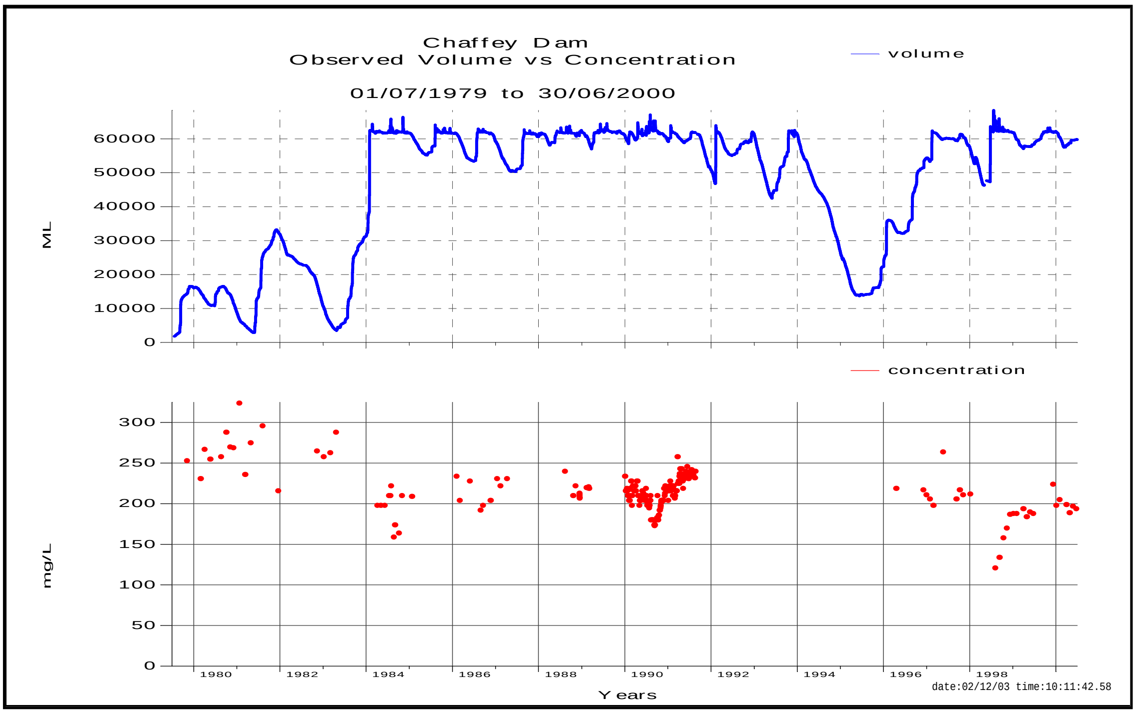


Figure 5.34. Chaffey Dam storage volume and concentration data

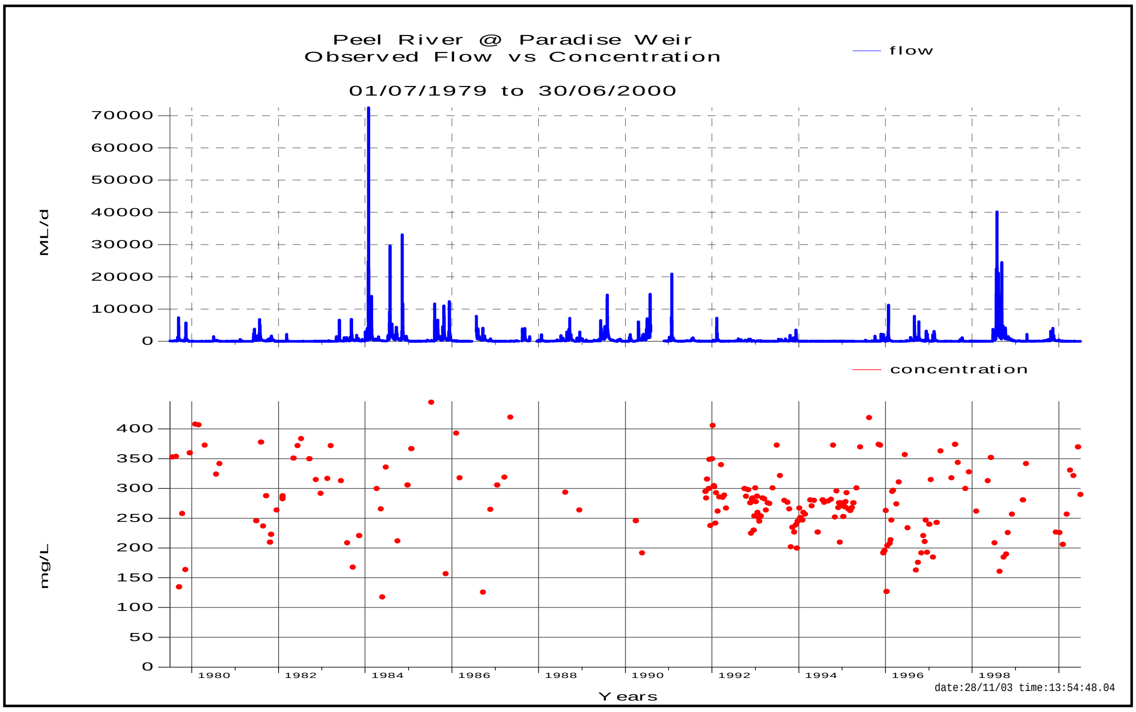


Figure 5.35. Gauging Station 419024: Peel River at Paradise Weir, flow and concentration data

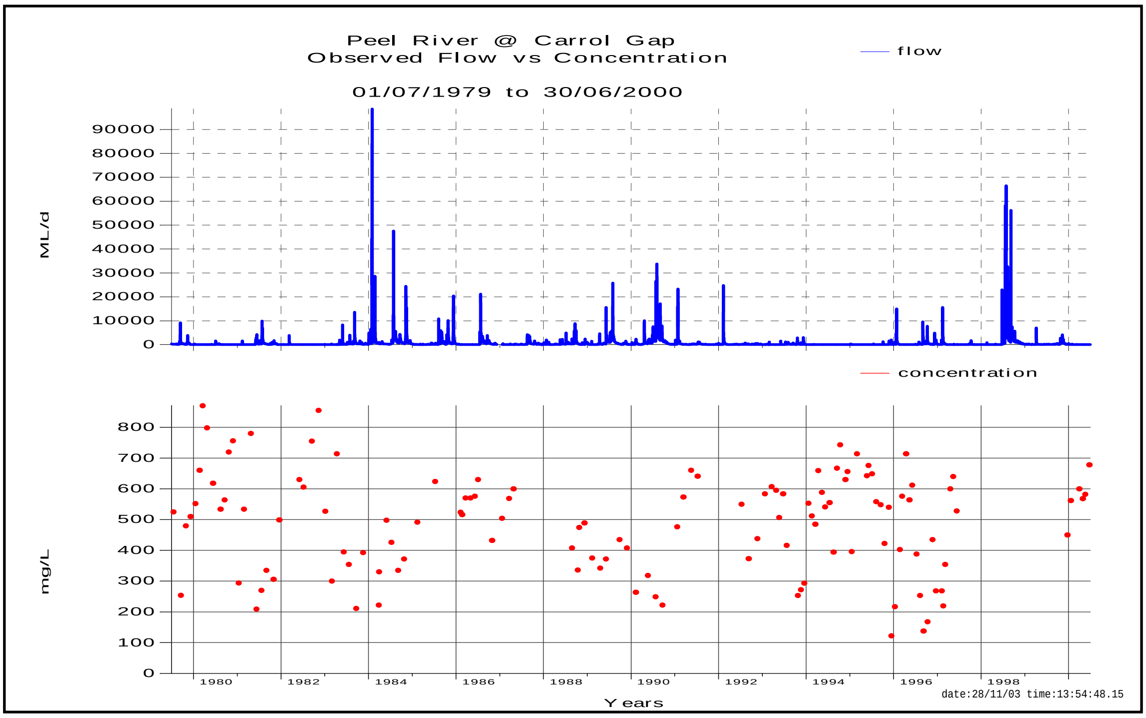


Figure 5.36. Gauging Station 419006: Peel River at Carrol Gap, flow and concentration data

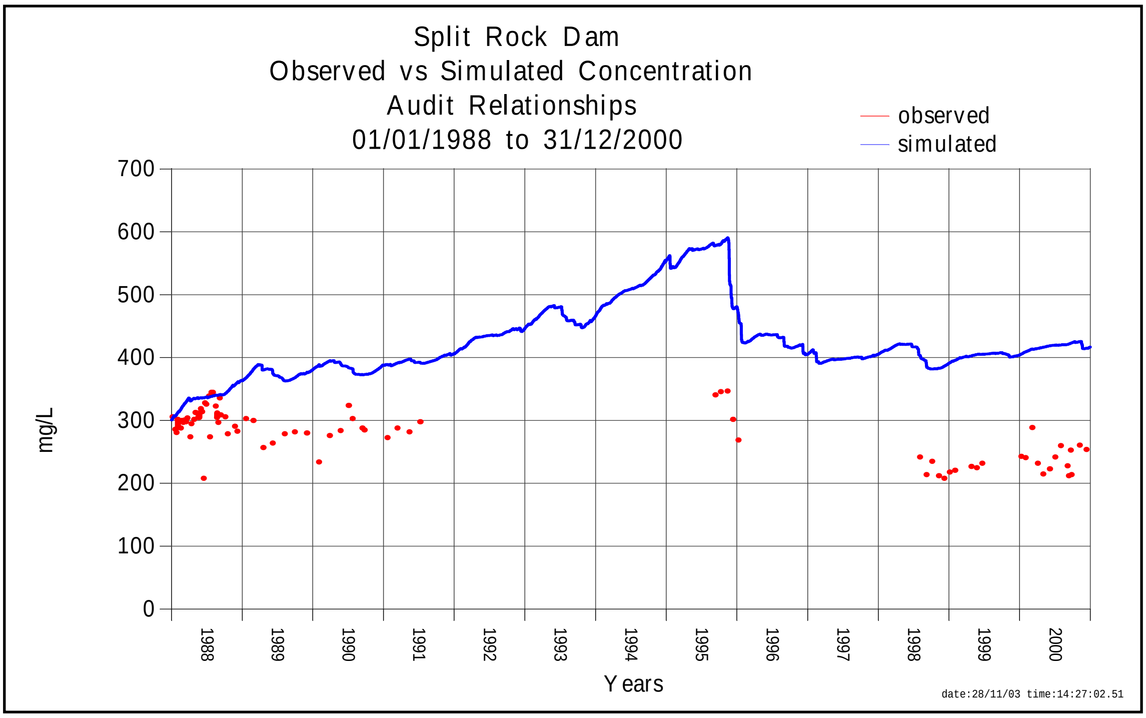


Figure 5.37. Simulated versus observed concentration at Split Rock Dam, using Salinity Audit relationships.

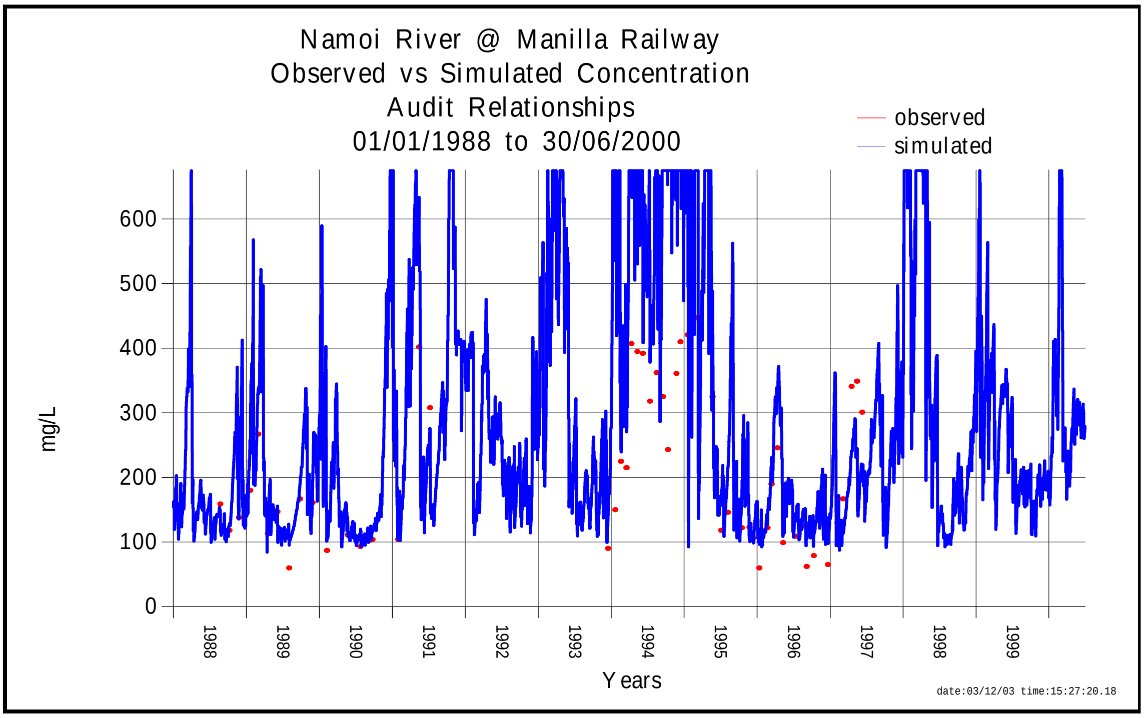


Figure 5.38. Simulated versus observed salinities at Gauging Station 419022: Namoi River at Manilla Railway Bridge, using Salinity Audit relationships.

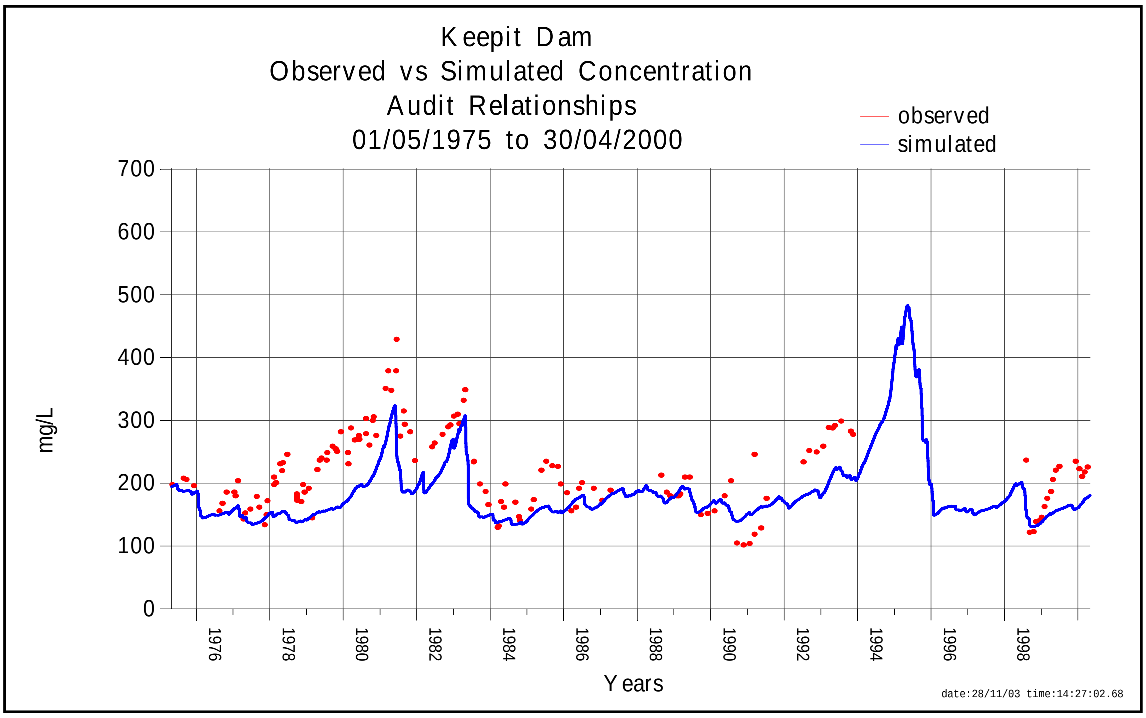


Figure 5.39. Simulated versus observed concentration at Keepit Dam, using Salinity Audit relationships.

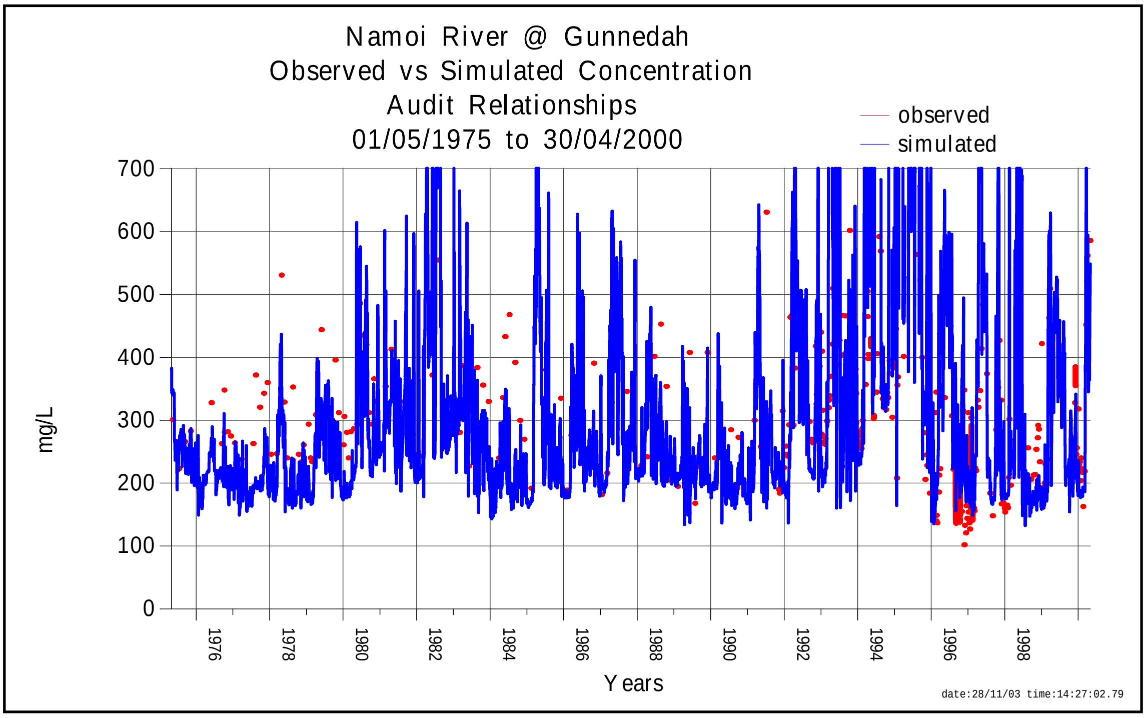


Figure 5.40. Simulated versus observed salinities at Gauging Station 419001: Namoi River at Gunnedah, using Salinity Audit relationships.

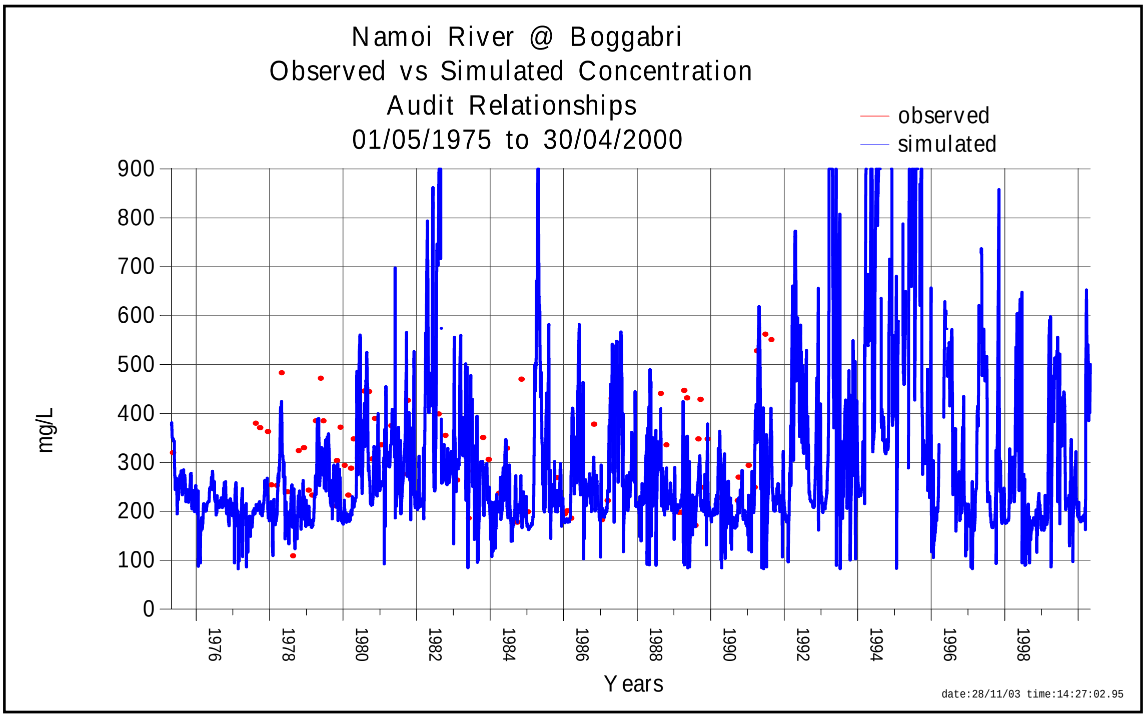


Figure 5.41. Simulated versus observed salinities at Gauging Station 419012: Namoi River at Boggabri, using Salinity Audit relationships.

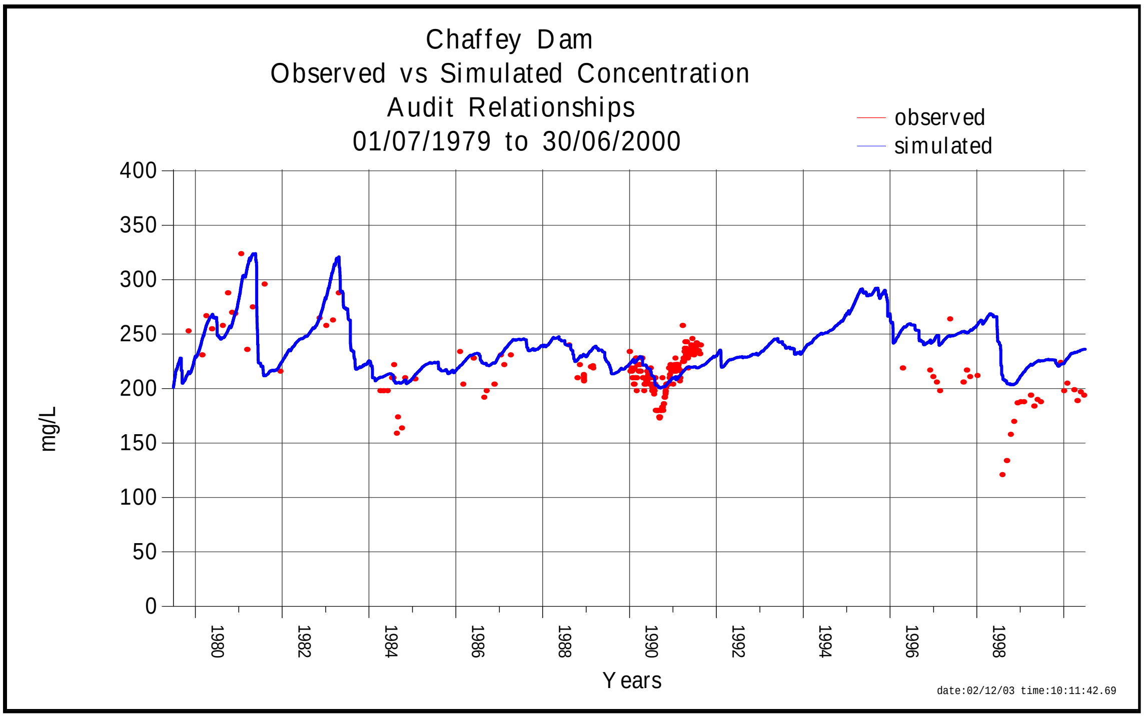


Figure 5.42. Simulated versus observed salinities at Chaffey Dam, using Salinity Audit relationships.

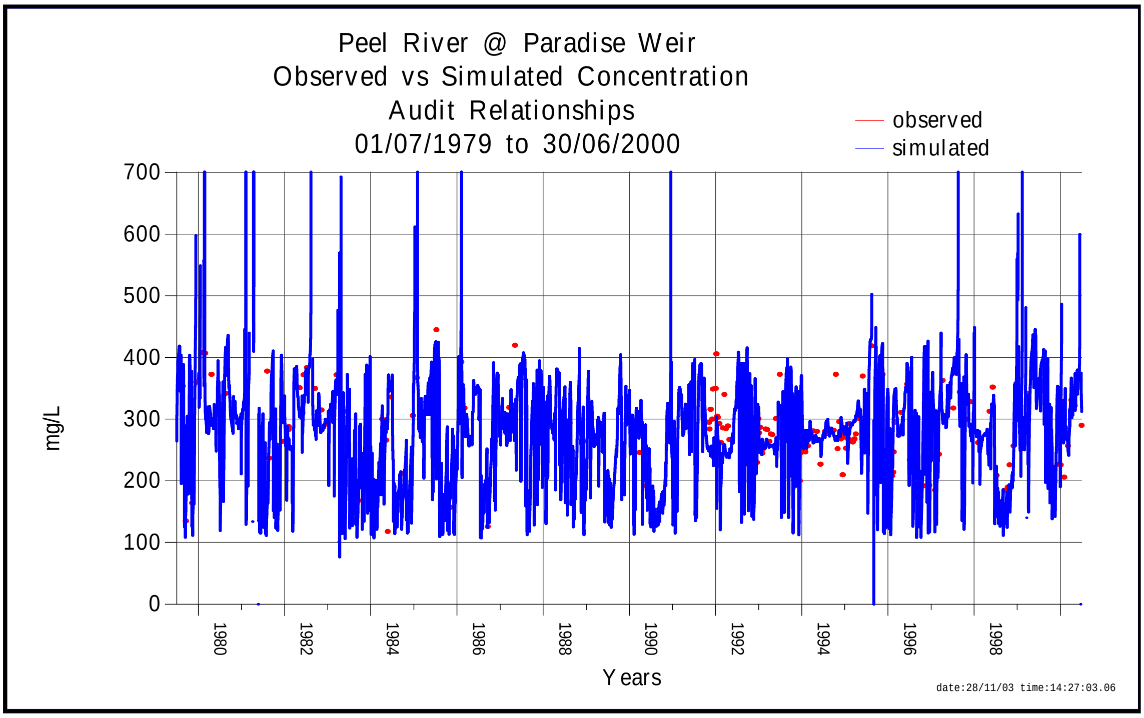


Figure 5.43. Simulated versus observed salinities at Gauging Station 419024: Peel River at Paradise Weir, using Salinity Audit relationships.

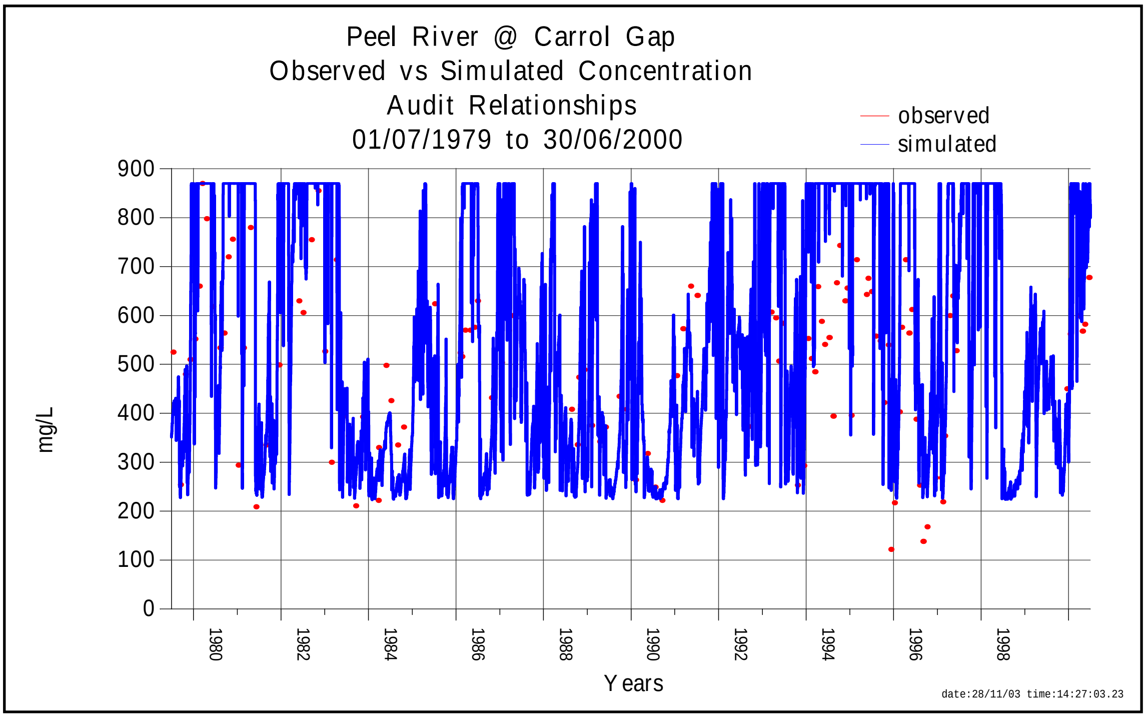


Figure 5.44. Simulated versus observed salinities at Gauging Station 419006: Peel River at Carrol Gap, using Salinity Audit relationships.

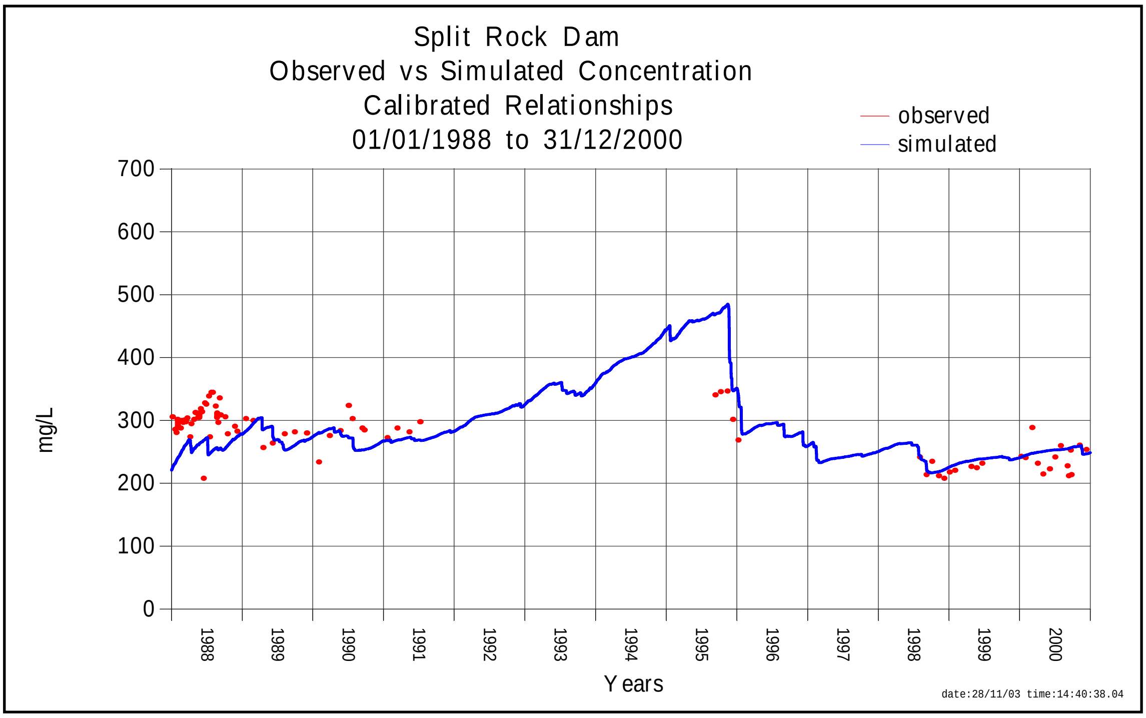


Figure 5.45. Simulated versus observed salinity at Split Rock Dam, using calibrated relationship.

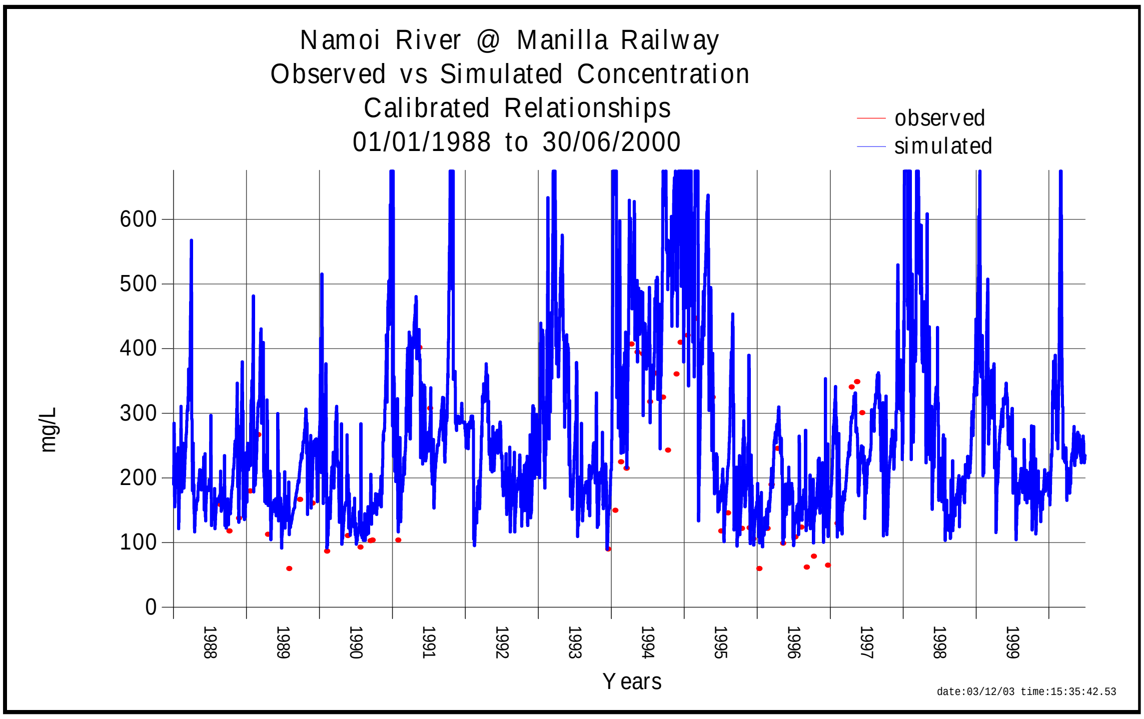


Figure 5.46. Simulated versus observed salinity for Gauging Station 419022: Namoi River at Manilla Railway Bridge, using calibrated relationship.

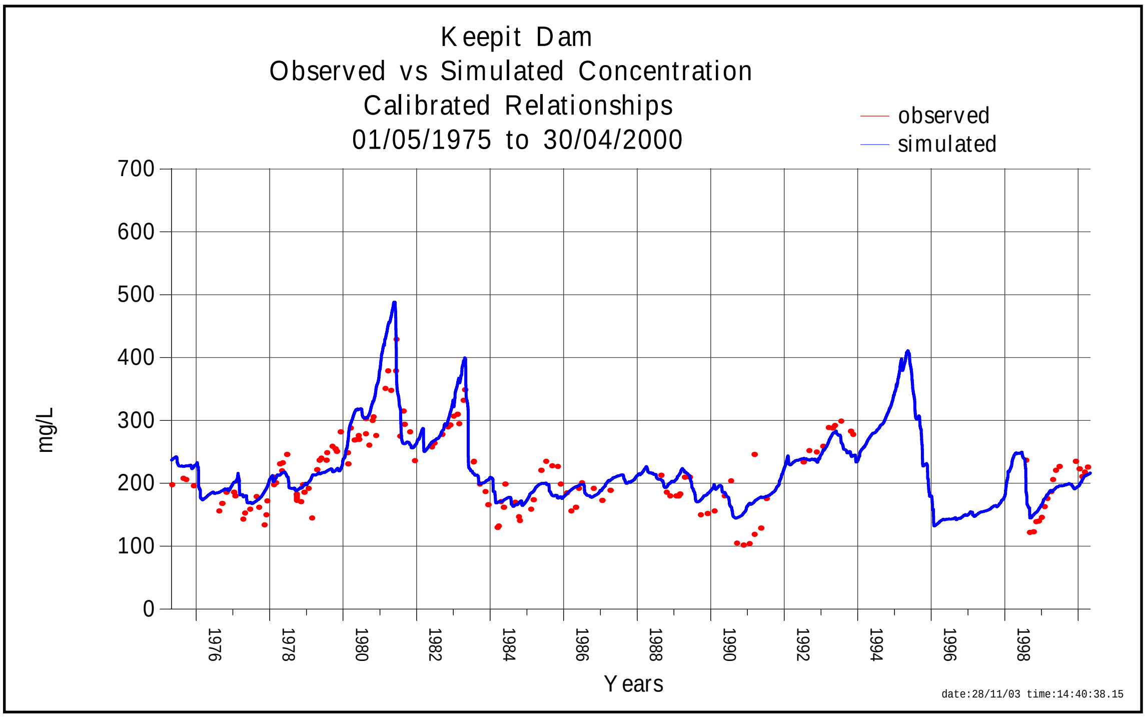


Figure 5.47. Simulated versus observed salinity at Keepit Dam, using calibrated relationship.

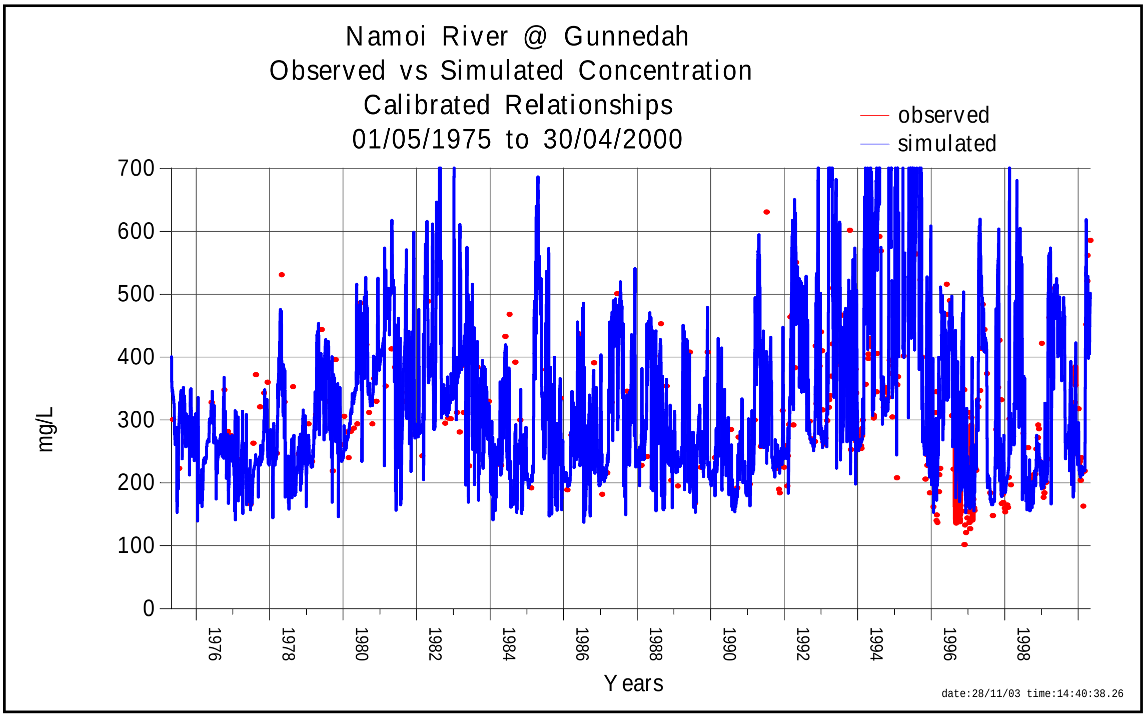


Figure 5.48. Simulated versus observed salinity for Gauging Station 419001: Namoi River at Gunnedah, using calibrated relationship.

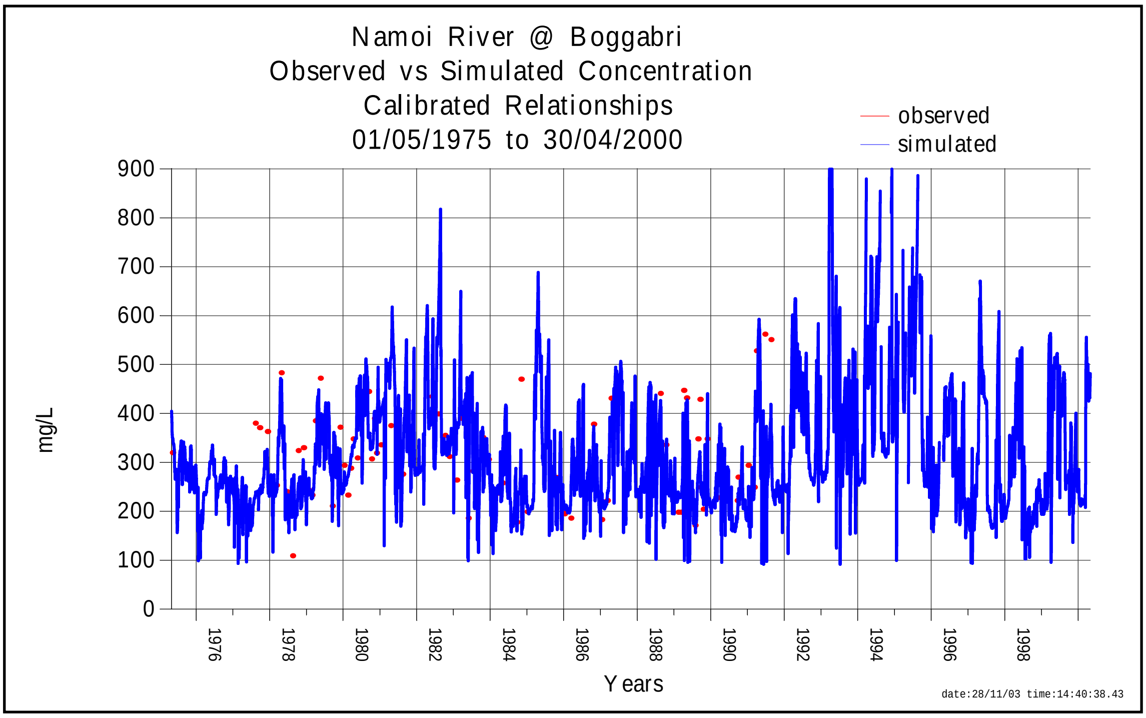


Figure 5.49. Observed versus simulated concentrations for Gauging Station 419012: Namoi River at Boggabri using calibrated relationship.

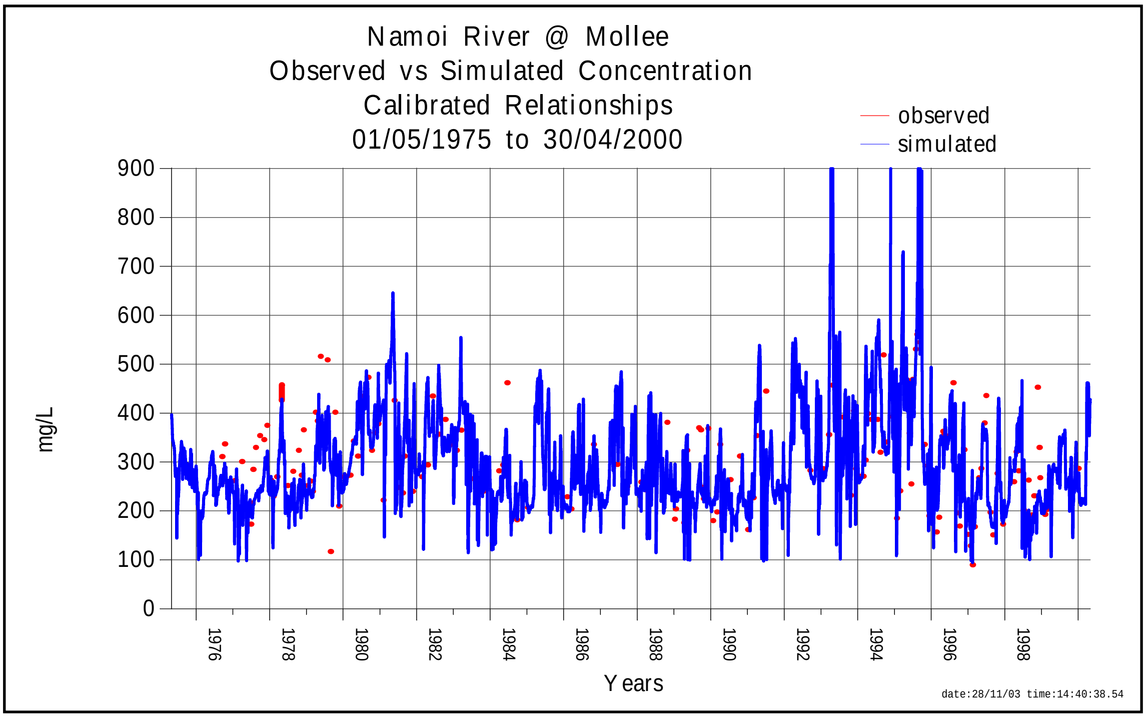


Figure 5.50. Observed versus simulated concentrations for Gauging Station 419039: Namoi River at Mollee, using calibrated relationships

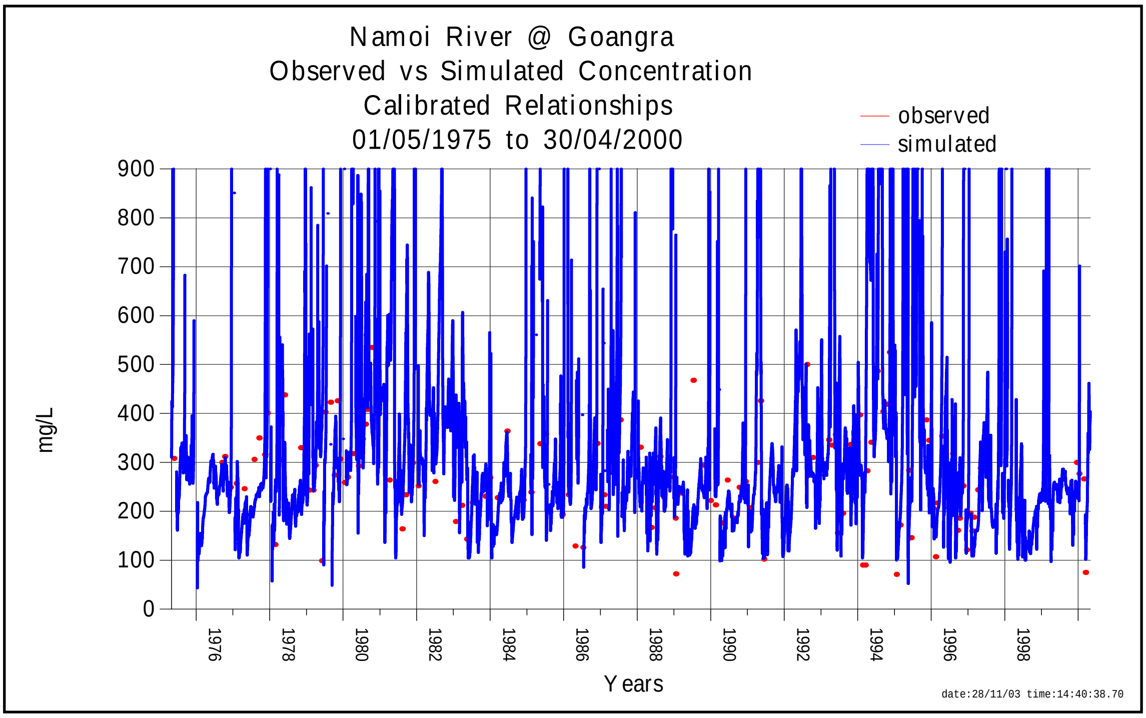


Figure 5.51. Observed versus simulated concentrations for Gauging Station 412026: Namoi River at Goangra, using calibrated relationships.

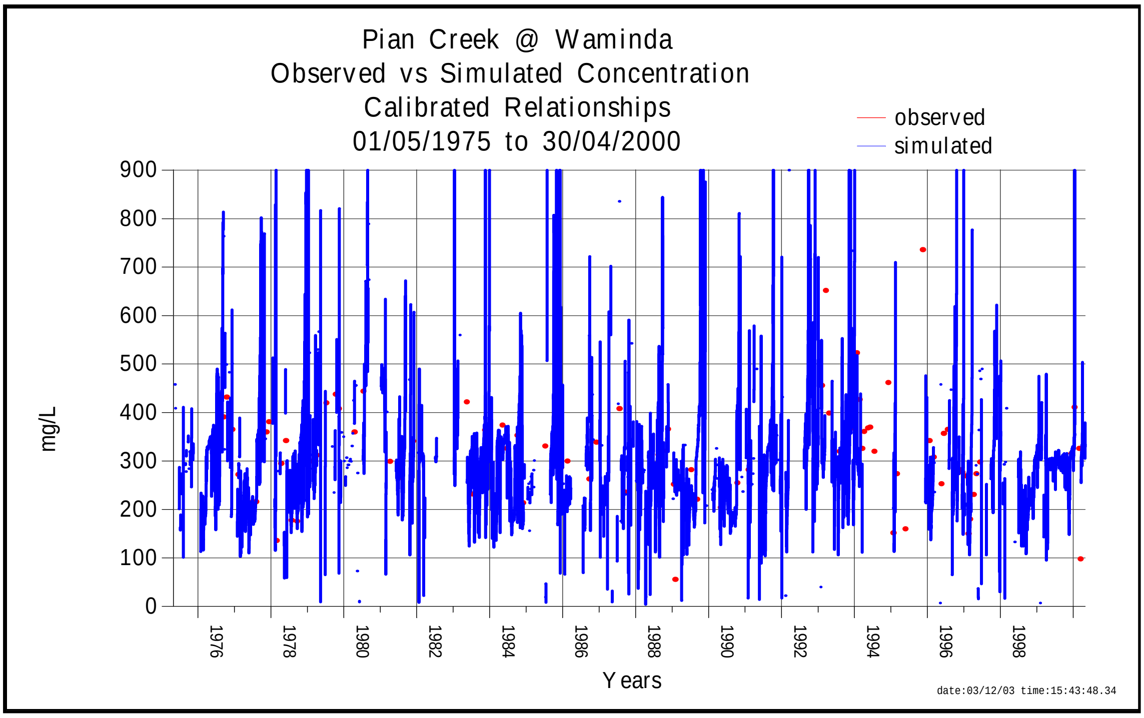


Figure 5.52. Observed versus simulated concentrations for Gauging Station 419049: Pian Crek at Waminda, using calibrated relationships.

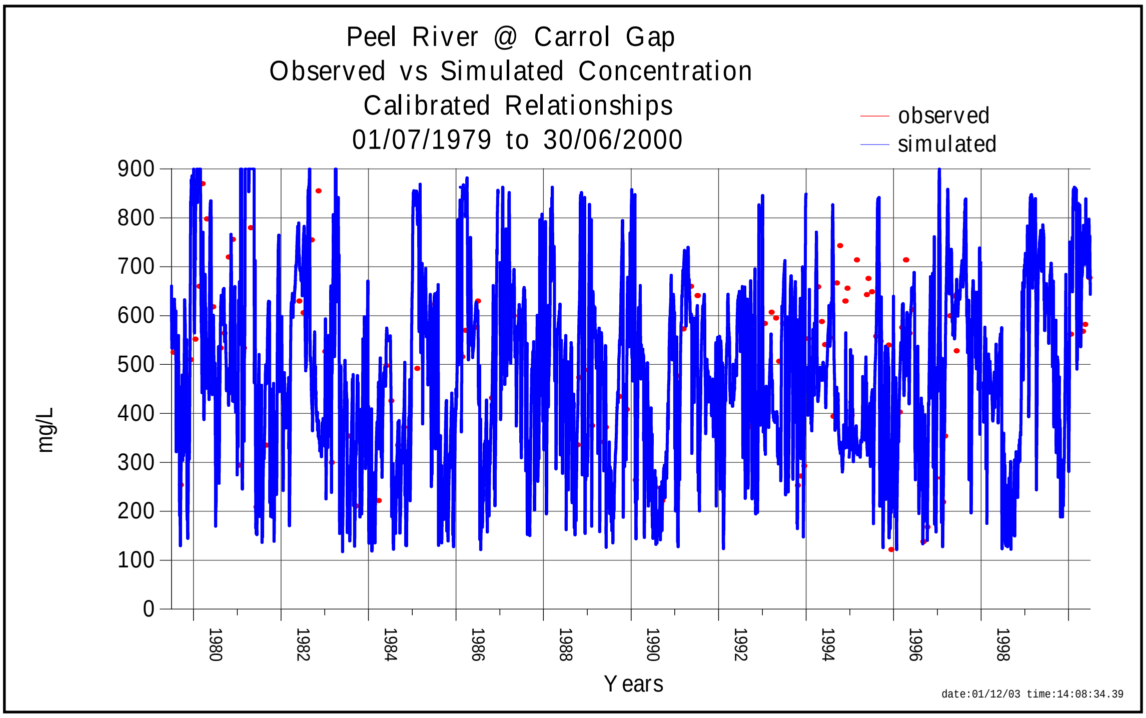


Figure 5.53. Observed versus simulated concentrations for Gauging Station 419006: Peel River at Carrol Gap, using calibrated relationships.

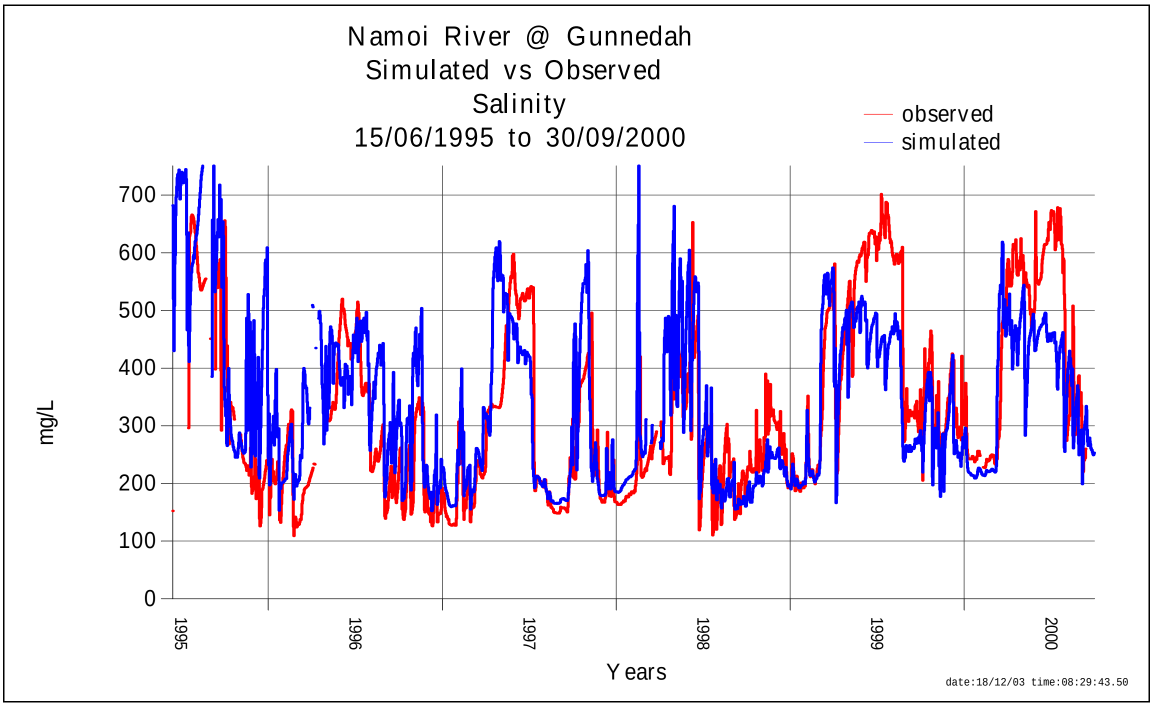


Figure 5.54 Continuous observed versus simulated salinities for Gauging Station 419001: Namoi River at Gunnedah using calibrated relationships

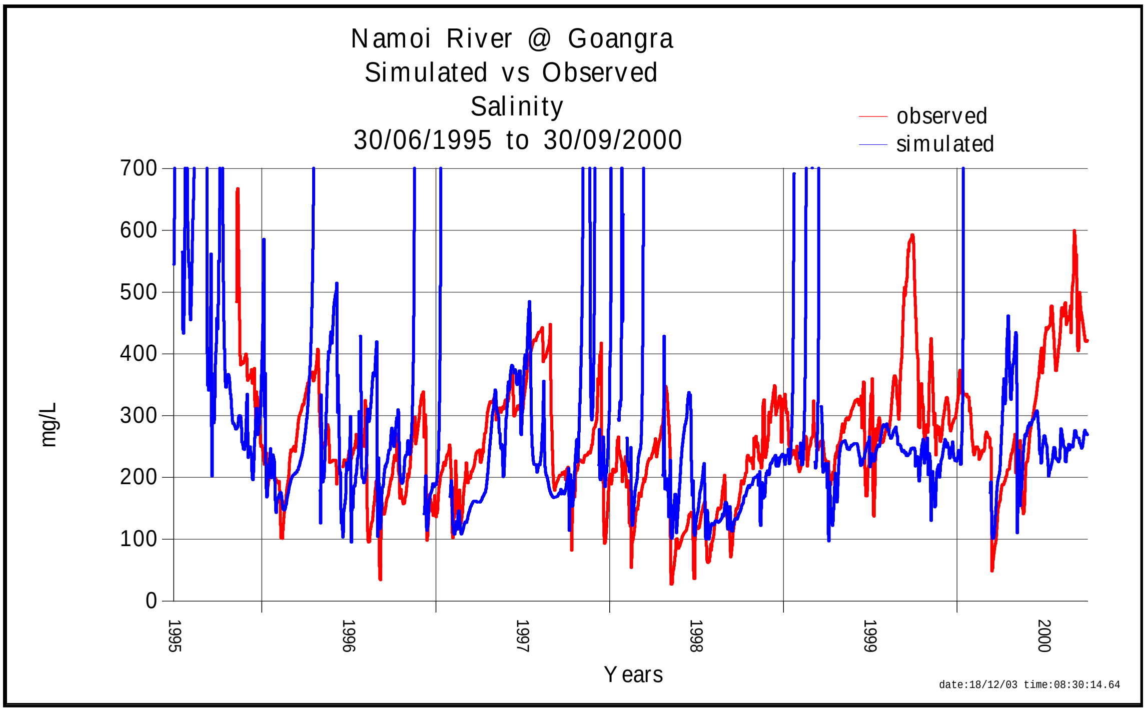


Figure 5.55 Continuous observed versus simulated salinities for Gauging Station 419026: Namoi River at Goangra using calibrated relationships

6. Baseline conditions model results

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 includes processes simulated in IQQM. Point (vii) may affect either catchment inflows, or IQQM operation.

Defining the points affecting inputs to the flows and salt inputs to the IQQM is problematic. Difficulties can arise from sparse data to describe the important biophysical characteristics, as well as how to reliably estimate the quantitative response of catchment 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, eg.; 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 or development over the period of record.

More information is available to define water use and river operating regimes in the Namoi River and Peel River systems. 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 salinity calibration for Peel IQQM and Namoi IQQM has been treated separately in this modelling. This is, the Peel River input to the Namoi River salinity model is not the modelled output from the Peel but rather a time series of flow that is converted to salinity by a calibrated flow verses salinity relationship. The salinity relationship being calibrated from observed data. Results from both models for the benchmark period have been included in this report. However, the validity of this approach for assessing impacts of salinity management strategies in the Peel Valley on Namoi Valley end of valley and within valley targets will have to be addressed in the future. The approach is considered suitable for initial benchmarking studies. The results from this simulation are reported in the following section.

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

(Namoi IQQM – NamoP004.sys, Peel IQQM– PeelP12.sys)

Water Balance Component	Namoi Value	Peel Value
Average annual inflows *(benchmark climatic period 1975 to 2000)*		
Split Rock Dam	77 GL/year	
Macdonald River	248 GL/year	
Peel River	274 GL/year	
Mooki River	136 GL/year	
Coxs Creek	95 GL/year	
Storages		
Split Rock Da,		
Active storage	397 GL	
Storage reserve	39.5 GL	
Transmission and operation losses	0	
Keepit Dam		
Active storage	425 GL	
Storage reserve	106.5 GL	
Transmission and operation loss account	30% of general security irrigation water account	
Chaffey Dam		
Active storage		61 GL
Storage reserve		12 GL
Transmission and operation losses		17 GL
Irrigation		
General security licences	256 GL/year	31 GL/year
High security licences	8 GL/year	2 GL/year
Proportion licences active	100 %	100 %
Maximum allocation	100 % (equivalent)	100 %
Maximum irrigable area	51,600 Ha (summer) 19,350 Ha (winter)	1,740 Ha
Pump capacity	11 GL/day	0.37 GL/day
On-farm storage capacity	178 GL	0
Accounting system	Continuous	Annual
Surplus flow entitlement	110 GL/year	0
Town water supply		
Manilla	35 ML/year	
Walgett	2.2 GL/year	
Tamworth		16.4 GL/year (only modelled at current demand of 9 GL)
In-stream water supply *(see Table 4.1)*		
Split Rock Dam	5 to 6 ML/day	
Keepit Dam	10 ML/day	
Pian Creek	14 GL/year	

6.2. RESULTS

The model was run for the Benchmark Climate period with the calibrated salinity inflows, and the water usage and policies that existed as at 1 January 2000. The results for the mean and percentile non-exceedances for daily concentration and daily salt load at all the evaluation points are reported in Table 6.2. The results for the mean and percentile non-exceedance annual salt load at all evaluation points are reported in Table 6.3.

The results for salt loads show that the major inflows to the Namoi River system have occurred by Mollee. The trend of observed salinity concentrations (Table 3.4) matches well the model baseline salinity concentrations up to the gauging station at Mollee. After Mollee the baseline salt loads decrease due to major irrigation extractions (including on farm storage diversions) and significant loss of water due to overbank flooding. Some of this salt will eventually reach the Barwon-Darling River in flood flows.

Table 6.2. 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		Concentration (mg/L)				Salt Load (T/day)			
Number	Name	*Mean*	*Percentile non exceedance*			*Mean*	*Percentile non exceedance*		
			20	*50*	*80*		*20*	*50*	*80*
419007	Namoi River d/s Keepit Dam	210	170	190	250	160	2	5	290
419001	Namoi River at Gunnedah	330	210	290	460	440	61	180	470
419012	Namoi River d/s Boggabri	320	210	280	430	440	61	170	480
419039	Namoi River at Mollee	280	210	260	350	440	59	190	480
419026	Namoi River at Goangra	310	190	270	390	300	9	42	270
419049	Pian Creek at Waminda	300	200	290	370	19	0	1	9
419024	Peel River at Paradise Weir	270	200	280	330	83	10	25	83
419006	Peel River at Carrol Gap	460	310	480	600	180	31	77	210

- Namoi River at Goangra statistics on concentration taken on days when flow > 5ML/d (92% of the time)
- Pian Creek at Waminda statistics on concentration taken on days when flow > 2 ML/d (54% of the time
- Number quoted to 2 significant figures
- Note: In Bewsher (2004) it has been recommended that the Namoi 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. The Class of the model may be improved if more upstream sites (where flow prediction tends to be more reliable) are chosen for salinity prediction.

Table 6.3. 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 1000 T/year)			
Number	Name	*Mean*	*Percentile non exceedance*		
			20	*50*	*80*
419007	Namoi River d/s Keepit Dam	58	39	54	77
419001	Namoi River at Gunnedah	161	75	136	245
419012	Namoi River d/s Boggabri	160	73	143	248
419039	Namoi River at Mollee	161	72	145	247
419026	Namoi River at Goangra	110	23	61	177
419049	Pian Creek at Waminda	7	1	4	12
419024	Peel River at Paradise Weir	30	12	25	49
419006	Peel River at Carrol Gap	64	29	53	97

- Namoi River at Goangra statistics on concentration taken on days when flow > 5ML/d (92% of the time)
- Pian Creek at Waminda statistics on concentration taken on days when flow > 2 ML/d (54% of the time
- Number quoted to 3 significant figures
- Note: In Bewsher (2004) it has been recommended that theNamoi 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. The Class of the model may be improved if more upstream sites (where flow prediction tends to be more reliable) are chosen for salinity prediction.

-

Table 6.4. Statistics of observed data for flow, salinity and salt load (1975-2000) at Namoi River at Goangra

Parameter	Units	Mean	Percent non exceedance		
			20	*50*	*80*
Flow	(ML/d)	1280	61	167	760
Salinity	(mg/L)	272	193	266	348
Salt load	(Tonnes/d)	254	13	49	191

The following graphs have been presented to allow the baseline model results at Goangra to be examined across the full statistics range and to compare the results to observed data.

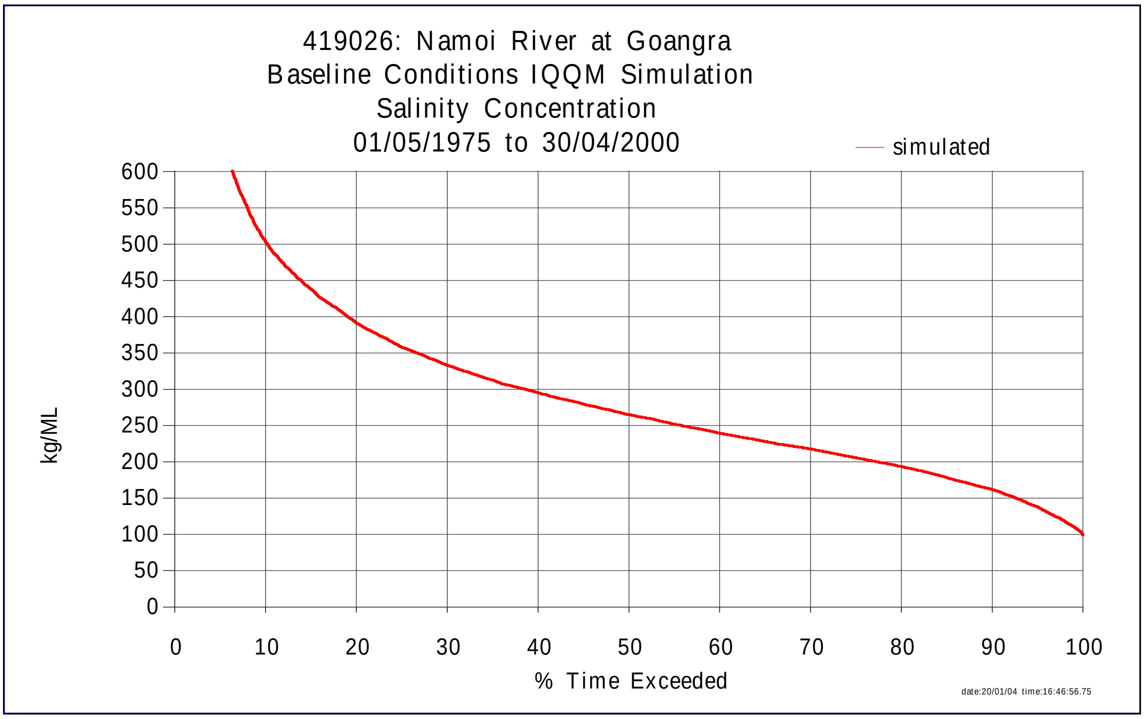


Figure 6.1. Frequency of exceedance of simulated salinity for Baseline Conditions scenario (1/5/1975-30/4/2000) for Namoi River at Goangra.

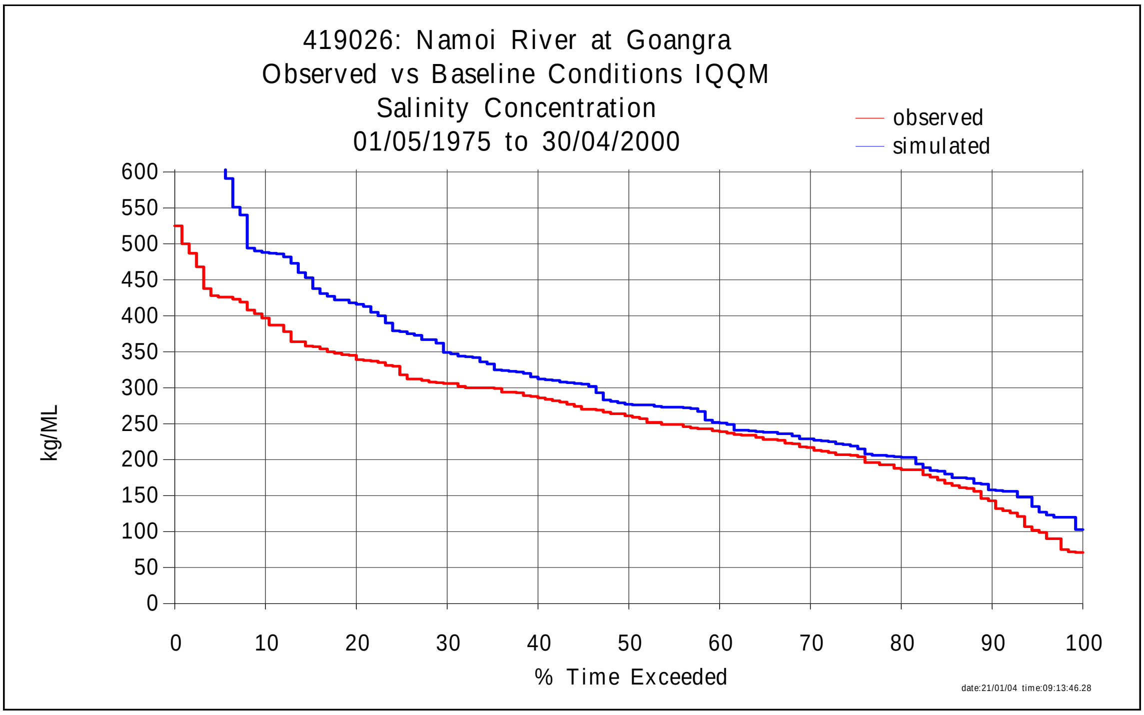


Figure 6.2. Frequency of exceedance of simulated salinity for Baseline Conditions scenario on days with salinity observations (1/5/1975-30/4/2000), compared with salinity observations for Namoi River at Goangra.

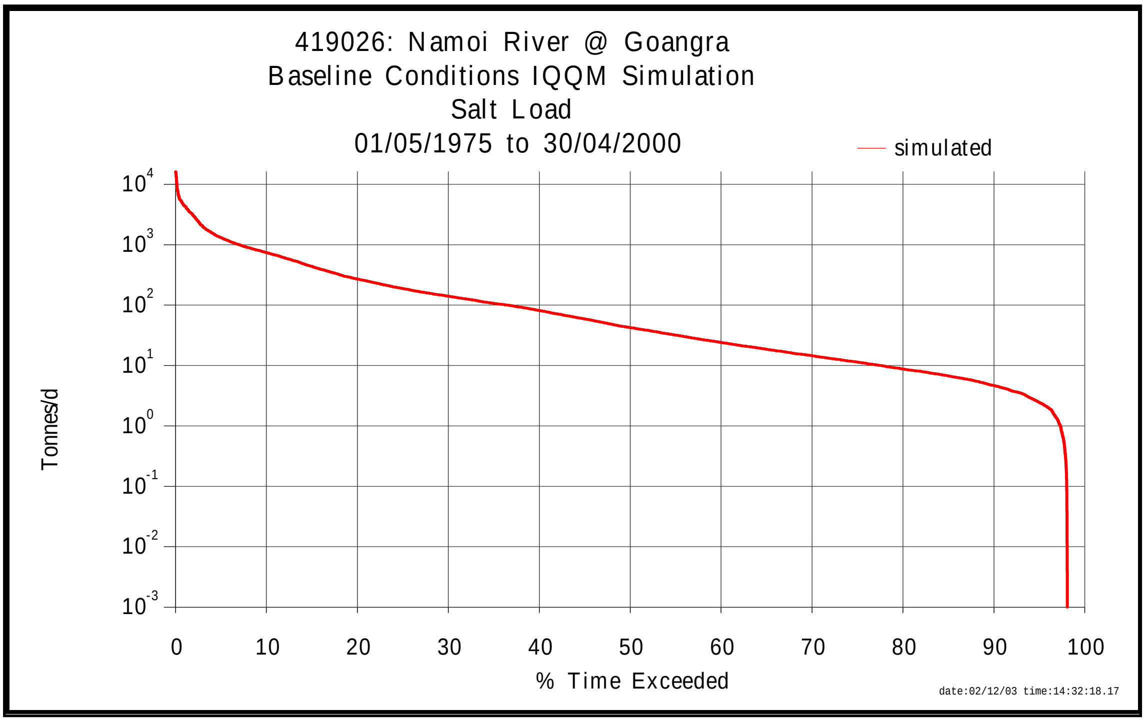


Figure 6.3. Frequency of exceedance of simulated salt load for Baseline Conditions scenario (1/5/1975-30/4/2000) for Namoi River at Goangra.

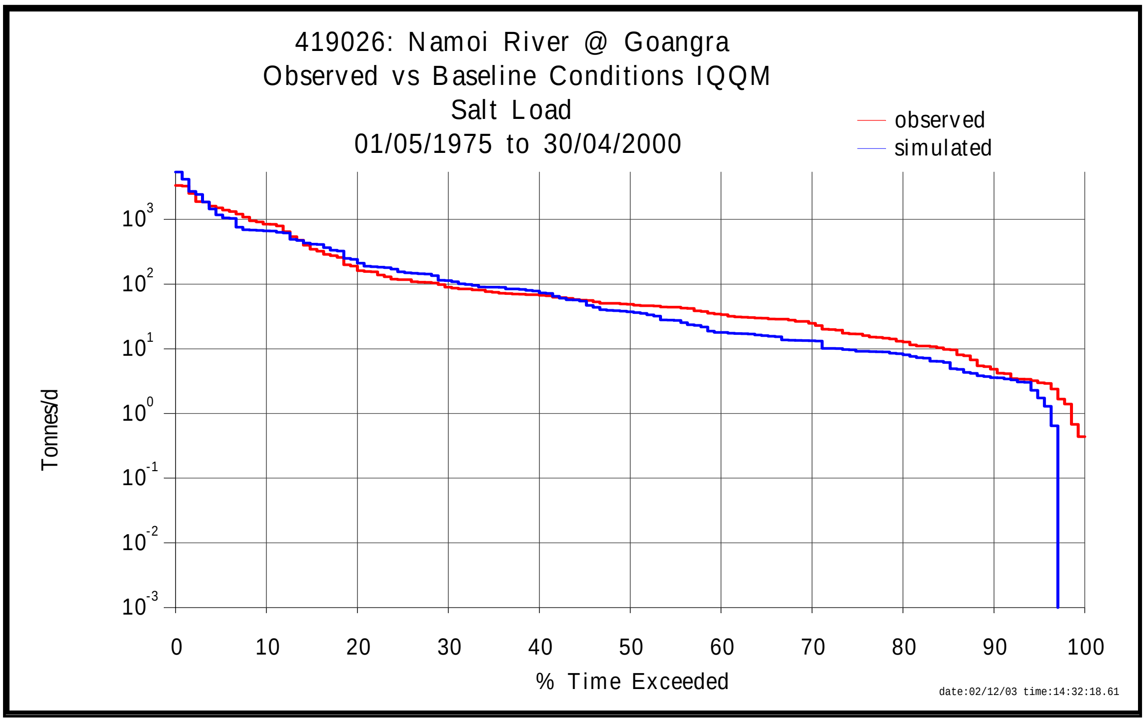


Figure 6.4. Frequency of exceedance of simulated salt load for Baseline Conditions scenario on days with salinity and flow observations (1/5/1975-30/4/2000), compared with salinity observations for Namoi River at Goangra.

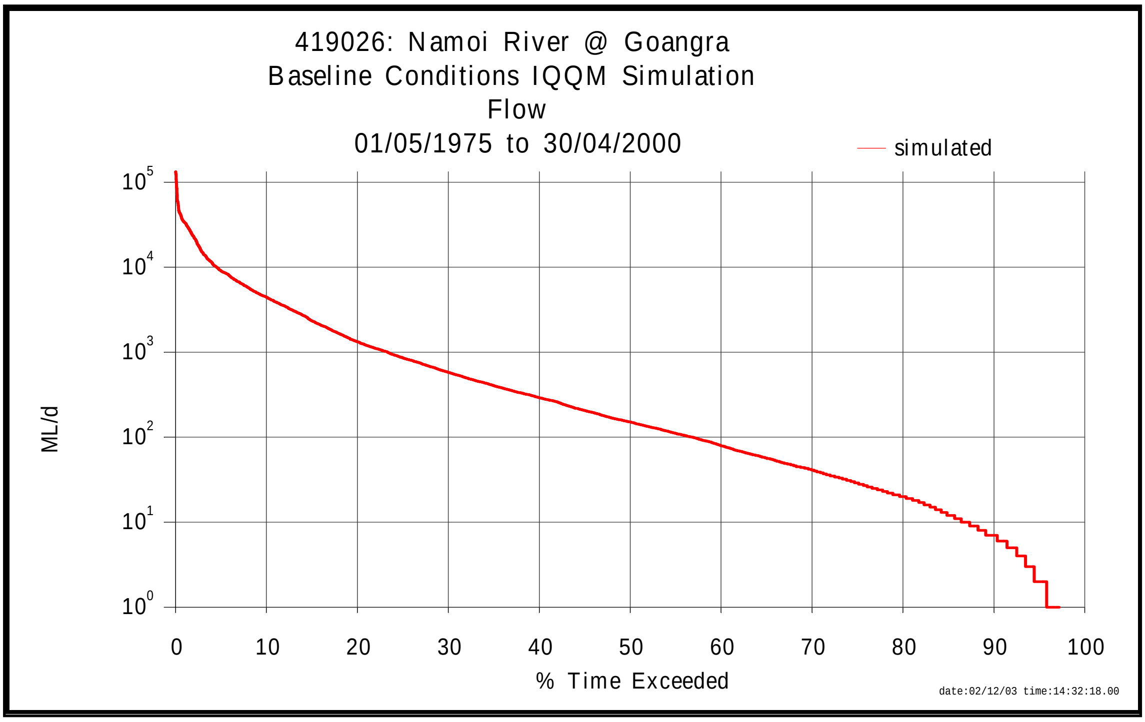


Figure 6.5. Frequency of exceedance of simulated flow for Baseline Conditions scenario (1/5/1975-30/4/2000) for Namoi River at Goangra.

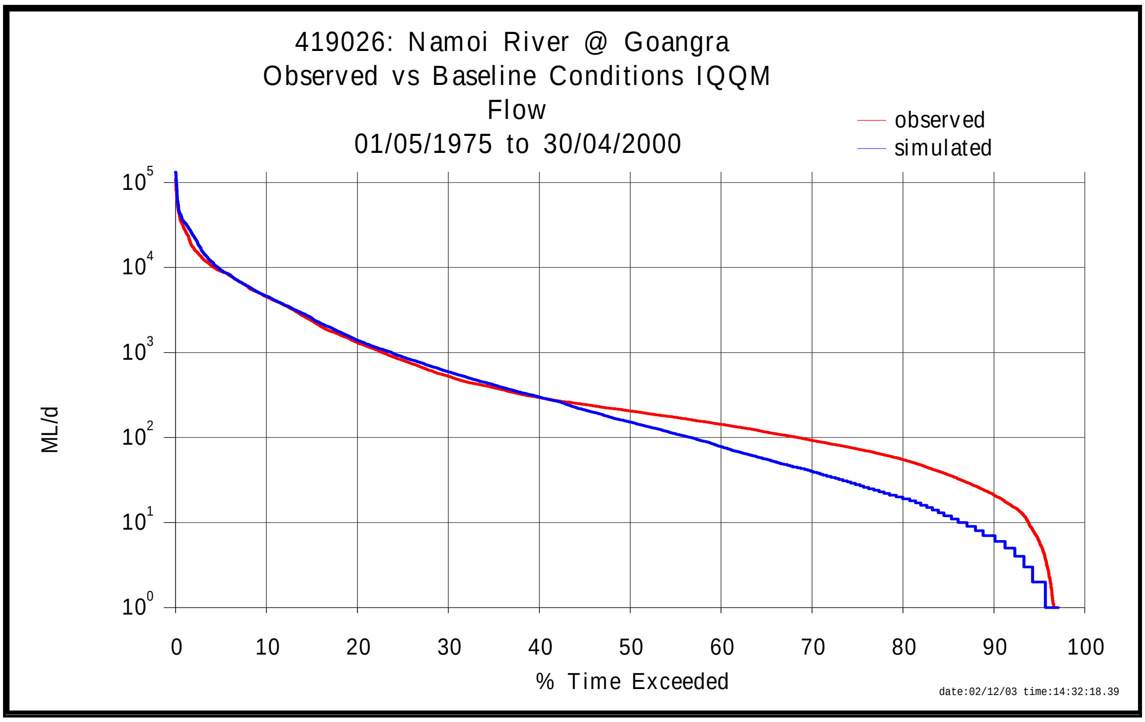


Figure 6.6. Frequency of exceedance of simulated flow for Baseline Conditions scenario on days with flow observations (1/5/1975-30/4/2000), compared with observed flow for Namoi River at Goangra.

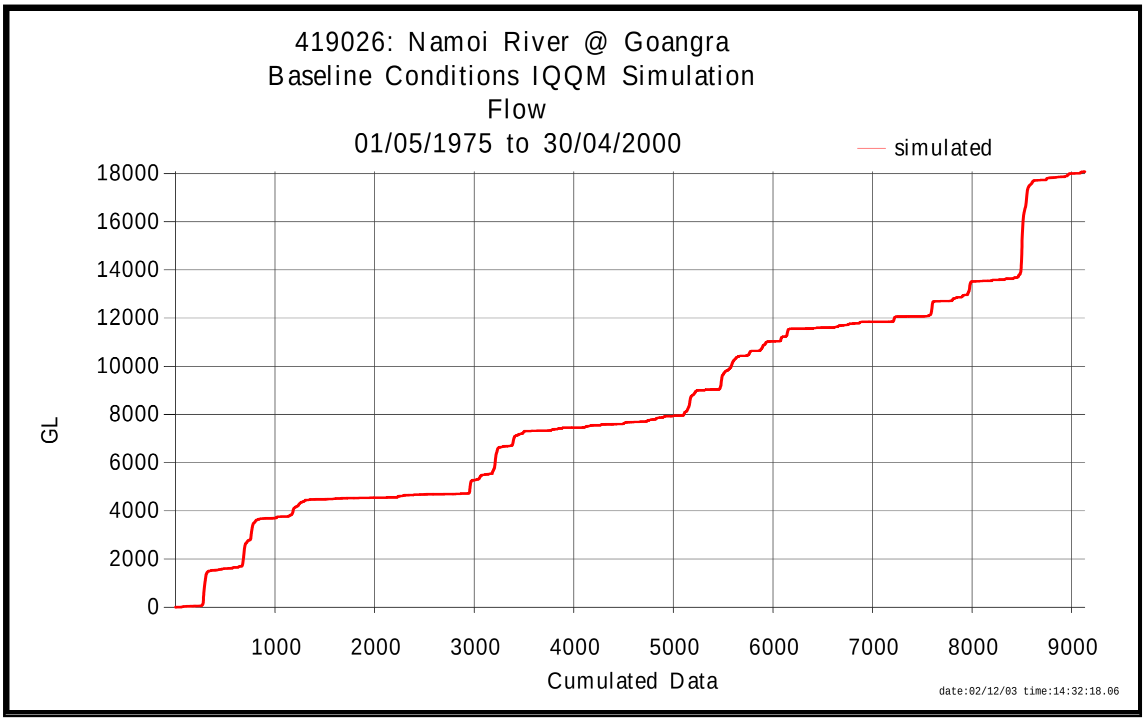


Figure 6.7. Cumulative simulated flow for Baseline Conditions scenario (1/5/1975-30/4/2000) for Namoi River at Goangra.

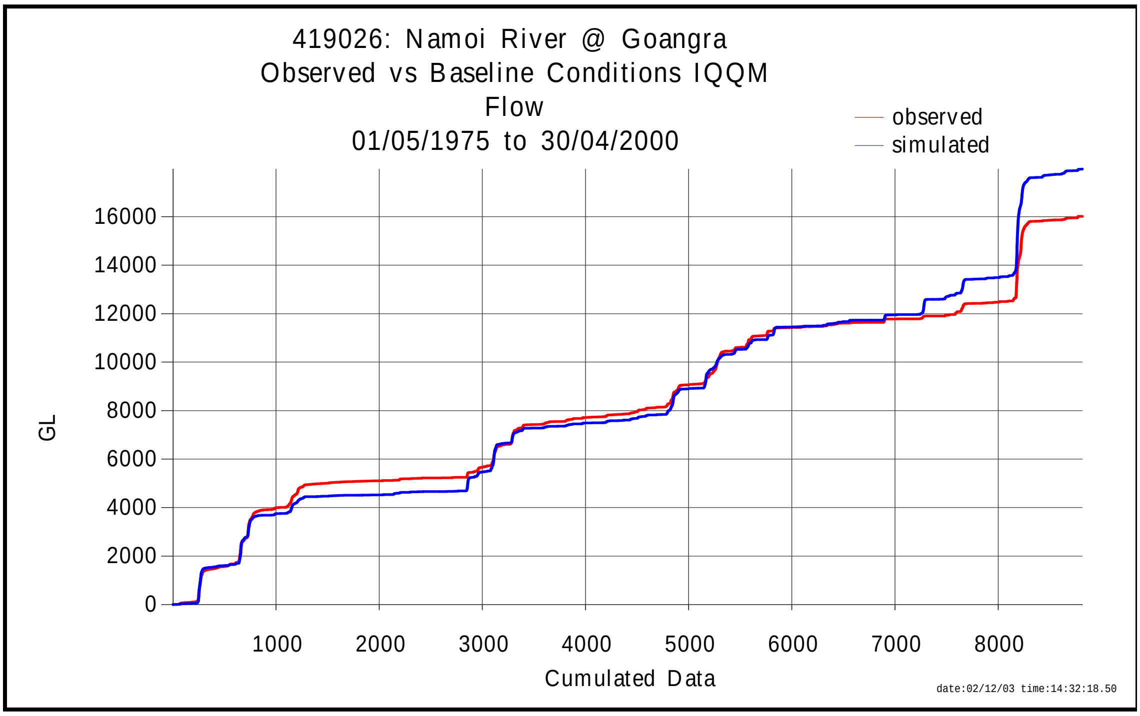


Figure 6.8. Cumulative simulated flow for Baseline Conditions scenario for days with observed flow, and observed flow (1/5/1975-30/4/2000) for Namoi River at Goangra.

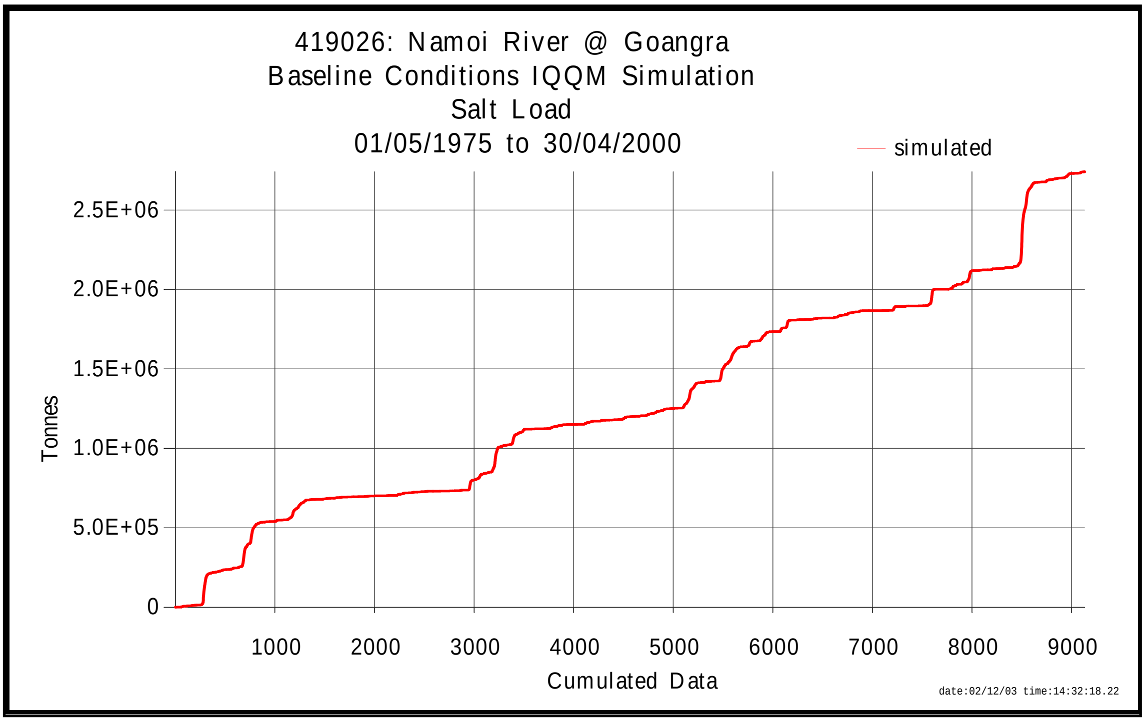


Figure 6.9. Cumulative simulated salt load for Baseline Conditions scenario (1/5/1975-30/4/2000 Namoi River at Goangra.

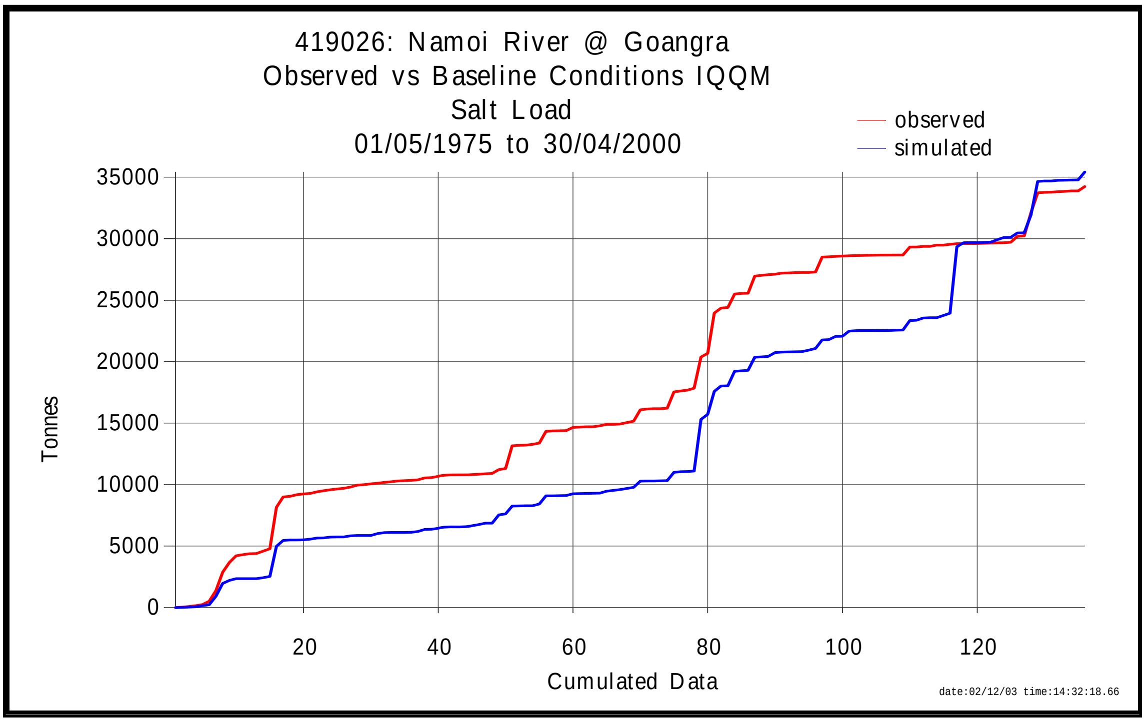


Figure 6.10. Cumulative simulated salt load for Baseline Conditions scenario for days with salinity and flow observations, and observed salt load (1/5/1975-30/4/2000) for Namoi River at Goangra..

7. Recommendations

7.1. CONCLUSION

The Namoi IQQM has produced a time series of flows and salt loads for the Benchmark Climatic Period under Baseline Conditions. The good match of flows, concentrations, and salt loads up to Boggabri suggests that these Baseline Conditions results are quite reliable to this point. The uncertainty in model results starts to increase from this point and is largely because of uncertainties in modelling the water balance in the lower floodplain areas. The model was primarily calibrated to simulate irrigation diversions, however, this process resulted in some differences between observed and modelled flows that was considered acceptable. Now with the need to match salinity concentrations and salt loads these deficiencies have become more important.

The Namoi and Peel IQQM are capable of estimating the flow and salinity impacts of water sharing policies. However, because of current model limitations there are difficulties in getting the correct distribution of flows in the Lower Namoi River. These flow limitations will result in limitations on the models ability to predict salinity changes. Limitations with the linking of the Peel and Namoi IQQM will have to be considered when assessing any future salinity management options on Namoi Valley targets.

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..

- Improvements could be made to the methods used to estimate salt loads under Baseline Conditions. The flows versus concentration relationships do not reproduce the variability in the salt load generation. Catchment process based modelling with continuous data would improve salt export relationships..

- The methods to achieve water balance in the Lower Namoi River should be reviewed. This will enable the model to better estimate the effects of land use change in the end of valley Namoi targets..

- The method for linking Peel IQQM and Namoi IQQM should be reviewed to allow better simulation of salinity management options for the Peel on Namoi salinity targets.

- There are significant groundwater inter-actions in both the Peel River and Namoi River upstream of Boggabri. An integrated model that simulates both the surface water and the groundwater component of the catchment would predict the effects of groundwater extraction on river salinity.

- Modelling reaches where there are large surface area should be checked to examine the effect of rainfall and evaporation in salinity..

- Re-calibration of transmission losses modelling taking into consideration salinity processes, especially in the lower Namoi River reaches, should be undertaken to improve salinity modelling..

7.3. RECOMMENDED FUTURE DATA COLLECTION

Catchment process based modelling like CATSALT has the capability to predict the effect of antecedent soil moisture conditions, rise in groundwater level and the impacts of land use changes on salt exports from the tributary catchments in the Namoi River. However, for salt inflows from ungauged catchments and from groundwater interaction within the river, more data will be required to identify the source of salt and to understand the processes affecting salinity in the main streams of the catchment. The following recommendation on salt load data collection are made.

- Sufficient continuous EC data at all gauging stations will improve estimate of salt balance in river reaches at all flow regimes, wet and dry periods, and summer and winter seasons. The increase in observed salinity from Keepit Dam (419043) to Gunnedah (419001) can be investigated further if continuous EC data d/s Keepit Dam, Peel River (419006), and Mooki River (419027) are available. Continuous EC data at Namoi River at Boggabri (419012) will improve the salt inflow estimate from residual catchment and groundwater contribution from Gunnedah to Boggabri.

- Continuous EC data at Peel River d/s Chaffey Dam, at Piallamore (419015), at Goonoo Goonoo Ck (419035) and at Carrol Gap (419006) will assist in estimating the salt load contributions from residual catchments and groundwater.

- Observed daily water diversions are necessary to calibrate low flows in the river. This is necessary to separate the transmission loss and irrigation diversion components when analysing water balance between gauging stations.

- Estimate of inflows and salt loads from residuals and ungauged catchments must be reviewed to consider local conditions like land use, soil properties and groundwater levels. Accuracy in the estimation of residual inflows reduces the uncertainty in estimating the losses and groundwater inflow within the river reach.

- Loss functions in IQQM must be revised to improve flow calibration at low flow events. This can be achieved by modelling the river-aquifer interaction to estimate the amount of water getting into/out of the river. To model this process, river cross-sections, surface water level, groundwater level near the river, aquifer storage and riverbed leakage properties must be available.

- Measurements of soil salinity and groundwater salinity near the river will assist in identifying possible sources of salinity, either from floodplain or directly from groundwater. This is important in the Peel River from Paradise Weir to Carrol Gap and in the Namoi River from Keepit Dam to Boggabri where there are possible groundwater interaction with the river.

- Evaporation loss at the river may be significant during summer season. This may increase the salinity in areas with large flood plain areas. In this case, a table of flow and flood plain areas can be modelled in IQQM. Abrupt changes in the reach storage volume may result to a sudden increase in simulated salinity.

- Continuous EC data at storage inflow and at outflows will assist in modelling salinity behaviour in storages (Split Rock, Keepit and Chaffey). Knowledge on changes in salinity due to changes in inflows and outflows will assist water resources managers in formulating the storage release rules.

- Continuous EC at Namoi River at Mollee (419039) would be helpful in estimating salt loads from the residuals between Boggabri and Mollee and from Mollee to Goangra (419026).

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.

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Appendix A. All available salinity data

Table A1. EC data in the Namoi River valley

Station number	Station name	Lat (S)	Long (E)	Data type	Period collected	Number of data days
419001	Namoi River at Gunnedah	30.9740	150.2540	Continuous	1995-2002	2345
419001	Namoi River at Gunnedah	30.9740	150.2540	Discrete	1970-2002	491
419002	Namoi R atNarrabri	30.3333	149.7717	Discrete	1976-1984	20
419003	Narrabri Creek atNarrabri	30.3292	149.7792	Discrete	1975-2002	238
419004	Peel River atBowling Alley	31.3978	151.1431	Discrete	1977-2002	209
419005	Namoi River at North Cuerindi	30.6800	150.7780	Discrete	1976-1990	71
419006	Peel River at Carrol Gap	30.9400	150.5260	Discrete	1970-2002	224
419007	Namoi River at Keepit	30.8930	150.4950	Discrete	1970-2002	220
419010	Macdonald R atWoolbrook	30.9681	151.3458	Discrete	1976-1990	80
419011	Namoi R atManilla Weir	30.7431	150.7333	Discrete	2002-2002	18
419012	Namoi River at Boggabri	30.6697	150.0567	Discrete	1970-1991	134
419014	Manilla R atWimborne	30.6667	150.6597	Discrete	1987-1987	1
419015	Peel River at Piallamore	31.1830	151.0650	Discrete	1970-1990	110
419016	Cockburn River at Mulla Crossing	31.0630	151.1250	Continuous	1995-1998	951
419016	Cockburn River at Mulla Crossing	31.0630	151.1250	Discrete	1970-1990	124
419019	Namoi R atWee Waa	30.2028	149.5083	Discrete	1969-1987	46
419020	Manilla River at Brabri (Merriwee)	30.7090	150.7020	Continuous	2000	35
419020	Manilla River at Brabri (Merriwee)	30.7090	150.7020	Discrete	1977-1991	77
419021	Namoi R atBugilbone (Riverview)	30.2742	148.8194	Discrete	1976-2002	343
419022	Namoi River at Manilla Railway Bridge	30.7530	150.7150	Discrete	1973-2002	168
419023	Namoi R atTurrawan (Walla)	30.4542	149.9444	Discrete	1976-1986	49
419024	Peel River at Paradise Weir	31.1020	150.9380	Continuous	1995-1998	1029
419024	Peel River at Paradise Weir	31.1020	150.9380	Discrete	1970-2002	287
419026	Namoi River at Goangra	30.1440	148.3860	Continuous	1995-2002	2479
419026	Namoi River at Goangra	30.1440	148.3860	Discrete	1970-2002	203
419027	Mooki River at Breeza	31.2750	150.4600	Discrete	1971-2002	192
419028	Macdonald R atRetreat	30.6275	151.1100	Discrete	1976-1986	56
419029	Halls Creek at Ukolan	30.7060	150.8260	Discrete	1976-1990	120
419030	Manilla River at Barraba	30.3900	150.6190	Discrete	1976-1987	77
419031	Manilla River at Glen Riddle (Woodsreef)	30.4500	150.6860	Discrete	1976-1988	210
419032	Coxs Creek at Boggabri	30.7750	149.9890	Continuous	1996-2001	2429
419032	Coxs Creek at Boggabri	30.7750	149.9890	Discrete	1971-2001	235
419033	Coxs Creek at Tambar Springs	31.3500	149.8860	Continuous	1995-1998	1004
419033	Coxs Creek at Tambar Springs	31.3500	149.8860	Discrete	1976-1998	124
419034	Mooki River at Caroona	31.4090	150.4297	Continuous	1995-1998	1128
419034	Mooki River at Caroona	31.4090	150.4297	Discrete	1977-1998	96
419035	Goonoo Goonoo Creek at Timbumburi	31.2720	150.9150	Discrete	1970-1990	121

Station number	Station name	Lat (S)	Long (E)	Data type	Period collected	Number of data days
419036	Duncans Creek atWoolomin	31.3211	151.1567	Discrete	1970-1986	104
419037	Mulla Creek atBullimball	31.0956	151.1467	Discrete	1976-1978	14
419038	Macdonald River atCobrabald	31.1914	151.4483	Discrete	1976-1987	71
419039	Namoi River at Mollee	30.2610	149.6810	Discrete	1976-2002	173
419040	Namoi River atWomerah	30.2653	149.3611	Discrete	1976-1986	52
419041	Namoi R at Keepit Dam Storage	30.8808	150.4919	Discrete	1976-1976	1
419042	Macdonald R at Bonnie Doon	30.8550	151.1517	Discrete	1976-1986	51
419043	Manilla River at D/S Split Rock Dam	30.5880	150.6880	Continuous	2000	101
419043	Manilla River at D/S Split Rock Dam	30.5880	150.6880	Discrete	1976-2002	305
419044	Maules Creek at Damsite	30.5292	150.2958	Discrete	1976-1991	44
419045	Peel River at D/S Chaffey Dam	31.3430	151.1420	Discrete	1970-2002	331
419047	Ironbark Creek a tWoodsreef	30.4100	150.7260	Discrete	1970-1991	118
419048	Namoi R at Hornabrooks	30.0672	148.2169	Discrete	1976-1986	28
419049	Pian Creek at Waminda	29.9240	148.3860	Discrete	1976-2002	147
419050	Connors Creek at Barraba	30.3640	150.6330	Discrete	1973-1991	81
419051	Maules Creek at Avoca East	30.4970	150.0840	Discrete	1976-1991	85
419052	Coxs Creek at Mullaley	31.1008	149.9011	Discrete	1972-1988	34
419053	Manilla River at Black Springs	30.4230	150.6500	Discrete	1976-1991	106
419054	Swamp Oak Creek at Limbri	31.0383	151.1692	Discrete	1976-1990	74
419055	Mulla Creek at Goldcliff	31.1117	151.1461	Discrete	1976-1988	67
419056	Manilla R at Upper Manilla	30.6461	150.6769	Discrete	1980-1991	36
419057	Namoi R at Walgett	30.0167	148.1194	Discrete	1989-2002	241
419058	Namoi R at Weir d/s Keepit Dam	30.8886	150.4867	Discrete	1984-1991	3
419059	Namoi R at d/s Gunidgera Weir	30.2042	149.4353	Discrete	1976-2002	111
419060	Namoi R at Gunidgera Weir - storage	30.2028	149.4367	Discrete	2000-2000	1
419061	Gunidgera Creek at d/s Regulator	30.1972	149.4278	Discrete	1975-2002	169
419062	Namoi R at Mollee Weir - storage	30.2667	149.7000	Discrete	1990-1991	3
419063	Gunidgera-Pian Cutting at Merah N	30.1889	149.2883	Discrete	1978-1991	55
419064	Pian Creek at Rossmore	30.0917	149.0667	Discrete	1978-2002	240
419065	Pian Creek at Old Burren	29.9500	148.9083	Discrete	1978-1989	20
419066	Goran Lake at Hokey Pokey	31.3072	150.1989	Discrete	1978-2002	24
419068	Namoi R at D/S Weeta Weir	30.2867	149.3367	Discrete	1978-2002	177
419070	Peel R at Tamworth Water Supply	31.1353	150.9658	Discrete	1980-1991	29
419071	MacDonald R at Bendemeer	30.8903	151.1550	Discrete	1902-2002	18
419072	Baradine Creek at Kienbri NO.2	30.8517	149.0319	Discrete	1981-1991	27
419073	Peel R at Appleby Crossing	30.9667	150.8500	Discrete	1902-2002	18
419074	Peel R at Bective	30.9683	150.7317	Discrete	1982-1987	11
419075	Peel River at Somerton	30.9400	150.6467	Discrete	1991-1991	1
419076	Warrah Creek at Old Warrah	31.6590	150.6430	Continuous	1995-1999	1192

Station number	Station name	Lat (S)	Long (E)	Data type	Period collected	Number of data days
419076	Warrah Creek at Old Warrah	31.6590	150.6430	Discrete	1982-1998	65
419079	Gunidgera Creek D/S cutting at Gunidgera	30.2056	149.2900	Discrete	1986-1991	19
419081	Peel River at Taroona	31.4250	151.0890	Continuous	1995-1998	1136
419081	Peel River at Taroona	31.4250	151.0890	Discrete	1991	1
419084	Mooki River at Ruvigne	31.0370	150.3330	Continuous	1995-2002	2330
419084	Mooki River at Ruvigne	31.0370	150.3330	Discrete	1996-1997	33
419085	Bomera Creek at Bomera Creek	31.3710	149.8680	Continuous	1995-1998	1165
419085	Bomera Creek at Bomera Creek	31.3710	149.8680	Discrete	1996-1998	28
419086	Bundella Creek at Bundella	31.5630	149.9920	Continuous	1995-1998	972
419086	Bundella Creek at Bundella	31.5630	149.9920	Discrete	1996-1998	30
419087	Big Jacks Creek at Warrah Ridge	31.5710	150.5220	Discrete	1996-1997	12
419097	Goonoo Ck at Meadows Lane	31.1814	150.9236	Discrete	2003-2003	2
41910001	Keepit Dam (Dam Wall) Station 1	30.8306	150.5064	Discrete	1979-2003	158
41910002	Keepit Dam Station 2	30.8306	150.5064	Discrete	1979-1994	85
41910003	Keepit Dam Station 3	30.8039	150.5308	Discrete	1979-1991	84
41910004	Keepit Dam Station 4	30.7975	150.5467	Discrete	1980-1991	64
41910021	Chaffey Dam (Aerator) Station 1	31.3464	151.135	Discrete	1979-1992	392
41910022	Chaffey Dam (Bottom Island) Station 2	31.3469	151.1378	Discrete	1979-1991	217
41910023	Chaffey Dam (Hay Shed) Station 3	31.3647	151.1286	Discrete	1979-1991	181
41910024	Chaffey Dam (Pickhill) Station 4	31.3758	151.1322	Discrete	1981-1991	132
41910025	Chaffey Dam (Andersons Flat) Station 5	31.3808	151.1283	Discrete	1984-1991	110
41910028	Chaffey Dam (Snake Island) Station 8	31.3553	151.1264	Discrete	1979-1985	94
41910031	Chaffey Dam Station 1A	31.3489	151.1275	Discrete	1992-2003	61
41910041	Split Rock Dam Station 1	30.5778	150.6981	Discrete	1987-2003	92
41910042	Split Rock Dam Station 2	30.5408	150.6775	Discrete	1987-1994	24
41910043	Split Rock Dam Station 3	30.5064	150.7072	Discrete	1988-1999	18
41910044	Split Rock Dam Station 4	30.4742	150.6992	Discrete	1990-1991	6
41910045	Split Rock Dam Station 5			Discrete	1991-1991	5
41910046	Split Rock Dam Downstream			Discrete	1988-1994	13
41910101	Canns Creek at Western Foreshore Road Br			Discrete	1989-1991	6
41910102	Jimmys Creek at Hembury Park			Discrete	1991-1991	2
41910103	Burrows Creek at Swamp Creek camping gro			Discrete	1991-1991	2
41910104	Nundle Creek at River Road Bridge			Discrete	1989-1991	3
41910106	Back Creek at Crawney Road Bridge			Discrete	1989-1991	4
41910107	Wombramurra Creek at Glen Oak			Discrete	1989-1991	5
41910108	Peel River at Head of Peel Road Bridge			Discrete	1989-1991	6
41910109	Woodleys Creek upstream of confluence/cr			Discrete	1989-1991	5
41910110	Talbots Creek upstream of Head of Peel R			Discrete	1989-1991	6
41910111	Oakenville Creek at Road Bridge (M.R. 10			Discrete	1991-1991	1

Station number	Station name	Lat (S)	Long (E)	Data type	Period collected	Number of data days
41910115	Peel River at Bective Reserve	30.971	150.7332	Discrete	1991-2002	181
41910214	Barbers Lagoon d/s Bollol Creek	30.6764	150.0925	Discrete	2000-2002	6
41910215	Namoi River (Wetland) d/s Bugilbone	30.2564	148.7553	Discrete	2000-2001	4
41910216	Namoi River (Wetland) u/s Bugilbone	30.275	148.8167	Discrete	2000-2001	2
41910217	Old Namoi River at Bullerawa Station	30.3014	149.0667	Discrete	2000-2001	4
41910218	Namoi River (Wetland) u/s Goangra	30.1667	148.4083	Discrete	2000-2002	6
41910219	Yarrie Lake	30.37	149.5181	Discrete	2000-2000	1
41910220	Manilla River at Mandowa Bridge	30.7464	150.7128	Discrete	2000-2000	2
41910221	Manilla River u/s Borah Creek at "Pines"	30.6492	150.6572	Discrete	2000-2000	1
41910222	Baradine Creek at Coonamble Road	30.4575	148.8017	Discrete	2003-2003	2

Appendix B. Salinity Audit comparison

B.1. COMPARISON OF FLOWS AND SALT LOADS WITH AUDIT RESULTS

The flow and salt load results from the ‘first cut’ model were tested for consistency with the Salinity Audit results by comparing these results to those published in Table 5.9 of the Salinity Audit. This test for consistency is necessary for confidence in the Namoi System IQQM, to check that the model can reliably reproduce the published results from the Salinity Audit. These results were also used to develop Salinity Targets (NSWG, 2000).

In addition to the straight comparison, the effect from undertaking the modifications described in Section 5 were also compared. This enabled the effect of these modifications to be quantified, and any differences explained in the event that the Salinity Targets are revised as result of these modifications in the future.

The model results (flow and salt load) were compared to the nodes listed in Table 5.1 and Table 4.10, as well as for all gauge nodes corresponding to the balance points used for the Salinity Audit. Prior to the comparison, some results had to be combined in cases where more than one inflow node represented a Salinity Audit catchment. For all the residual catchments the results of flow and salt loads removed at the calibration nodes (shown at Figure 4.3 to Figure 4.6) were subtracted to produce net flow and salt load for that catchment.

These results are summarised in Table B.1. The shaded rows in the Table represent Salinity Audit balance points, and the other rows represent inflow points.

Table B.1. Salt transport model results compared with Audit results

Audit inflow / balance point		Mean flow (GL/year)			Mean salt load ('000 t/year)				
Number	Name	*Audit*	*1*	*2*	*Audit*	*1*	*2*	*3*	*4*
	Peel System model								
419045	Peel River at Chaffey Dam	*46.0*	45.2	48.4	*9.7*	9.9	10.6	9.9	9.9
R6	Ungauged catchment into Peel River from Chaffey Dam to Piallamore	*46.2*	60.5	60.8	*13.2*	12.3	12.3	11.5	11.0
419016	Cockburn River at Mulla Crossing	*79.9*	80.1	79.3	*13.7*	13.7	13.6	12.8	11.4
R7	Ungauged catchment into Peel River from Piallamore to Paradise Weir	*4.8*	19.7	19.4	*2.0*	1.0	0.9	0.8	1.1
419024	Peel River at Paradise Weir	*190.4*	188.3	189.7	*37.9*	33.6	34.0	31.9	30.6
419035	Goonoo Goonoo Creek at Timbumburi	*27.7*	27.4	29.9	*9.1*	9.6	10.2	9.5	9.5
R8	Ungauged catchment into Peel River from Paradise Weir to Carrol Gap	*40.4*	54.2	61.5	*12.0*	13.9	15.2	14.2	13.2
419006	Peel River at Carrol Gap	*270.9*	272.1	283.5	*79.7*	60.9	63.3	59.3	57.4
	Namoi System model								
419043	Manilla River at Tarpoly (Split R dam)	*59.4*	60.9	72.9	*19.7*	22.0	26.3	24.7	24.7
R1	Ungauged catchment into Manilla River from Split R dam to Brabri	*32.9*	32.6	38.7	*3.2*	3.4	3.9	3.7	3.7
R2	Ungauged catchment into Manilla RiveratBrabri to Namoi RatManilla Bridge		14.8	15.7		4.0	4.2	3.9	3.5
419029	Halls Creek at Ukolan	*37.1*	22.0	23.4	*6.3*	5.3	5.5	5.2	4.8
419005	Namoi River at North Cuerindi	*225.9*	226.9	248.5	*25.7*	25.7	27.8	26.1	25.9
R3	Ungauged catchment into Namoi R at Manilla Bridge to Keepit Dam	*12.0*	14.9	12.9	*4.1*	2.3	2.3	2.1	2.2
419007	Namoi River at Keepit	*302.1*	295.4	314.8	*66.4*	55.8	57.9	54.3	53.6
419006	Peel River at Carrol Gap	*270.9*	272.8	274.3	*79.7*	79.5	79.9	74.9	73.3
419027	Mooki River at Breeza	*107.3*	107.4	136.6	*33.8*	35.1	43.2	40.5	40.5
R4	Ungauged catchment into Namoi R at Keepit Dam to Gunnedah	*197.0*	197.0	242.9	*8.3*	11.7	14.7	13.7	13.7
419001	Namoi River at Gunnedah	*735.3*	712.7	787.9	*161.5*	148.9	159.5	149.5	148.1
R5	Ungauged catchment into Namoi R at Gunnedah to Boggabri		81.2	95.3	*3.0*	9.8	11.0	10.3	9.4
419032	Coxs Creek at Boggabri	*106.4*	81.2	95.3	*9.8*	9.8	11.1	10.4	9.4
419012	Namoi River at Boggabri	*768.4*	762.0	847.0	*178.6*	148.4	159.1	149.1	146.1
419051	Maules Creek at Avoca East	*21.8*	18.9	24.4	*3.1*	3.1	3.7	3.4	3.1

Notes:

(1). Direct comparison, same climate period, same conversion factor, and no concentration limit

(2). Different comparison period, same conversion factor, no concentration limit

(3). Different comparison period, lower conversion factor, no concentration limit

(4). Different comparison period, lower conversion factor, concentration limit

Peel Residuals;
R6 (Chaffey Dam to Piallamore)= inflows nodes 100 + 109 + 62 minus loss from node 68

R7(Piallamore to Paradise Weir) = inflow from node 51 minus loss node from node 52 minus loss from node 72
R8 (Paradise Weir to Carrol Gap) = inflow from node 75 minus loss from node 76

Namoi Residuals;
R1(419043 to 419020) = inflow at node 5 minus loss at node 9
R2(419020 to 419022) = inflow at node 15
R3(419022 to 419007) = inflow at node 19 minus loss at node 21
R4(419007 to 419001) = inflow at node 29 minus loss at node 32
R5(419001 to 419012) = inflow at node 57

B.2. FLOW

B.2.1. Direct comparison

At 10 gauged inflow sites 8 sites have similar inflow (within 5%) and 3 have significantly different inflow. The 3 sites are Halls Creek, Coxs Creek and Maules Creek with variation ranging from 59% to 87%. The Namoi IQQM tributary inflow have been updated since the Salinity Audit. The net inflows at 4 of the 6 residual inflow sites are different from that in the audit. This is due to the differences in the way the residuals were modelled in the audit and in IQQM.

At the 5 evaluation sites (gauged) the model flows compare very well with observed with the largest deviation being 97%.

Possible explanations for discrepancies with gauged inflows are:

Rounding errors when converting to mean annual runoff, and then back to volume.

(iii) Reporting in the Audit using only observed flow data, without gaps filled. (There is not sufficient detail in the report to assess if this is the case).

(iv) Changes to inflows used in IQQM as better data became available in HYDSYS, as may happen when rating tables are upgraded.

The results at the balance points are also slightly different between IQQM and the Salinity Audit. The differences in this case could be partially attributable to the former using observed data and the latter using modelled results, partially based on the 1993/4 MDBMC Cap scenario.

B.2.2. Climatic period

The mean annual flows for the BSMS climatic period (01/05/1975-30/04/2000) are higher for 13 of the 16 inflow points than the mean annual flows for the Salinity Audit climatic period (01/01/1975-31/12/1995). This indicates that the additional period used for the BSMS is wetter on average than the preceding twenty-one years, a conclusion supported by the higher than average rainfall in the latter years at Narrabri (Figure 2.7).

The overall modelled difference in water at the end of the system is approximately 5% at the end of the Peel River and 10% at Namoi River at Boggabri.

B.3. SALT LOADS

B.3.1. Direct comparison

In the Peel River system, the salt inflows to Chaffey Dam and Cockburn River are within 2% of that in the audit. The use of the IID relationship for the Goonoo Goonoo Creek inflow results in salt loads higher by 6%. The residual downstream of Paradise Weir (R8) is higher than that in the audit by 16%. The salt load at Carrol Gap (419006) at the end of the Peel River is lower than that in the audit by 24%.

In the Namoi River system, the salt inflows from the Peel River system were taken from the flow-salt audit relationship. The salt inflow to Split Rock Dam is higher by 12% to that in the audit. The gauged inflows are within 5% of that in the audit. Some residual salt inflows are different from that in the audit. Downstream of Keepit Dam, the salt loads are lower than that in the audit by 16%. At Gunnedah, the salt load difference is reduced to 8% due to increased salt load from residual and tributary inflows. At Boggabri, the salt load is lower by 17% than that in the audit.

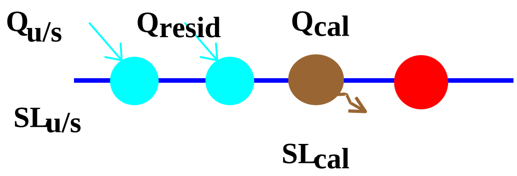
The probable reason for these differences is that the Salinity Audit relationships are applied to different time series. The basic equation for Model IIC calculates salt load using a linear relationship with flow (Equation 4.1). Referring to Figure 8.1, the Salinity Audit relationship would have been applied to the net residual inflows, i.e., after flows removed by the calibration node were subtracted (Equation 4.2). However, in IQQM the salt loads are calculated by applying the Salinity Audit relationship before flows removed by the calibration node are subtracted, and then salt loads removed by the calibration node are subtracted (Equation 4.3). The salt load removed at the calibration node is not just the salt load from the residual catchment, it also includes salt load from upstream. These differences in structure between the Salinity Audit and IQQM makes it difficult to directly compare salt load inflows for residual catchments.

$$SL = \eta + \lambda Q \quad (4.1)$$

$$SL_{resid} = \eta + \lambda (Q_{resid} - Q_{cal}) \quad (4.2)$$

$$SL_{resid} = \eta + \lambda Q_{resid} - SL_{cal} \quad (4.3)$$

Where: η, λ are salt load relationship parameters



*SL*__, *Q*__ are shown in Figure 8.1.

Figure 8.1. Schematic for calculating net salt load inflow from residual catchments in IQQM

The salt loads at the balance points in IQQM are generally lower than those reported in the Salinity Audit. This is in part because of the incompatible configurations of the residual catchments and calibration nodes.

B.3.2. Climatic period

The mean annual salt loads for the BSMS climatic period (01/05/1975-30/04/2000) are both higher and lower than the mean annual salt loads for the Salinity Audit climatic period (01/01/1975-31/12/1995). The changes result in the salt load at the evaluation points generally increasing (Carrol Gap increases from -24% to -21% and Boggabri from -17% to -11%).

B.3.3. Conversion factor

Applying a lower EC→salinity conversion factor has a predictable effect in reducing salt loads (a constant ratio of 0.9375 (or 0.60/0.64)).

B.3.4. Concentration cap

Capping the concentration has a noticeable effect on the total salt loads for most of the inflow points. These changes are mostly within the range of 0-10% lower than those in Column 3.

B.4. CONCLUSION

The direct comparison (same climate period, same EC→Salinity conversion factor, and no concentration cap) of mean annual flow results reported in the Salinity Audit and those from IQQM show only minor differences. The net difference at Namoi River at Boggabri is approximately -1%.

The direct comparison of mean annual salt loads reported in the Salinity Audit and those from IQQM showed some differences. The net difference at Namoi River at Boggabri is approximately -17%. Some probable reasons for this were put forward. Some of this difference is because of differences in flows, as well as differences in the configuration of the residual catchments and the calibration nodes.

The net mean annual flows for the BSMS Benchmark climate period was 5-10% higher than that used in the Salinity Audit. These higher flows resulted in a around a 6% increase in mean annual salt loads compared with the IQQM results however, still about –11% compared to the Salinity Audit.

These mean annual salt loads were then reduced by 6% using the lower EC→ Salinity conversion factor and a further 1% by adopting a realistic maximum concentration for the salinity inflows.

The net difference in mean annual salt loads (with all the modifications) is -18% (Namoi River att Boggabri) compared with the Salinity Audit.

Appendix C. Model Details

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

- IQQM version = 6.76.1
- System file = NamoBL01.sqq & PeelBL01.sqq (all other files needed are detailed in the system files)