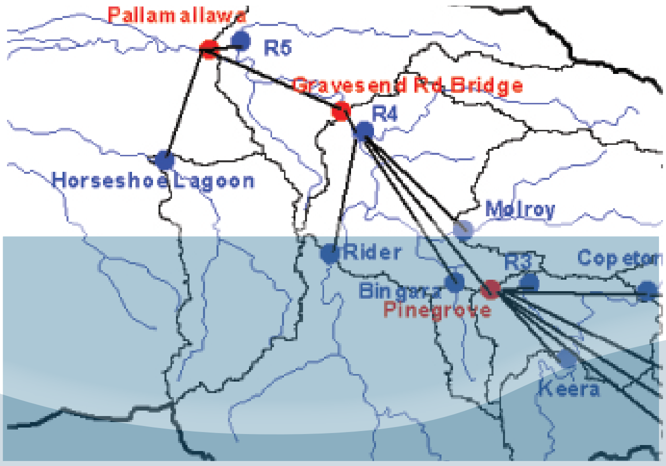
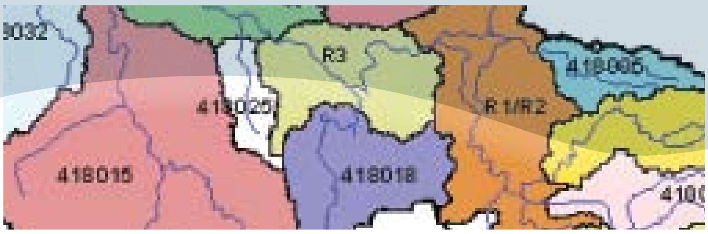
Instream salinity models of NSW tributaries in the Murray-Darling Basin

Volume 2 – Gwydir River Salinity Integrated Quantity and Quality Model





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Volume 2 – Gwydir 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 Gwydir 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 Gwydir 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 Gwydir 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 Gwydir 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 biophysical data has recently been analysed which confirm the actual extent of salinity outbreaks and current status of in-stream salinity. However, these studies have also cast serious doubt on trends predicted using rising groundwater extrapolations (DECC 2006). A concerted effort to improve understanding of the extent of salinity, and its relationship with climatic regime and groundwater behaviour in the hydrological cycle in different contexts, has shown inconsistencies with the general regional rising water tables theory (Summerell et al. 2005).

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

1.3. CURRENT POLICY FRAMEWORK

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

1.3.1. MDBC Integrated Catchment Management

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

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

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

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

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

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

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

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

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

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

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

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

1.3.3.1. Schedule C of the Murray-Darling Basin Agreement

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

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

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

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

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

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

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

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

1.3.4. Catchment Action Plans

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

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

1.3.5. NSW Water Sharing Plans

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

1.3.6. NSW Salinity Strategy

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

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

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

1.3.7. NSW Environmental Services Scheme

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

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

1.3.8. CMA Incentive schemes

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

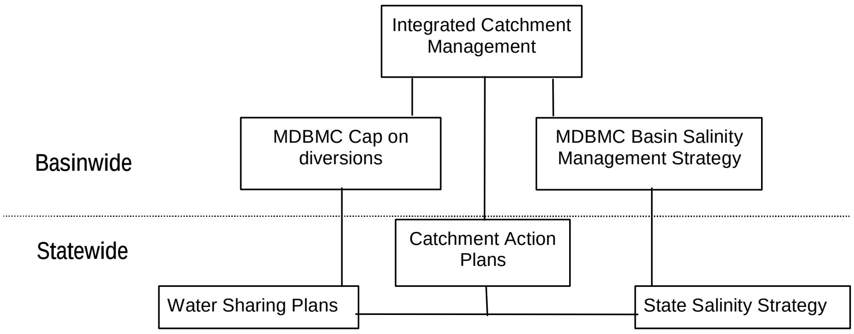


Figure 1.1. Relationship of Basinwide and Statewide policies and plans

1.4. DWE MODEL FRAMEWORK

NSW has developed a framework of models that link the surface water hydrology and salinity processes to support salinity management. A range of processes are represented in models that vary from the property scale to the basin scale. The scale of application of a model, in both spatial sense and temporal sense, influences the model structure and detail. Aspects of natural processes that are important at one scale may not matter at another. Figure 1.2 shows the linkages between the surface water and salinity models, their application at different scales and the desired outcomes of within valley and end of valley salinity targets.

1.4.1. Objectives of modelling

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

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

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

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

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

1.4.2. Modelling requirements

The modelling had the following requirements:

- Daily predictions

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

1.4.3. Strengths and Limitations

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

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

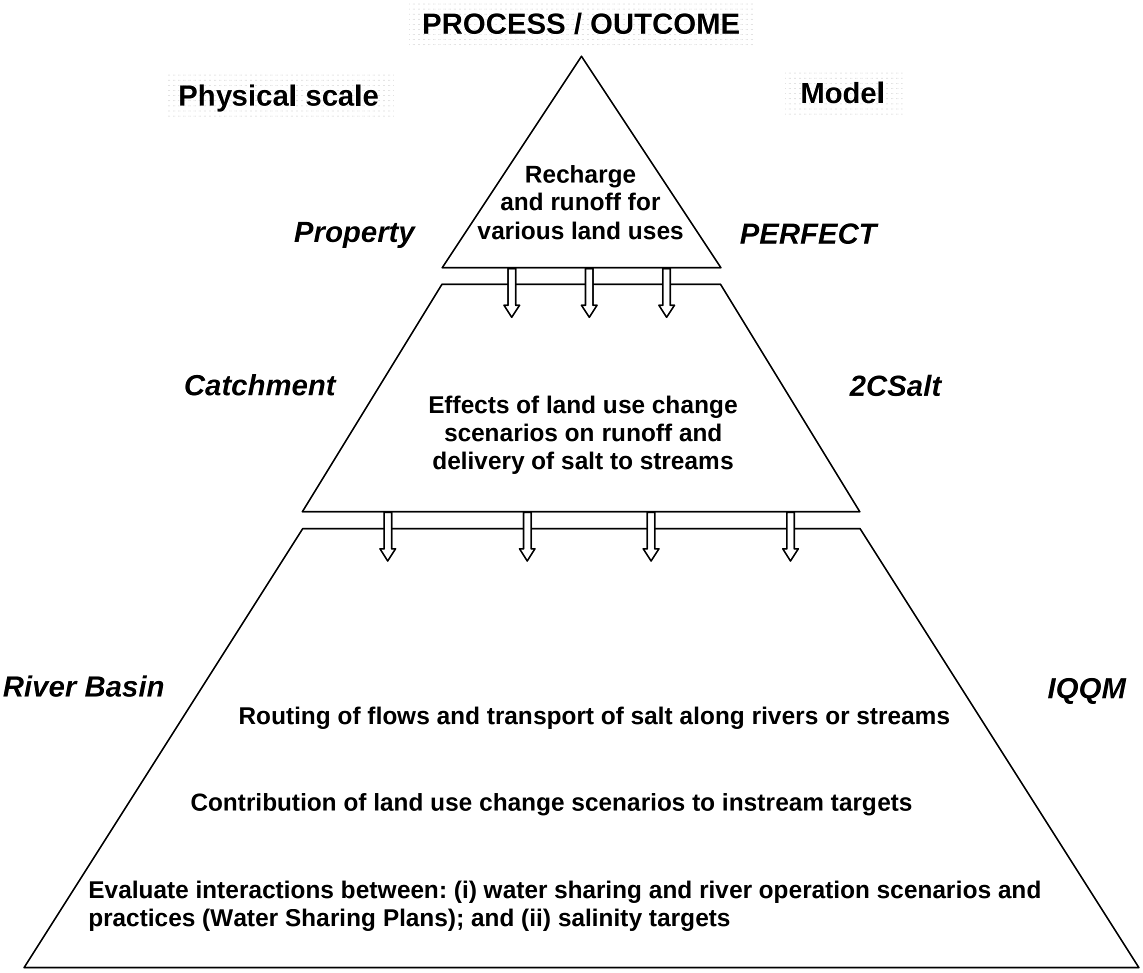


Figure 1.2. Applications and linkages of DECC and DWE models at different scales

1.5. STAGED MODEL DEVELOPMENT

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

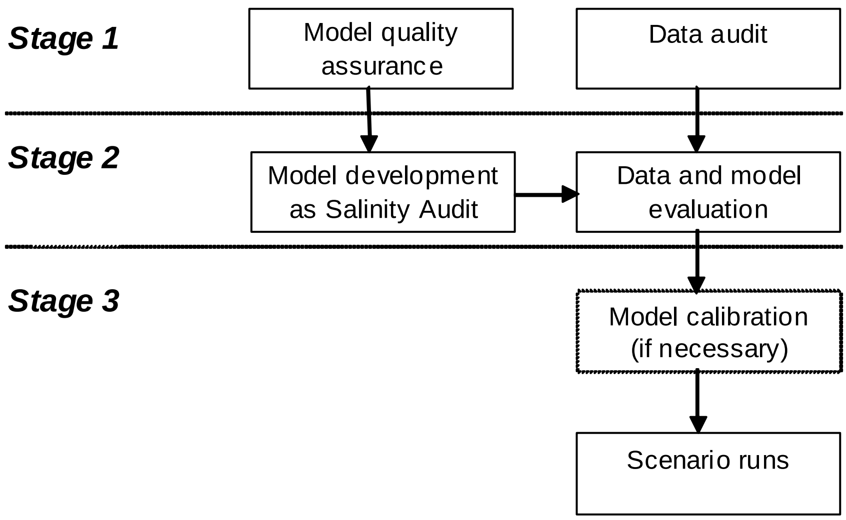


Figure 1.3. Stages of model development

1.5.1. Stage 1: Model QA and Data Audit

The existent IQQM that had been configured and calibrated for the Gwydir 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 Gwydir System

2.1. PHYSICAL FEATURES OF THE CATCHMENT

2.1.1. General

The Gwydir River Valley is located in the Murray Darling Basin, west of the Great Dividing Range in northern NSW. It is bounded by Mastermans Range to the north, the Great Dividing Range to the east and the Nandewar Range to the south. Extending over 310 km from Guyra in the east to Collarenebri in the west, the basin covers a total area of 25,900 square km.

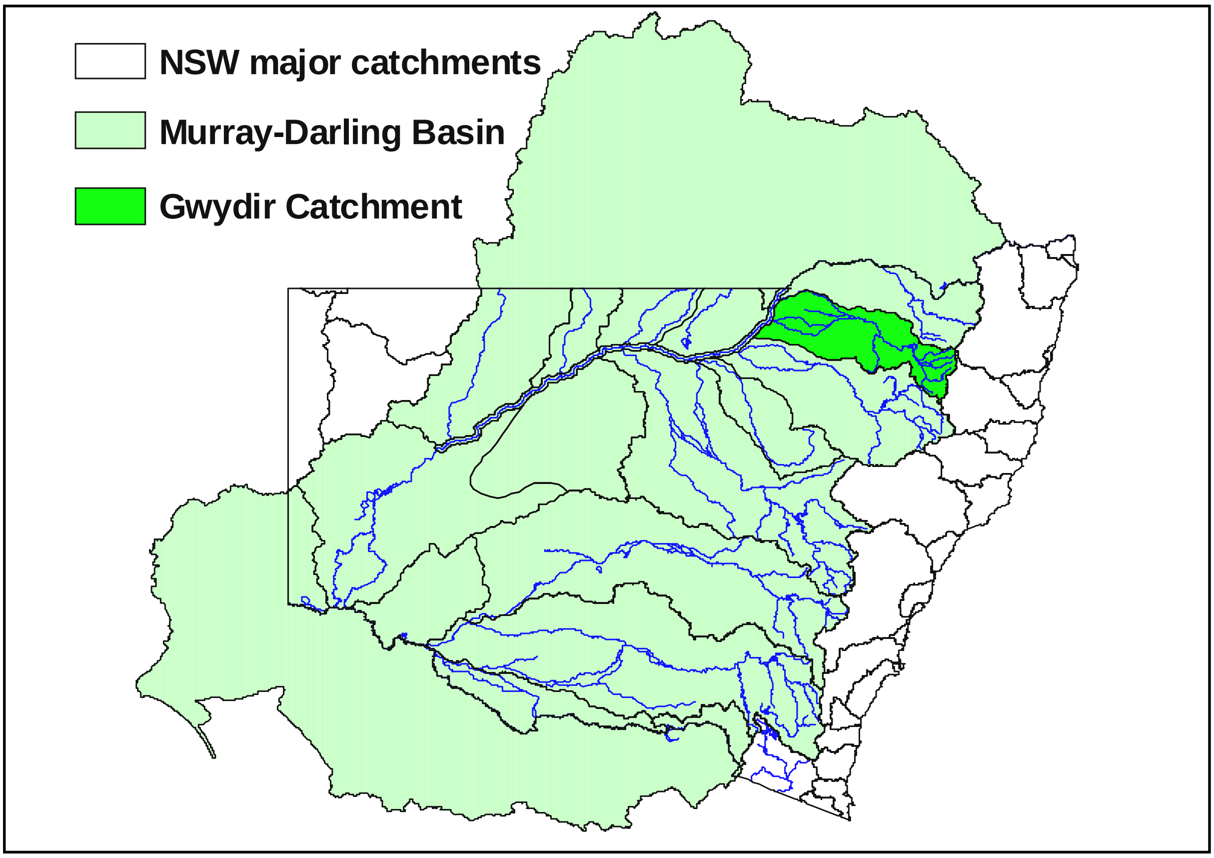


Figure 2.1. Relationship of the Gwydir catchment to the Murray-Darling Basin

The Gwydir valley has a total catchment population of 23,487. The major towns within the valley are:

- Moree (population: 10,000)
- Uralla (population: 2300)
- Guyra (population: 2000)
- Warialda (population: 1285)
- Bingara (population: 1250)
- Collarenebri (population: 600)

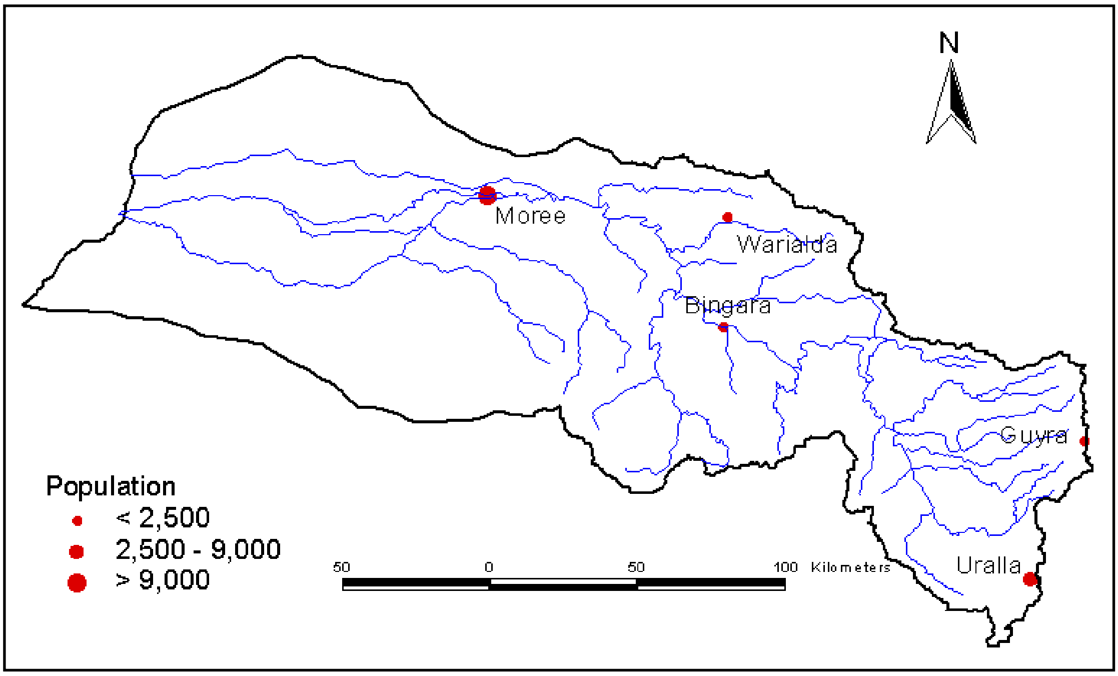


Figure 2.2. Cities and towns in the Gwydir catchment.

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

(i) Gwydir River upstream of Copeton Dam (headwater source region)

(ii) Gwydir River from Copeton Dam to Gravesend (region of major tributary inflow).

(iii) Gwydir River from Gravesend to Collymongle (region of extraction and inflow to Barwon River.) Mehi River from Moree to Collarenebri (region of major extraction and inflow to Barwon River.)

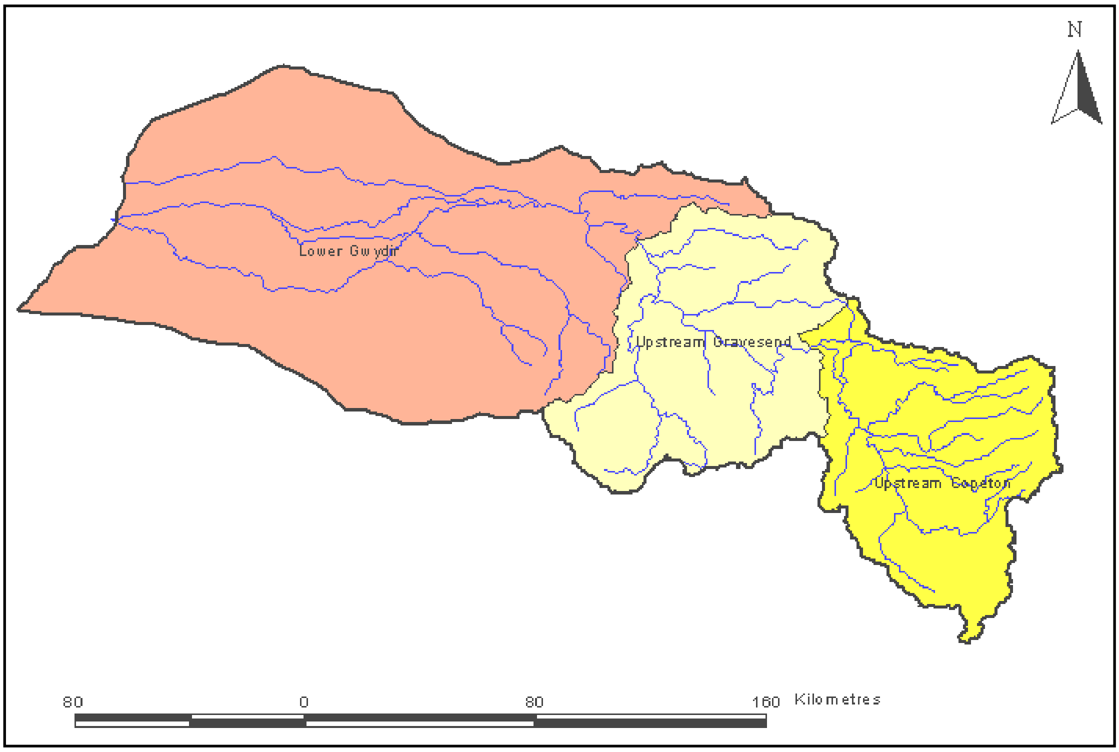


Figure 2.3 Major regions of Gwydir Catchment

2.1.2. Stream network

2.1.2.1. Gwydir River Upstream of Copeton Dam

The headwater inflows of the Gwydir catchment emerge between Uralla and Guyra in the New England Tablelands at an elevation of 1,050 metres above sea level. The main tributaries contributing to the river above Copeton Dam are Copes Creek, Moredun Creek, Georges Creek, Laura Creek, Bakers Creek, and Copes Creek.

2.1.2.2. Gwydir River from Copeton Dam to Gravesend

Between Copeton Dam and Gravesend, the Gwydir River flows westward linking five major catchments through Keera Creek, Halls Creek, Horton River, Myall Creek, and Warialda Creek. There are no more major inflows to the Gwydir catchment beyond Gravesend.

2.1.2.3. Gwydir River from Gravesend to Collymongle

After leaving the highlands the Gwydir river becomes a slow moving river with well-developed and complex pattern of effluents, anabranches, and tributaries. The lower Gwydir Basin below Moree forms an inland terminal delta resulting in an alluvial fan of 20,000 ha (DLWC,1999). This region is referred to as The Gwydir Valley wetlands. The wetlands absorb much of the flow during normal climatic conditions, largely restricting the amount of water contributing to the Barwon-Darling system. During flood-events, however the floodplain becomes inundated at water freely flows into the Barwon River at a number of locations in the wetlands.

2.1.2.4. Mehi River from Moree to Collarenebri

The Mehi River takes the majority of the flow from the Gwydir River 30km upstream of Moree. Other anabranches and effluent streams include Moomin, Mallowa and Gingham Creeks.

2.1.3. Hydrometeorology

2.1.3.1. rainfall

Annual rainfall varies from around 900mm at the top of the catchment to 450mm in the west. Rain is generally summer dominant and summer storms may cause severe flooding and erosion (Figure 2.1.3.2). Winter flooding may also occur if soils remain saturated after summer rains. Figure 2.1.3.3 shows the annual distribution of rainfall at Gravesend over the baseline period of 1975 to 2000.

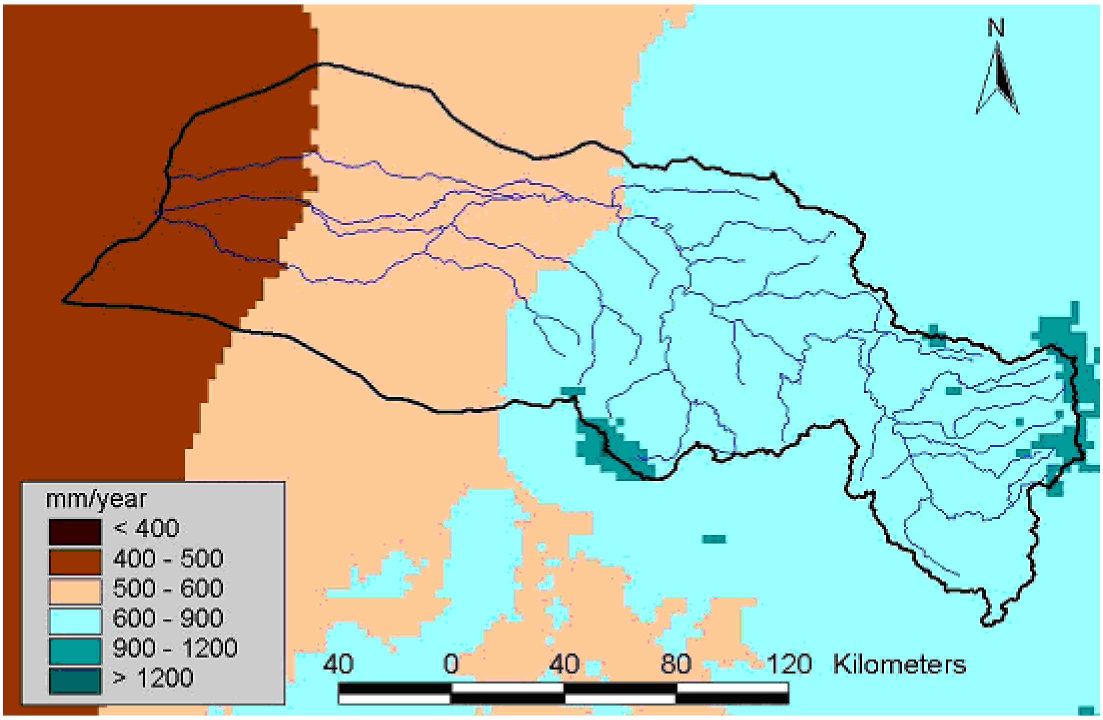


Figure 2.4. Average annual rainfall in Gwydir catchment

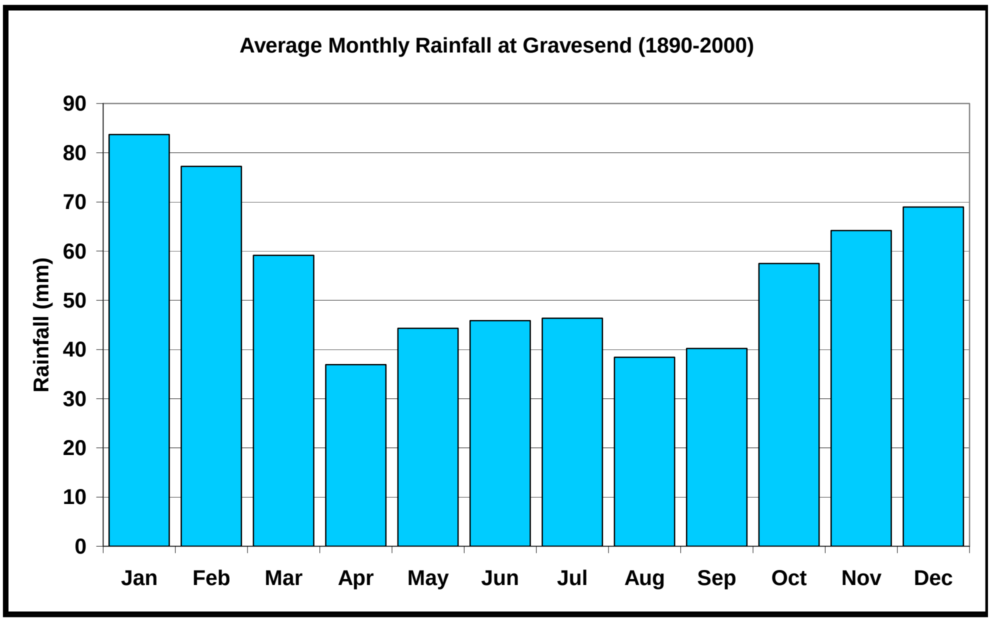


Figure 2.5. Average monthly rainfall at Gravesend 1890-2000.

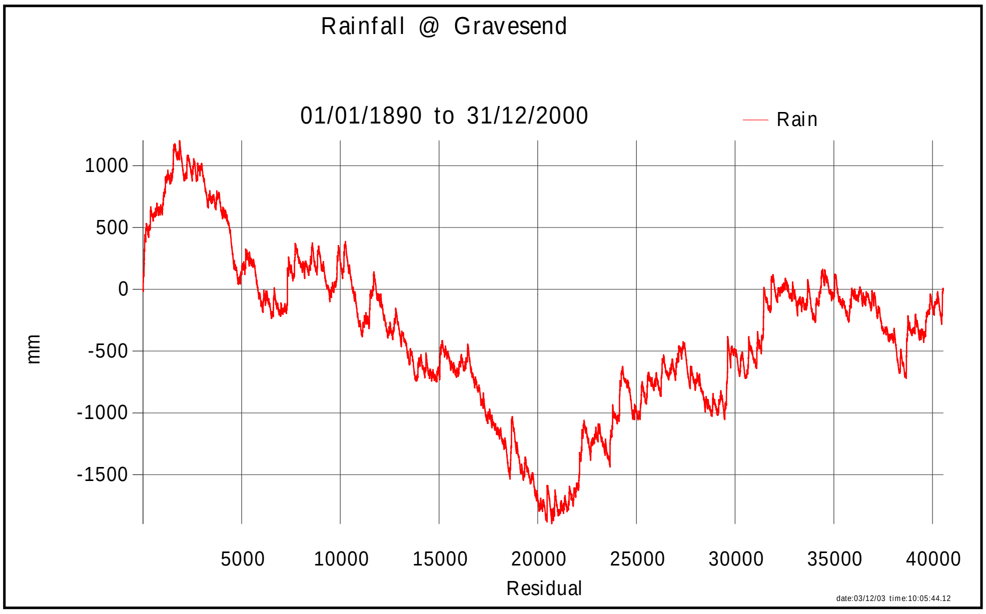


Figure 2.6. Residual mass curve of rainfall at Gravesend

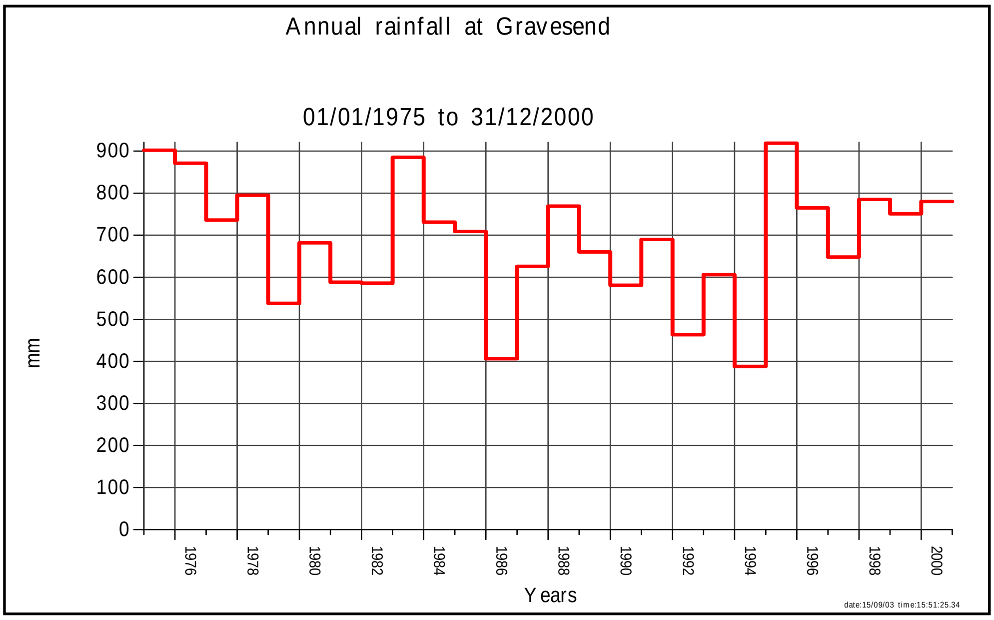


Figure 2.7. Annual rainfall at Gravesend 1975-2000

2.1.3.2. Evaporation

Pan evaporation in the Gwydir catchment has a strong east-west gradient (Figure 2.8). Average Class A pan evaporation varies from around 1200 mm/year in the south-east, to over 1750 mm/year in the north-west. Pan evaporation is also strongly seasonal, varying from around 2-3 mm/d during June/July at Moree, to around 9-10 mm/d during December/January.

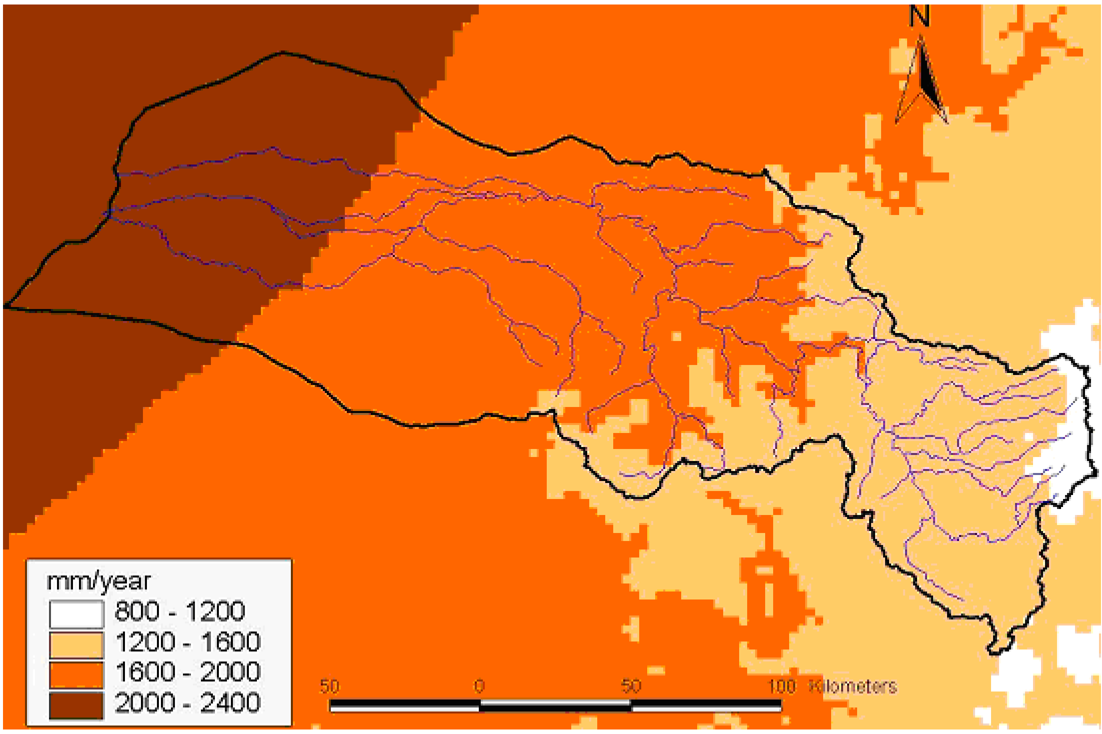


Figure 2.8 Average annual Class A Pan evaporation in the Gwydir valley (1973-1995)

2.1.3.3. Flow

The following table outlines average annual flows from the major catchments in the Gwydir catchment.

Table 2.1. Average annual flows in Gwydir

Tributary / catchment	Average annual inflow (GL/year)
Copeton Dam	488
Keera Creek	40
Myall Creek	38
Horton River	195
Warialda Creek	23
Tycannah Creek	34

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 Gwydir River. Salt from groundwater can enter the river system by two pathways: (i) capillary rise from shallow water tables and mobilisation in surface runoff; or (ii) groundwater discharge directly into the river system. The surface water groundwater interaction can also see salt leave the river system to the groundwater by recharge.

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.

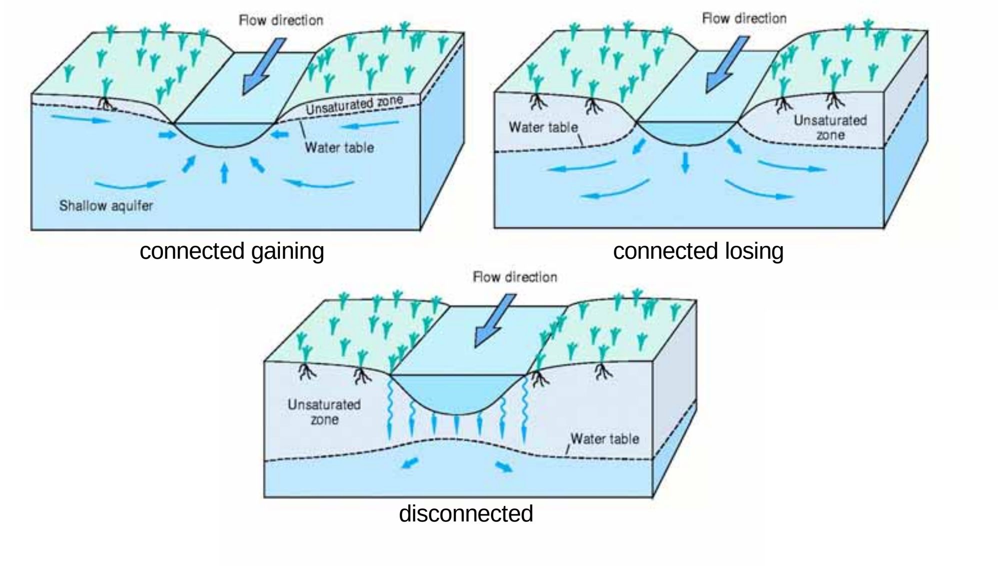


Figure 2.9. Types of river reach with respect to groundwater interaction
(*after Gates and Braaten, 2002*)

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 Gwydir and Mehi Rivers downstream of Moree.

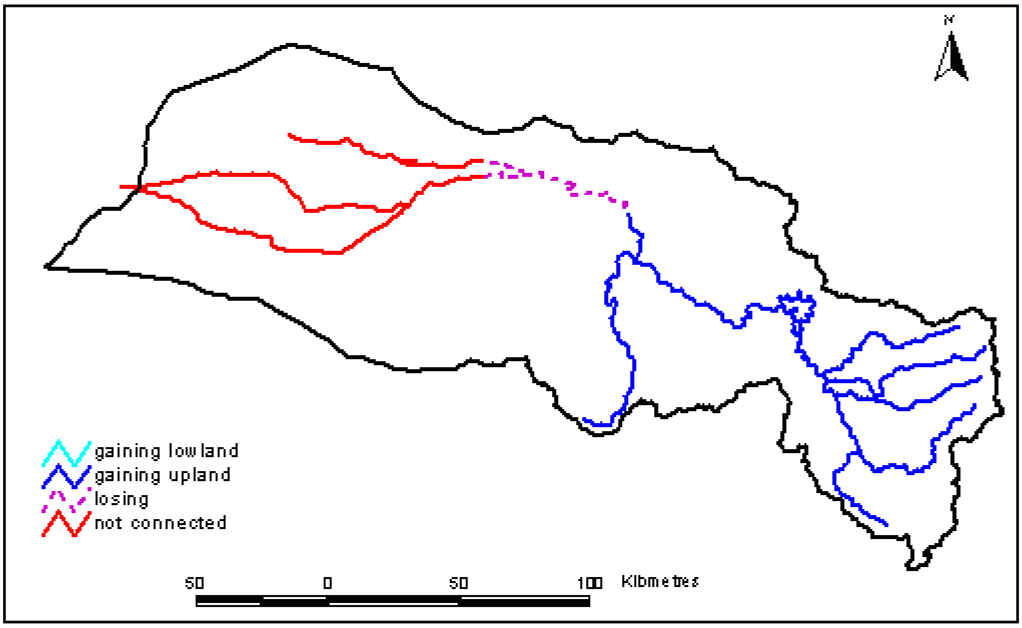


Figure 2.10. Hydraulic connection

2.1.5. Vegetation and Land Use

Table 2.2 Summary of Land Use in the Gwydir Valley

Land Use Description	Total Extent ('000 ha)	Percentage
Nature conservation / minimal use	394	15
Livestock grazing	1,530	58
Forestry	39	2
Dryland agriculture	620	23
Irrigated agriculture	730	3
Built environment	2	< 1
Water bodies not elsewhere classified	1	< 1

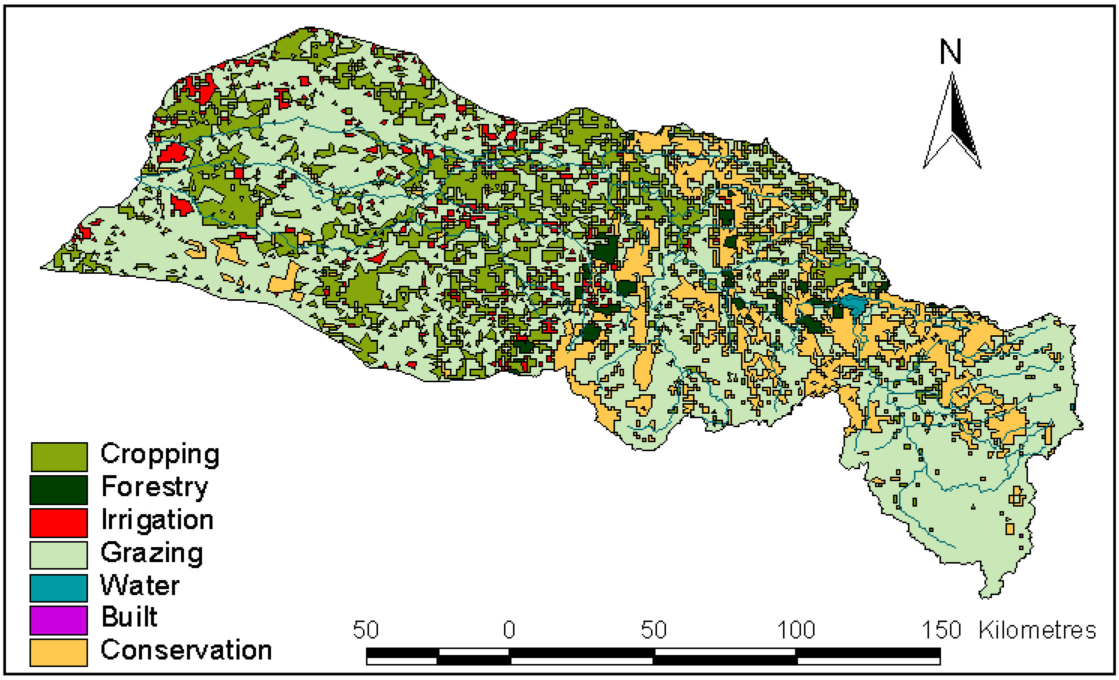


Figure 2.11 Landuse in Gwydir catchment

Land use in the Gwydir catchment is dominated by extensive agriculture (Table 2.2) with nearly three-fifths of the catchment used for grazing, and approximately one-quarter for dryland crops. Irrigated crops, while economically important, cover just three percent of the catchment area, and forests and conservation areas combined about seventeen percent.

The grazing land is distributed throughout the catchment, and features heavily in all the regions (Figure 2.11). Dryland agriculture is located downstream of Copeton Dam, with a heavy distribution through the Upper Mehi, and the Lower Gwydir region. Forest areas are concentrated in the Middle to Upper Gwydir Region.

The Gwydir catchment has seen much change in it's vegetation since the 1830s. There are many influential factors on vegetation: geology and soils, climate (particularly rainfall and temperature) and altitude. In the north-west of NSW, geology and climate are the dominant influencing factors on vegetation communities. Due to extensive clearing, much of the original vegetation only exists as remnants on the poorer agricultural land (Roberts, 2001).

2.2. WATER RESOURCE MANAGEMENT

The Gwydir River system is operated (or regulated) to meet the needs of water users and the environment in the river from Copeton Dam to the junction with the Barwon/Darling above Collarenebri. The water storage at Copeton Dam (1,3644 GL) plus a number of re-regulation and/or diversion weirs are operated by DWE to meet user needs. Where possible the tributary inflows from the Keera Creek, Halls Creek, Myall Creek, Horton River, and Warialda Creek are utilised before dam releases are made.

The major water users in the Gwydir River are general security irrigators with an annual entitlement of 510 GL. General security irrigators needs are meet 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 150% 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.

Under the continuous accounting system, DWE maintains a reserve plus a working account (to cover transmission and operation losses) within Copeton Dam to ensure the security of water users. The reserve is used to meet the essential commitments of the system, including town water supply, high security irrigation, stock and domestic needs, and environmental flows. An environmental contingency allowance (ECA) of 25 GL is also available in Copeton Dam.

About 22 GL of high security entitlement exists within the valley including town water supply needs and high security irrigation. Minimum flow requirements are in place downstream of Copeton Dam. Stock and domestic flow replenishment flow rules are also in operation for the Gingham, Lower Gwydir, Mallawa, Thalla and Ballinboora Creek systems.

When flows in the river are greater than orders, access to this surplus water is declared. During these times, irrigators can divert water from the river without debit to their account. Because of the large volume of on-farm storages in the Gwydir Valley and subsequent competition for surplus water, DWE attempts to equally share surplus water. Under 1999/2000 conditions there was no limit to the volume of surplus water that could be diverted each year.

Environmental flow rules were introduced in the Gwydir Valley in 1998 to share surplus water. DWE, in consultation with water users, introduced flow rate thresholds to protect low flow and determine surplus water access. For each individual surplus flow event, irrigators are only allowed to access 50% of the surplus flow volume with the other 50% remaining in the river for environmental use.

2.3. SALINITY IN CATCHMENT

Salinity is currently not as great a threat in the Gwydir catchment as it is in other catchments in NSW. The most likely reason for this is that the Gwydir catchment was developed for intensive agricultural production more recently than southern catchments (Gwydir Catchment Blueprint). However unless resource management practices are changed, modelling has indicated that salinity is likely to increase over time.

Known occurrences of dryland salinity in the Gwydir catchment as identified by aerial photo interpretation are shown in Figure 2.12. These are heavily concentrated in the upper part of the Gwydir region, in the Roumalla Creek and Rocky River catchments.

Salt loads from subcatchments in the Upper Gwydir, and the Copeton Dam to Pallamallawa reach were estimated as part of the Salinity Audit (Beale et al., 1999), and are mapped in Figure 2.13. The highest salt loads (17-30 t/sq.km) enter the system from the west via Horton River, Halls Creek and Keera Creek. This region has a high runoff/area ratio, and salinity concentrations are also high in these subcatchments. The distribution of salt loads for this location do not appear to reflect the known occurrences map (Figure 2.12). This could be because of either:

- occurrences of dryland salinity have not been mapped as comprehensively in this catchment; or
- a good portion of the salt in this catchment comes from baseflow.

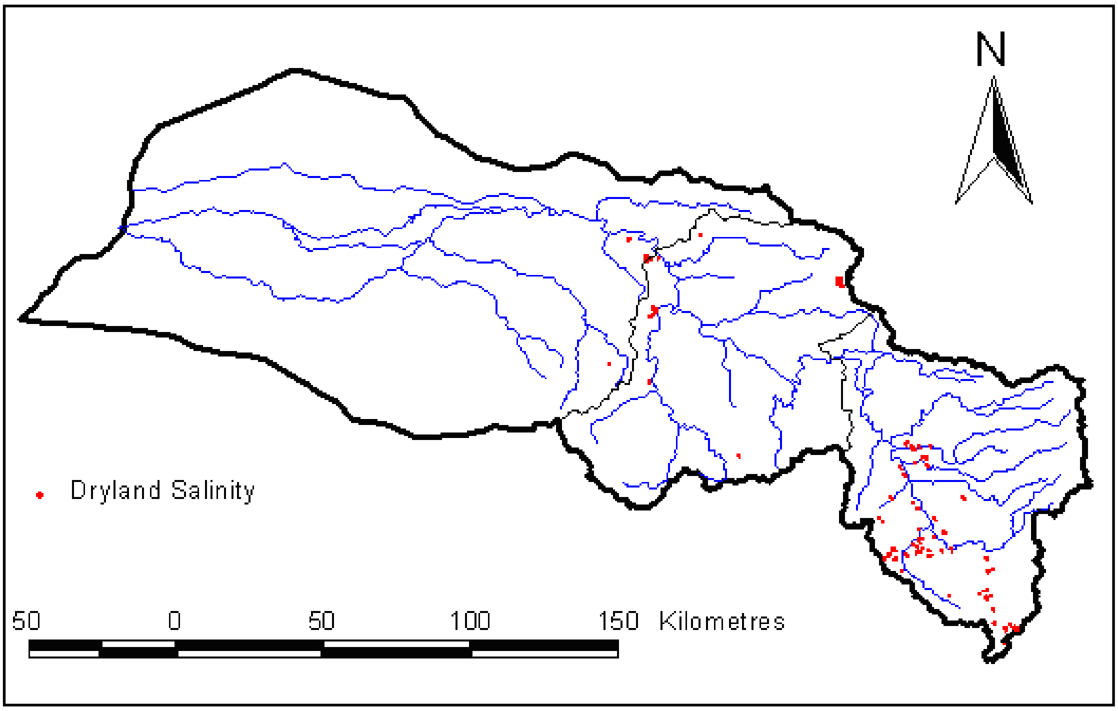


Figure 2.12. Dryland salinity occurrences in Gwydir catchment

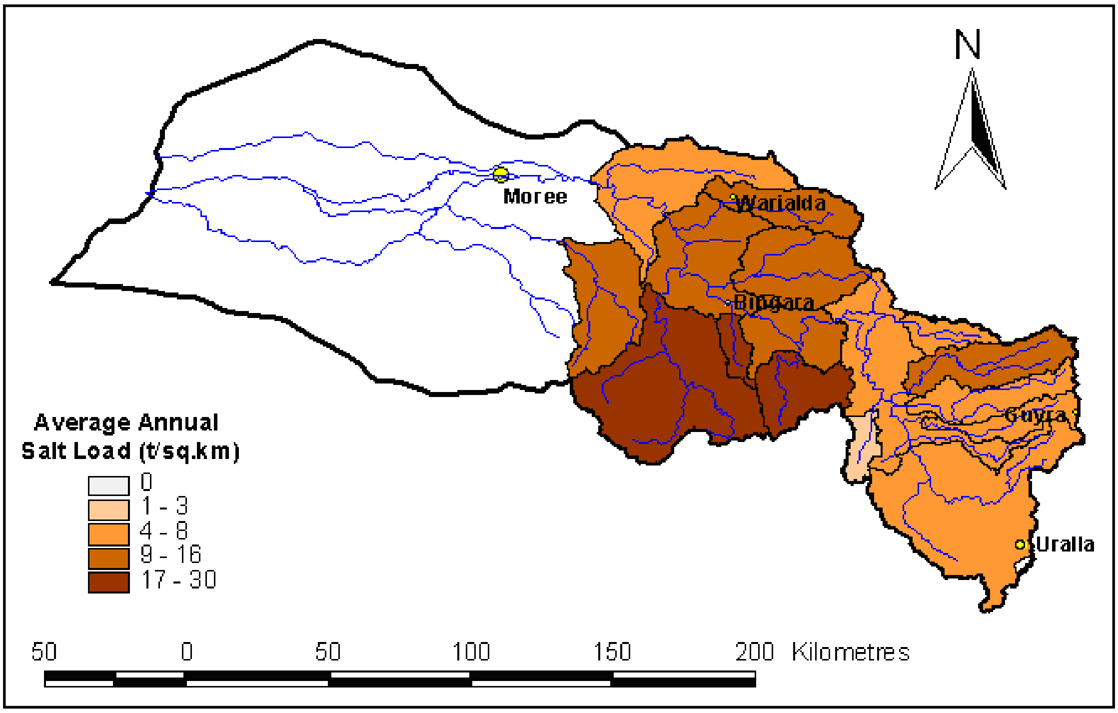


Figure 2.13 Modelled average annual salt load (tonnes/km^2) from Gwydir River catchment

3. Salinity data

3.1. AVAILABLE DATA

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

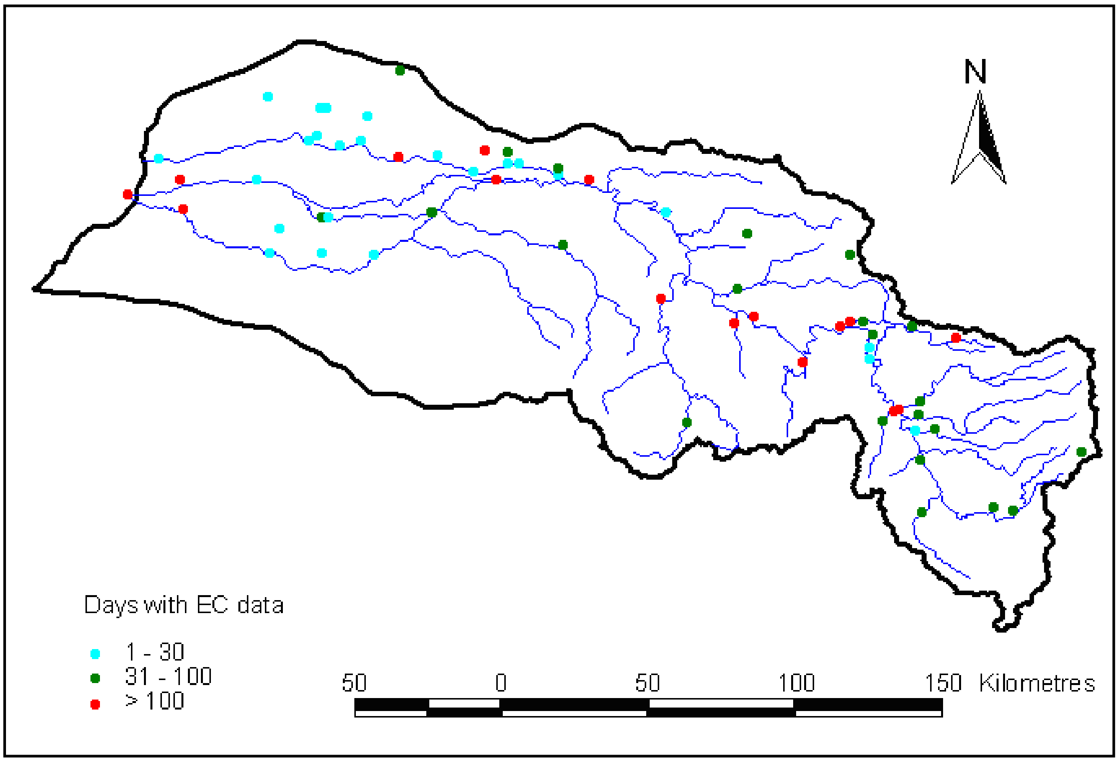


Figure 3.1. Location and record length size for discrete EC data stations

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 69 total reported in Appendix A, 37% have less than 30 data points, and 27% have more than 100 data points. Many of these data sets with a small number of points are concentrated in the lower Gwydir Region (Figure 3.1), ie most of the catchment has poor data. The other data sets look to give a good coverage across the whole catchment, although the Upper Gwydir region does not appear to have many data sets with more than 100 points.

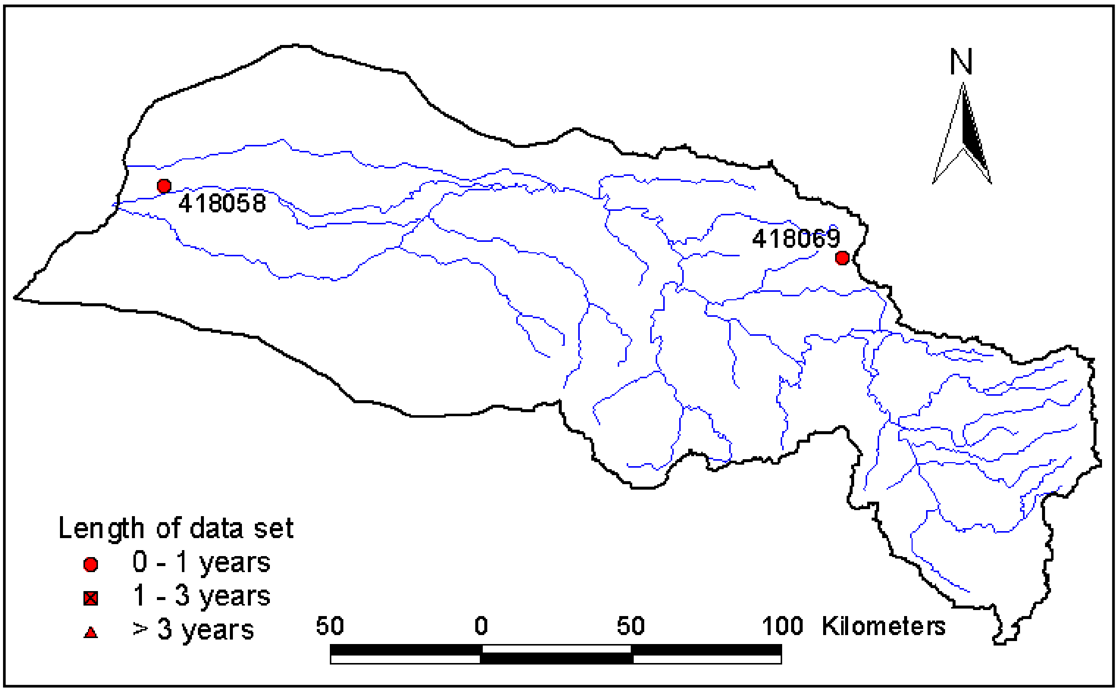


Figure 3.2. Location and record length for continuous EC data stations

The Gwydir River System has a poor coverage of continuous stations compared with most other NSW MDB valleys. Both of the stations have less than one year of data, and only one corresponds to a node in the Gwydir IQQM.

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. A total of twenty-five of the sixty-nine stations with discrete EC data can potentially be 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. There are eleven such stations with discrete EC data in this list (Table 3.1). This data was screened to remove outliers and observations on days with no flow records. A further fourteen stations with discrete EC data are also located at points that could be used to evaluate model results (Table 3.2)

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 catchments such as Myall Creek (Station No. 418017), Halls Creek (418025) and Warialda Creek (418016) contribute moderate quantities of high salinity water. The Horton River (418015) produces significant amounts of moderate salinity water, and the Gwydir River at Stonybatter (418029) contributes large amounts of low salinity water.

The longitudinal overview of median salinities (Figure 3.4) shows the major catchments in the upper Gwydir (above Copeton Dam) have very low median concentrations. This fresh water is transferred to the storage which has an outflow median concentration of just 90 mg/L. Further downstream the concentrations in the main river increase dramatically with high concentrations (and salt load) entering from Myall, Warialda and Halls Creek. These catchments have median salinities of 648, 502 and 650 mg/L respectively.

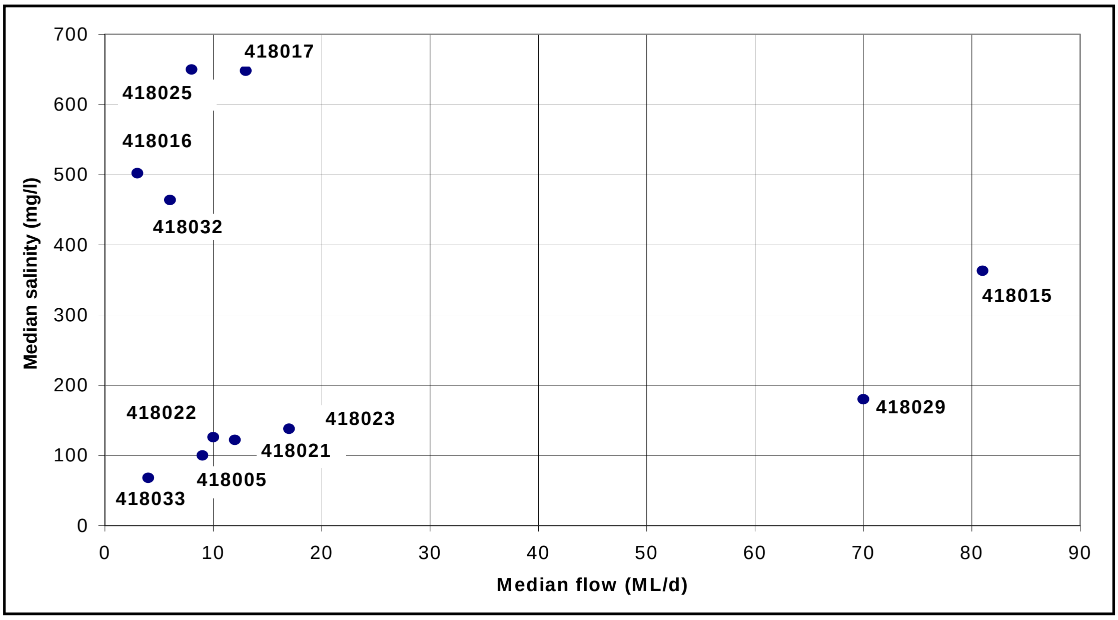


Figure 3.3. Median salinity versus median flow for inflow sites with discrete EC data

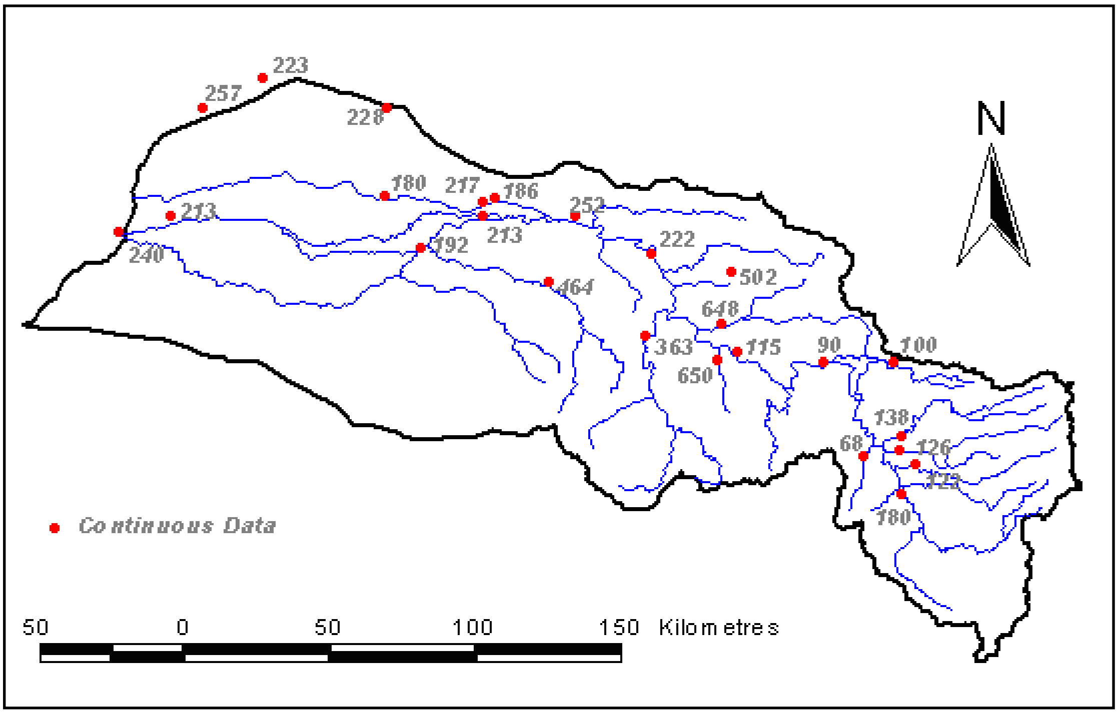


Figure 3.4. Median salinity along main stream

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

Station Number	Station Name	Data use	Data points removed <15 µS/cm	Data points removed zero or missing flow	Data points removed outliers	Final data days
418005	Copes Creek @ Kimberley	Inflow	0	9	0	84
418015	Horton River @ Rider (Killara)	Inflow	2	12	2	252
418016	Warialda Creek @ Warialda No.3	Inflow	0	21	0	65
418017	Myall Creek @ Molroy	Inflow	0	9	0	58
418021	Laura Creek @ Laura	Inflow	0	51	0	46
418022	Georges Creek @ Clerkness	Inflow	0	55	0	40
418023	Moredun Creek @ Bundarra	Inflow	0	8	0	47
418025	Halls Creek @ Bingara	Inflow	0	2	0	108
418029	Gwydir River @ Stonybatter	Inflow	0	43	0	42
418032	Tycannah Creek @ Horseshoe Lagoon	Inflow	0	3	0	84
418033	Bakers Creek @ Bundarra	Inflow	0	35	0	56

All stations are discrete data

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 <15 µS/cm	Data points removed zero or missing flow	Data points removed outliers	Final data days
416027	Gil Gil Creek @ Weemelah	Evaluation	0	7	0	73
416052	Gil Gil Creek @ Galloway	Evaluation	0	31	0	114
418001	Gwydir River @ Pallamallawa	Evaluation	0	1	0	131
418002	Mehi River @ Moree	Evaluation	0	68	0	94
418004	Gwydir River @ Yarraman Bridge	Evaluation	0	35	0	296
418011	Carole Creek @ D/S Regulator(Bells Crossing)	Evaluation	0	0	0	62
418012	Gwydir River @ Pinegrove	Evaluation	0	22	0	145
418013	Gwydir River @ Gravesend Road Bridge	Evaluation	0	31	0	302
418026	Gwydir River D/S Copeton Dam	Evaluation	0	15	0	220
418031	Gwydir River @ Collymongle	Evaluation	0	2	0	18
418048	Moomin Creek @ Combadello Cutting	Evaluation	0	0	0	56
418052	Carole Creek @ Near Garah	Evaluation	0	1	0	44
418053	Gwydir River @ Brageen Crossing	Evaluation	0	178	0	103
418055	Mehi River @ Near Collarenebri	Evaluation	0	27	0	92
418058	Mehi River @ Bronte	Evaluation	0	40	0	217

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*		
No continuous gauges were used for the Gwydir Valley						

Table 3.4. Cumulative distribution statistics of screened EC data sets

Station Number	Station name	Data type	Data use	Salinity statistics mg/L C_{25}	C_{50}	C_{75}	Q_{50} ML/d
416027	Gil Gil Creek @ Weemelah	Discrete	Evaluation	300	223	149	55
416052	Gil Gil Creek @ Galloway	Discrete	Evaluation	326	257	164	25
418001	Gwydir River @ Pallamallawa	Discrete	Evaluation	339	252	151	732
418002	Mehi River @ Moree	Discrete	Evaluation	265	213	156	369
418004	Gwydir River @ Yarraman Bridge	Discrete	Evaluation	279	217	162	172
418005	Copes Creek @ Kimberley	Discrete	Inflow	128	100	71	9
418011	Carole Creek @ D/S Regulator(Bells Crossing)	Discrete	Evaluation	282	186	129	110
418012	Gwydir River @ Pinegrove	Discrete	Evaluation	166	115	104	452
418013	Gwydir River @ Gravesend Road Bridge	Discrete	Evaluation	285	222	157	711
418015	Horton River @ Rider (Killara)	Discrete	Inflow	442	363	292	81
418016	Warialda Creek @ Warialda No.3	Discrete	Inflow	569	502	404	3
418017	Myall Creek @ Molroy	Discrete	Inflow	778	648	504	13
418021	Laura Creek @ Laura	Discrete	Inflow	186	122	91	12
418022	Georges Creek @ Clerkness	Discrete	Inflow	198	126	93	10
418023	Moredun Creek @ Bundarra	Discrete	Inflow	180	138	101	17
418025	Halls Creek @ Bingara	Discrete	Inflow	684	650	582	8
418026	Gwydir River D/S Copeton Dam	Discrete	Evaluation	118	90	77	251
418029	Gwydir River @ Stonybatter	Discrete	Inflow	234	180	128	70
418031	Gwydir River @ Collymongle	Discrete	Evaluation	285	235	187	0
418032	Tycannah Creek @ Horseshoe Lagoon	Discrete	Inflow	503	464	356	6
418033	Bakers Creek @ Bundarra	Discrete	Inflow	81	68	57	4
418048	Moomin Creek @ Combadello Cutting	Discrete	Evaluation	252	192	134	121
418052	Carole Creek @ Near Garah	Discrete	Evaluation	315	228	128	72
418053	Gwydir River @ Brageen Crossing	Discrete	Evaluation	250	180	140	56
418055	Mehi River @ Near Collarenebri	Discrete	Evaluation	306	240	182	49
418058	Mehi River @ Bronte	Discrete	Evaluation	291	213	143	30

4. The Gwydir IQQM

4.1. QUANTITY MODEL

The Gwydir IQQM covers the Gwydir River from Copeton Dam to its confluence with the Barwon River. It also covers three major river sub-systems including Carole Ck, Gwydir/Gingham downstream of Yarraman and the Mehi – Moomin river systems. The Gwydir IQQM is a very complex model with more than 250 nodes representing 19 different node sub-types. These represent a variety of the natural system configuration and the human-influenced processes associated with water resources management in the Gwydir Valley. A full description of the features and calibration of the Gwydir River IQQM is presented in Sivkova and O'Neill (2003).

4.2. GWYDIR SYSTEM

The IQQM began implementation in the Gwydir Valley to perform long-term simulations for different scenarios in 1997. The model has since been refined on several occasions to incorporate the latest data and model capabilities and also to enable it to handle emerging water management modelling needs. Further refinements were anticipated during the course of this project to improve its capability to reliably model salt inflows and transport. The overall structure of the initial Gwydir System IQQM is shown in Figure 4.1.

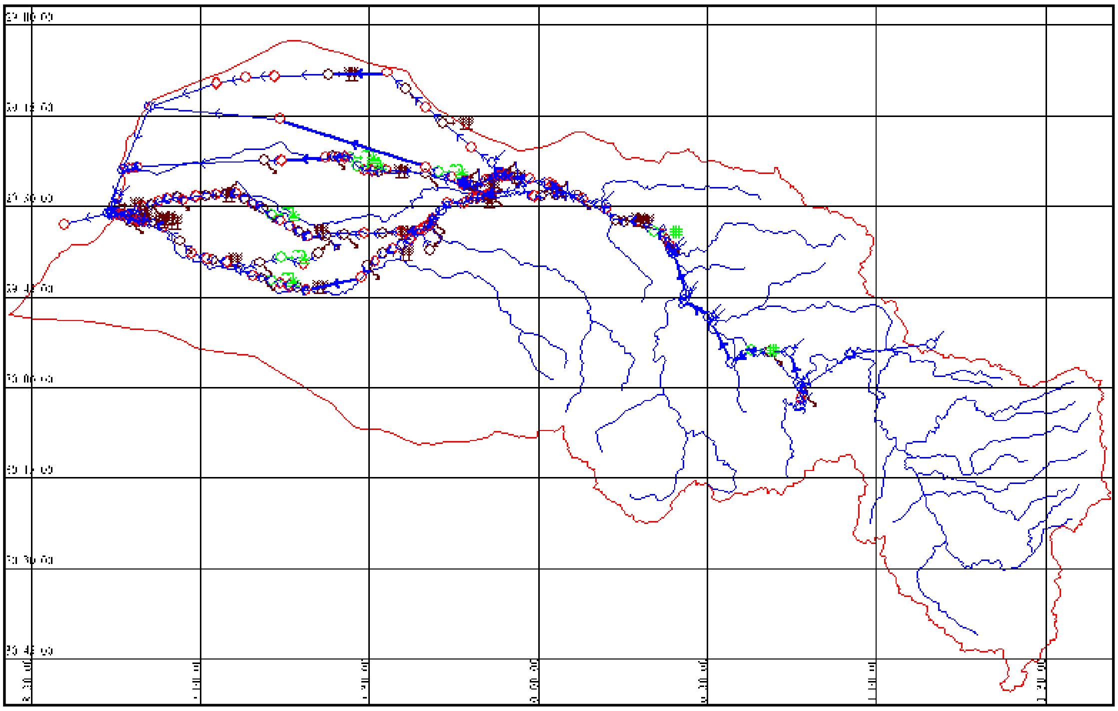


Figure 4.1. Schematic Gwydir System IQQM

This figure is only meant to present an overview of the Gwydir System IQQM. The complexity of the Gwydir System IQQM is such that the detail cannot be presented effectively 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 (Figure 4.2 to Figure 4.4)
- storages (Figure 4.5)

- irrigation demands (Figure 4.6), and
- instream and environmental nodes (Figure 4.7)

The features of the Gwydir System IQQM are discussed in Sections 4.2.1 to 4.2.4.

4.2.1. Inflows and calibration

The Gwydir System IQQM uses a total of twenty-eight inflow nodes to represent head-water storage inflows (one), gauged inflows (seven), residual inflows (fourteen) and water management processes in the system (six). The model includes thirty-three gauge nodes used in flow calibration along the main stream. The magnitude and distribution of these inflow nodes is shown in Figure 4.2 to Figure 4.4.

Most of the total unregulated inflow of about 762 GL/year in the Gwydir IQQM (56%) comes into the system between the Copeton Dam and Gravesend gauge (418013). Almost 60% of that inflow is gauged and is comprised of the flow from five tributaries, namely Keera Creek (13%), Halls Creek (2%), Myall Creek (13%), Warialda Creek (8%) and Horton River (64%).

Gauged inflow nodes and associated residual inflow nodes in the Gwydir IQQM are followed by an flow calibration node to calibrate mass balance and distribution of flows of recorded flows, eg., at Gravesend gauging station. The flow calibration at Gravesend indicated fairly insignificant losses up to that point in the system (<4% of total flows). There is only one another inflow node above Pallamallawa. This node represents the residual inflow of about 16 GL/year between Gravesend and Pallamallawa. There is also a loss in this reach of approximately 6% of total flows.

In contrast, the rest of the Gwydir System has more loss nodes and fewer inflow nodes. There are eight inflow nodes in the system downstream of Pallamallawa, five of which are in the Mehi-Moomin sub-system, two in the Carole sub-system, and one in the Lower Gwydir. All of these nodes represent residual inflows in the corresponding part of the catchment. By contrast, there are twenty-eight loss nodes in the system downstream of the Pallamallawa gauge. This high number was needed to achieve good calibration of flow, and therefore, better represent availability of water for irrigation.

There are eleven effluent nodes in the Gwydir system down stream of Pallamallawa, and none upstream of Pallamallawa. Six of these represent regulated effluent off-takes (Mehi River, Carole Creek, Moomin Creek, Mallowa Creek, Gingham Watercourse and Gwydir Northern Arm). The other five represent either flow by-pass (Mehi high flow bypass and Mogil Mogil flow bypass) or stream bifurcation (Ballin Boora Creek, Gwydir bifurcation and Gingham bifurcation). All five of these effluents return back to the system, but not necessarily to the same stream (eg. Gingham Watercourse returns 25% of its flow into the Lower Gwydir and 50% into Gil Gil Creek).

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 Gwydir Valley Cap calibration report (in preparation). 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.

4.2.2. Storages

There are five storages in the Gwydir System, however only Copeton Dam, with a storage volume of 1,131 GL, was considered significant enough to include in the current Gwydir IQQM (Figure 4.5). Other storages include Tareelaroi, Boolooroo and Tyreel Weirs on the Gwydir River at the points of the Mehi River, Carole Creek and Gingham Watercourse off-takes respectively, and Combadello Weir on the Mehi River at the point of Moomin Creek off-take. These weirs are used to catch surplus water, originating either from rainfall rejection or tributary inflows and redistribute this water to downstream irrigators.

Copeton Dam releases water for:

- General and high security irrigators along the main streams;
- Environmental releases in the Gwydir River as described in Section 4.2.4
- Town water supplies for Inverell (3,054 ML/year), Bingara (660 ML/year) and Gravesend (120 ML/year);
- Stock and Domestic replenishments for users along Ballinboora Creek, Thalaba Creek, Mallowa Creek, Gingham Creek and Lower Gwydir.
- Flood operation.

4.2.3. Extractive demands

Allocation of water to irrigators in the Gwydir River System occurs under a volumetric allocation system, as with other regulated river systems. The total active licence entitlement in this river system is 528 GL, of which about 3% are for high security users, including town water supplies and permanent crop types such as orchards. The majority of the licences are general security, for irrigating crops, with the dominant crop types being cotton, cereals and wheat. The distribution of water usage for irrigation is shown in Figure 4.6. Over 95% of total valley water usage is downstream of Pallamallawa. The distribution of water usage downstream of Pallamallawa is as follows:

- Mehi River (24%);
- Moomin Creek (32%);
- Carole Creek (24%); and
- Lower Gwydir (20%).

4.2.3.1. Surplus water usage

Surplus river water, ie., water in excess of water released from Copeton 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 flood mitigation releases from Copeton Dam. Water extracted is typically stored in on-farm storages for later use. Restrictions are set on the flow thresholds that trigger access to these extractions and the amount of surplus water available for irrigation extractions during an event. However, there is no limit on the total volume that can be extracted by all users in a single water year in the Gwydir Quality Model, which is based on the 1999/2000 development conditions model with such rule in place.

4.2.4. In-stream demands

In-stream demands are simulated at nine locations in the Gwydir System IQQM (Figure 4.7) using Type 9.0, and Type 10 nodes. The purpose of these particular nodes is described in Table 4.1.

Table 4.1. Function of in-stream ordering nodes in Gwydir System IQQM

Node type	In-stream ordering node name	Purpose
Flow control (Nt9.0)	Gwydir River @ Wandoona Minimum Flow Requirement (MFR)	Orders water if required from Copeton Dam to maintain a minimum of 10 ML/d at location.
Flow control (Nt9.0)	Carole Creek at Galloway MFR	Orders water if required from Copeton Dam to maintain a minimum of 10 ML/d at location.
Flow control	Mehi River at Collarenebri MFR	Orders water if required from Copeton Dam to maintain a minimum of 10 ML/d at location.
Environment (Marsh)	Gwydir Wetlands (Environmental Contingency Allowance, ECA)	A maximum of 25,000 ML is allocated for ECA requirements (subject to announced allocation). However, unused allocated volume can be carried over to the following year. The ECA requirements are supplied from Copeton dam if required from mid August to the end of May. ECA releases are triggered by the magnitude of the events at Yarraman. When flows at Yarraman are less than 10,000 ML/month no ECA releases take place. When flow is between 10,000 ML/month and 20,000 ML/month immediate releases are made to supply regulated flow at the rate of 300 ML/d at Yarraman. When flow is in excess of 20,000 ML/month but less than 150,000 ML/month the ECA releases are made 30 days after such an event takes place. No ECA releases are made when a flow event in excess of 150,000 ML/month takes place at Yarraman.
Environment (on river)	Lower Gwydir Stock and Domestic Replenishment (S&D)	A maximum of 4,000 ML/year (subject to announced allocation) is released from Copeton Dam if demand is not met from surplus flows at the rate of 40 ML/day twice a year (every 6 months): from February to March, and from August to September.

Node type	In-stream ordering node name	Purpose
Environment (on river)	Thalaba Creek S&D	A maximum of 4,000 ML/year (subject to announced allocation) is released from Copeton Dam if demand is not met from surplus flows at the rate of 50 ML/day twice a year (every 6 months): from February to March, and from August to September.
Environment (on river)	Gingham Creek S&D	A maximum of 6,000 ML/year (subject to announced allocation) is released from Copeton Dam if demand is not met from surplus flows at the rate of 50 ML/day twice a year (every 6 months): from February to March, and from August to September.
Environment (on river) (Nt10.2)	Mallowa Creek S&D	A maximum of 6,000 ML/year (subject to announced allocation) is released from Copeton Dam if demand is not met from surplus flows at the rate of 50 ML/day twice a year (every 6 months): from February to March, and from August to September.
Environment (on river)	Ballinboora Creek S&D	A maximum of 500 ML/year (subject to announced allocation) is released from Copeton Dam if demand is not met from surplus flows at the rate of 20 ML/day twice a year (every 6 months): from February to March, and from August to September.

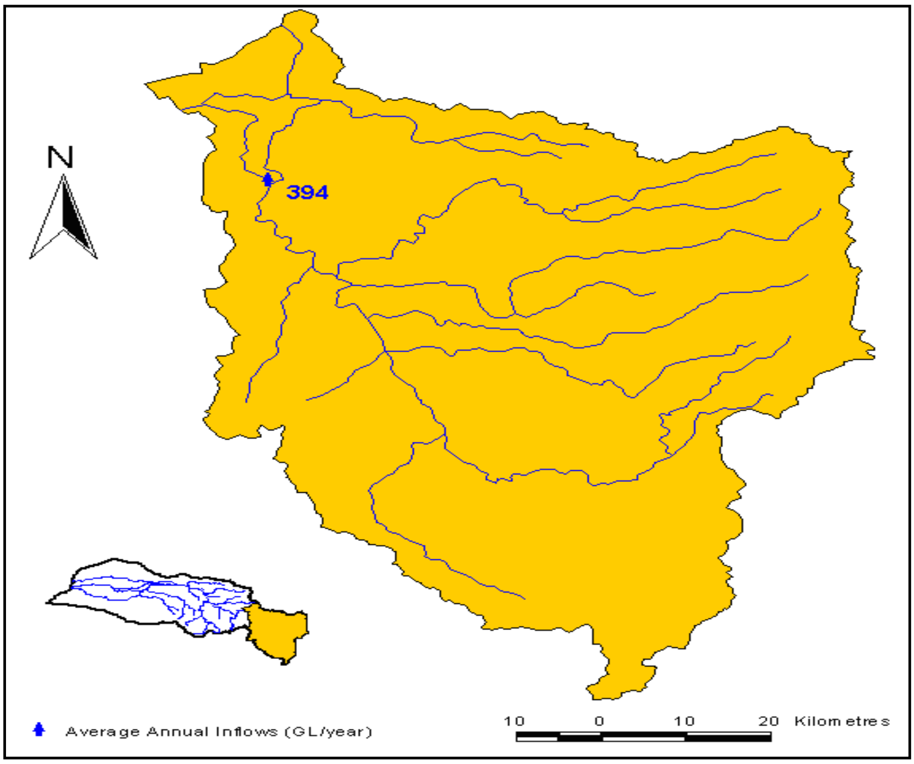


Figure 4.2. Distribution of modelled annual average (1975-2000) inflows and losses upsteam of Copeton Dam in the Gwydir Valley.

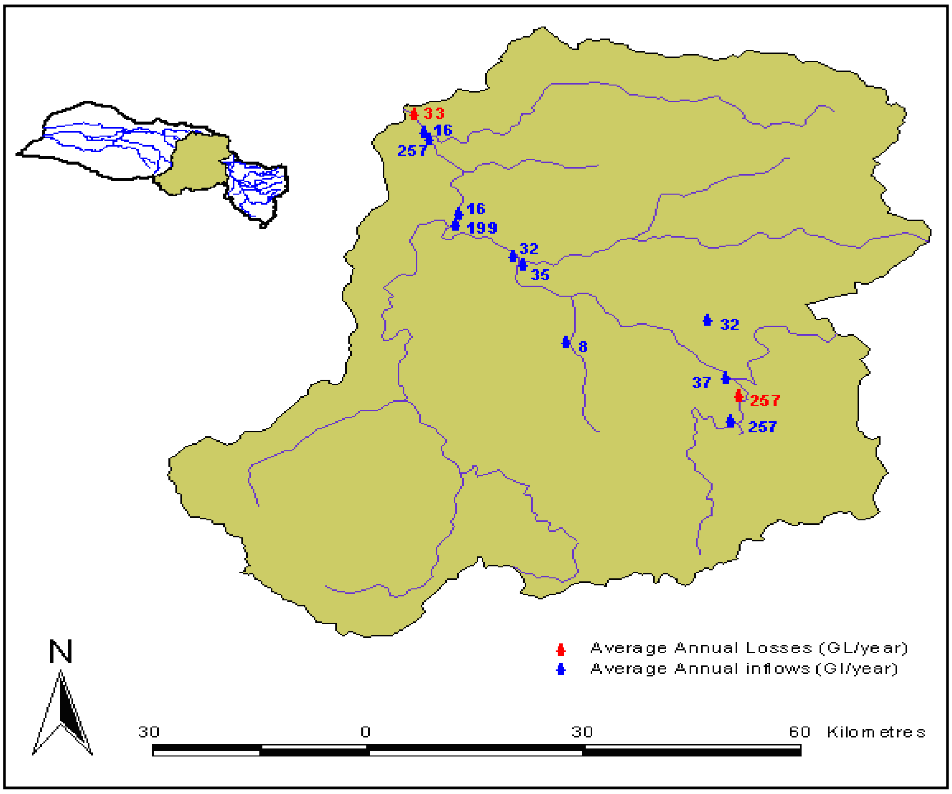


Figure 4.3. Distribution of modelled annual average (1975-2000) inflows and losses in upstream of Gravesend region of Gwydir Valley

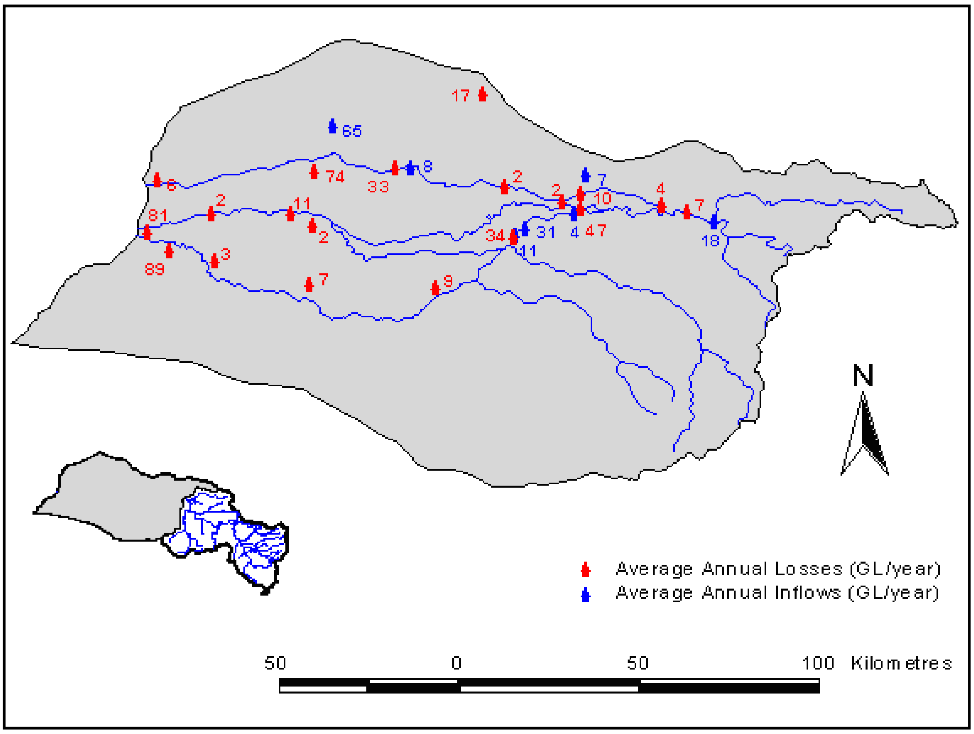


Figure 4.4. Distribution of modelled annual average (1975-2000) inflows and losses in lower Gwydir region of Gwydir Valley

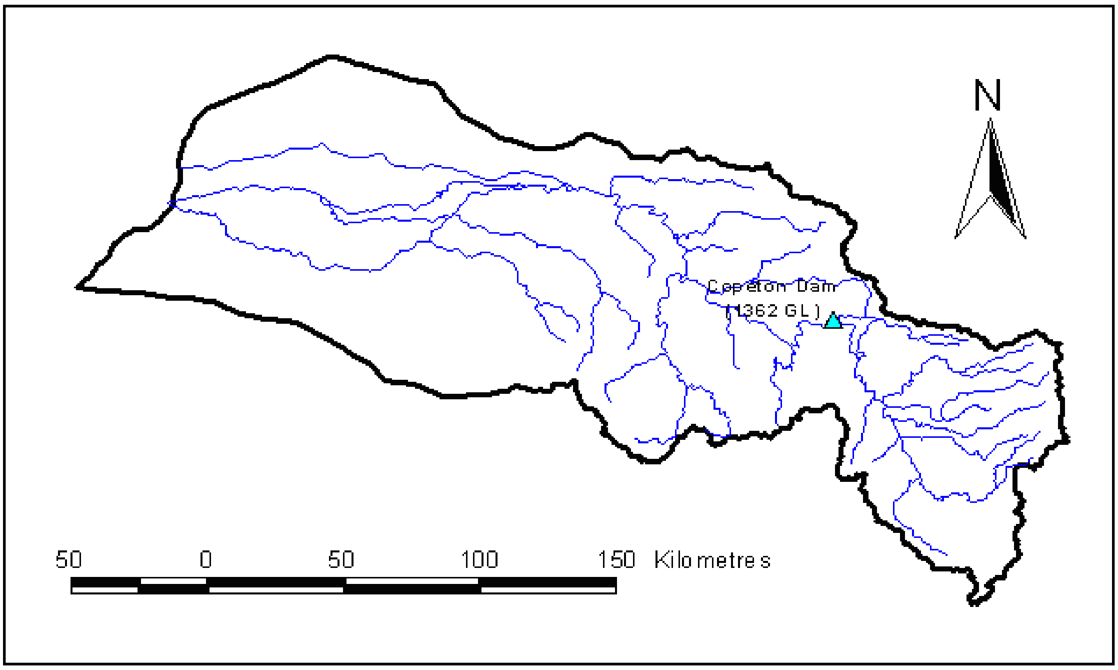


Figure 4.5. Modelled storage in Gwydir System IQQM

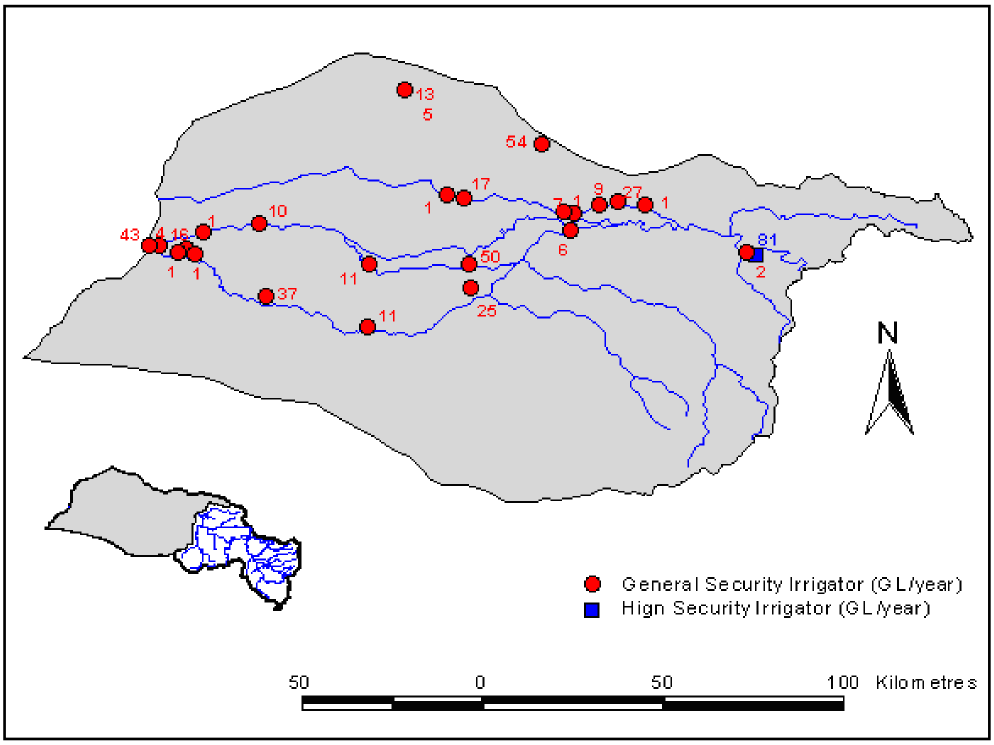


Figure 4.6. Modelled average annual irrigation diversions (GL/year; 1975-2000) for lower Gwydir region of Gwydir Valley

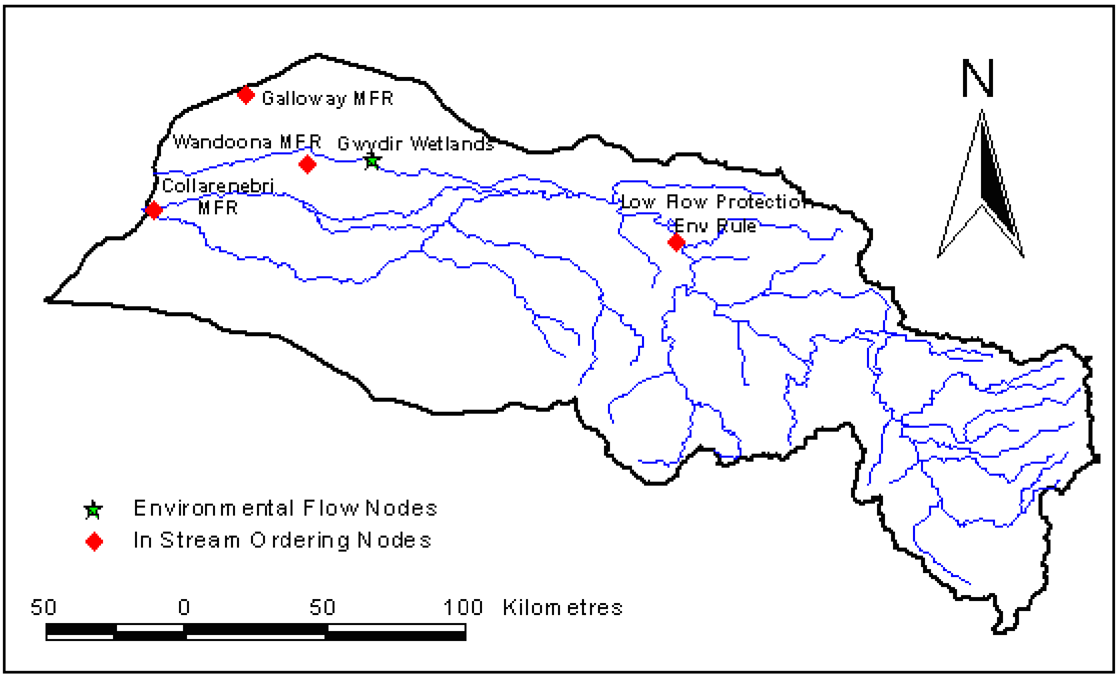


Figure 4.7. Distribution of nodes for ordering in-stream and environmental flow requirements

4.2.5. Peer Review

There has been a peer review of the quantity component of Gwydir Rivers IQQM undertaken by University of New England on behalf of the irrigator representatives of the Gwydir River Management Committee. Findings from this review have not been formally made available to the Department. Consultation with Gwydir Rivers irrigators is currently underway to ensure model input parameters for on-farm storage volume are indicative of on-farm management practices.

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

4.3. QUALITY UPDATES

The quantity IQQM model for the Gwydir Valley uses a back calculation from dam storage and outflow data to estimate the inflows to Copeton Dam. Salt loads calculated in the salinity audit include individual catchments above Copeton Dam.

To produce a salinity model for the Gwydir that allows us to model salinity similarly to how it was done in the audit it was necessary to design an IQQM model that represents these catchments upstream of the dam. Modelling of salinity and various scenario runs will also be able to be carried out in greater detail with the inclusion of this model.

The model for the upper Gwydir uses the gauge 418029 (Gwydir River at Stonybatter) to record the head-water inflow into the valley. Between this gauge and the dam five major tributaries enter the system:

- 418021: Laura Creek at Laura
- 418022: Georges Creek at Clerkness
- 418023: Moredun Creek at Bundarra
- 418033: Bakers Creek at Bundarra
- 418005: Copes Creek at Kimberly

The layout of the model is illustrated in figure in Figure 4.8

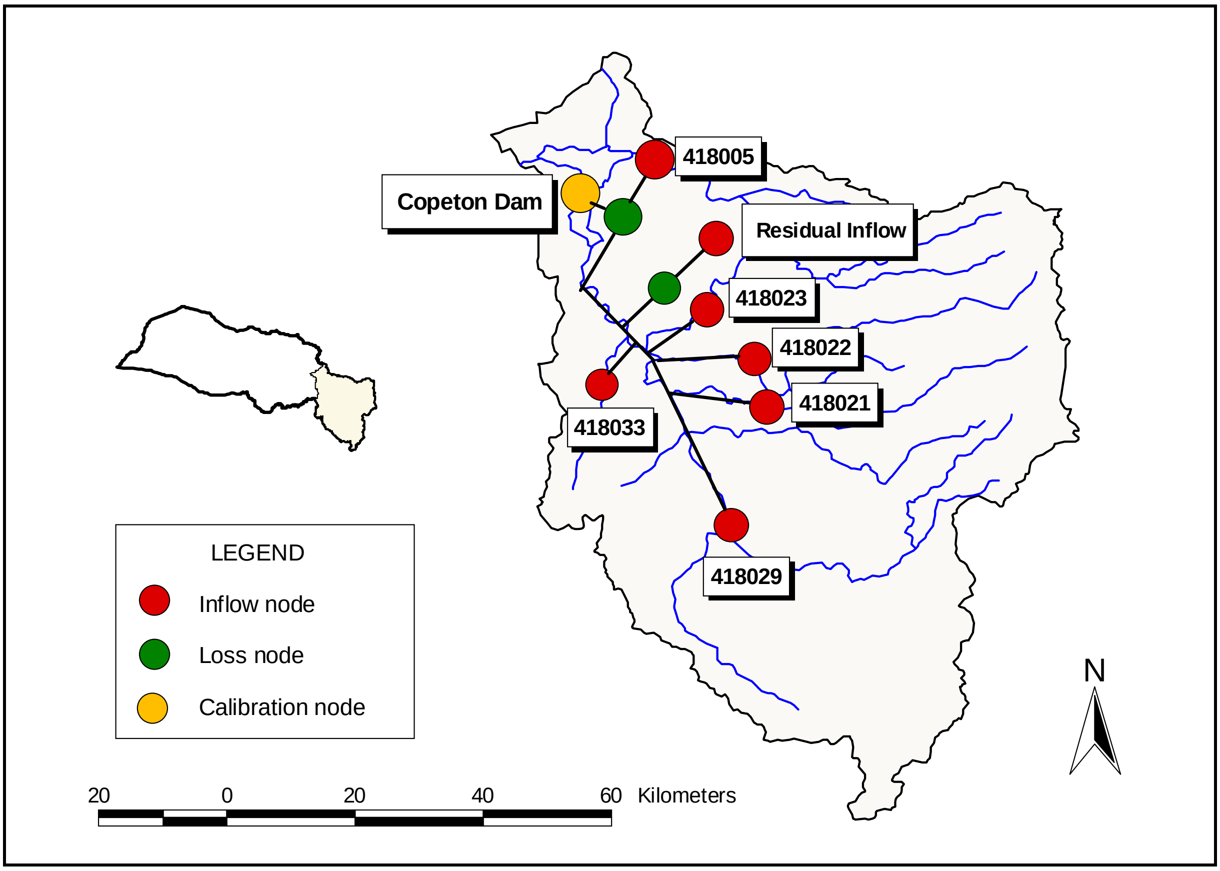


Figure 4.8. Upstream Gwydir model schematic

Flow calibration for the upper Gwydir was achieved based on a comparison with back-calculated data from copeton dam. The period available for calibration was 01/01/1980 to 30/09/2001.

4.4. QUALITY ASSURANCE OF QUALITY MODEL

4.4.1. QA Test 1: Update base quantity model

The results of the mass balance check for of all the major water balance components of the base quantity model over the simulation period 1975-2000 are shown at Table 4.2. The total error over the period of simulation is 2 ML, out of a total inflow of $119*10^6$ ML, or 0.000002 %. The magnitude of these results is typical of the order of magnitude that would be expected from rounding errors in the calculations, and we can conclude that there are effectively no mass balance errors in the IQQM software.

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

Water balance component	Sum over simulation period (ML)
Inflows	119130562
Losses	108172005
Extractions	11128011
Storage change	169456
Error	2

4.4.2. 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 no changes for the water balance components. The salt mass balance report is shown in 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 Gwydir 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	119130562	119130562
Losses	108172005	108172005
Extractions	11128011	11128011
Storage change	169456	169456
Error	2	2

Table 4.4. Salt mass balance report for Gwydir 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

4.4.3. 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 ± 0.0 mg/L, indicating the model is able to maintain stability under a constant flow and concentration scenario.

4.4.4. 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 ($\mu \pm \sigma$) 100.0 ± 0.0 mg/L. The actual result was 100.0 ± 0.6 mg/L, indicating there were still some minor instabilities that need addressing in the code.

4.4.5. 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 4.9. 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 ($\mu \pm \sigma$) 100.0 ± 0.0 mg/L. This result was achieved.

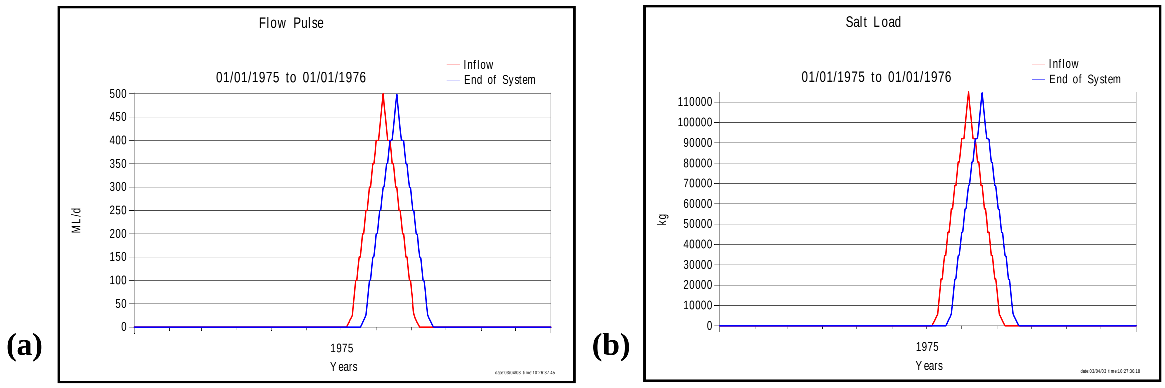


Figure 4.9. (a) Inflows and resultant EOS flows; (b) Salt load inflows and EOS salt loads

4.4.6. 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 4.10. 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.

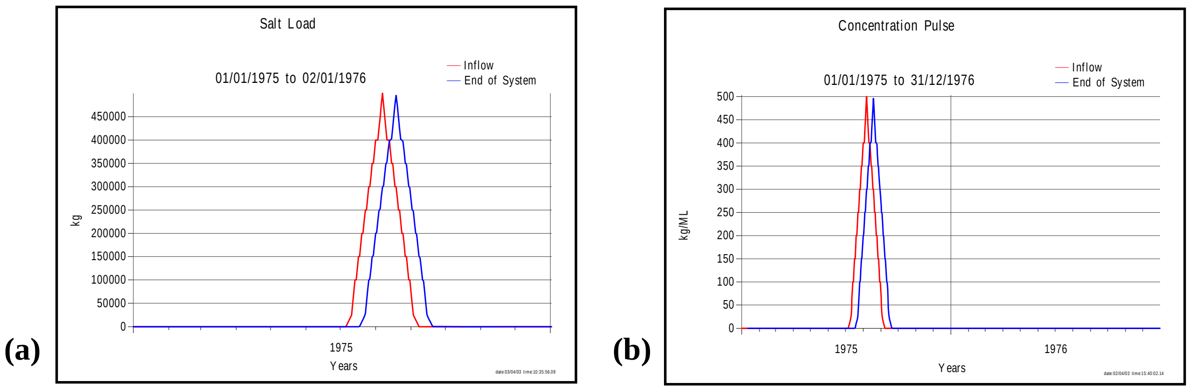


Figure 4.10. (a) Salt load inflows and EOS salt loads; (b) Concentration inflows and EOS concentration

4.5. QUALITY MODEL DEVELOPMENT

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

5. Salt inflow estimates and evaluation

5.1. INITIAL ESTIMATES

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 are firstly tested for consistency with the Salinity Audit results (Appendix B). These results are then evaluated against in-stream concentration data, and if necessary, the salt inflow estimates are calibrated to improve the match with the concentration data.

The schematisation of the salt load inflows and balance points from Figure 5.9 of the Salinity Audit is reproduced in geographical form for reference (

Figure 5.1), with Figure 5.2 showing the catchment boundaries for these inflow and balance points.

The relationships from Table 5.9 in the Salinity Audit were modified in the following:

(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 relationship between the IQQM network structure and the Salinity Audit inflows referred in point (i) above is listed in Table 5.1 for gauged catchments and Table 5.2 for residual catchments. In many cases the parameters of the salt load relationships from the Audit are directly transferable, e.g., catchments 418016, and 418018, whereas for others the parameters had to be modified as more than one IQQM inflow node was used to model flow from that catchment, e.g, R4 with four inflow nodes. The concentration cap adopted for point (iv) above is also shown in Table 5.1 and Table 5.2.

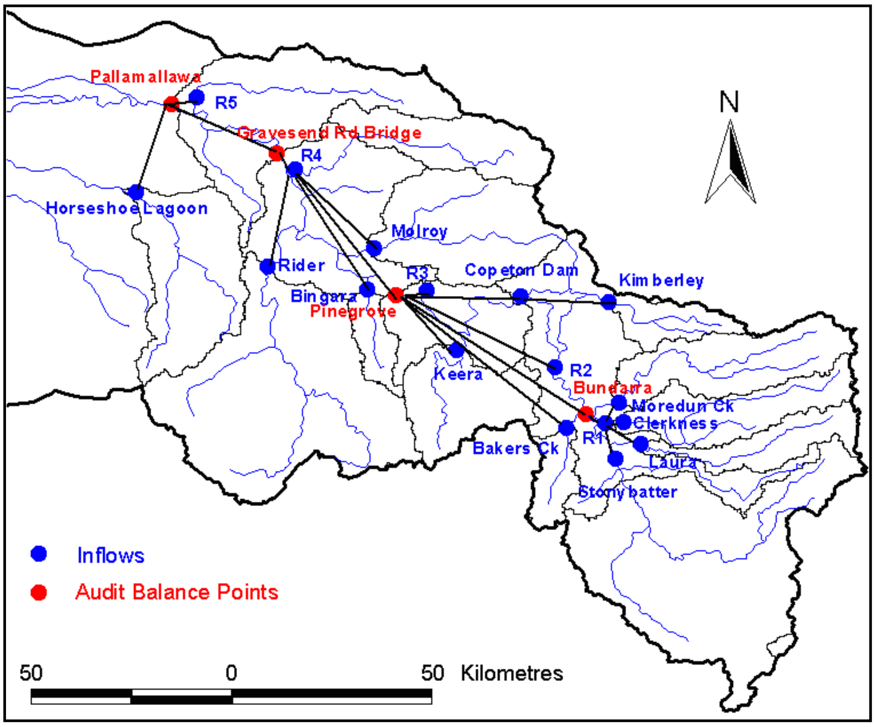


Figure 5.1. Geographic representation of 1999 Salinity Audit schematic of inflows and balance points

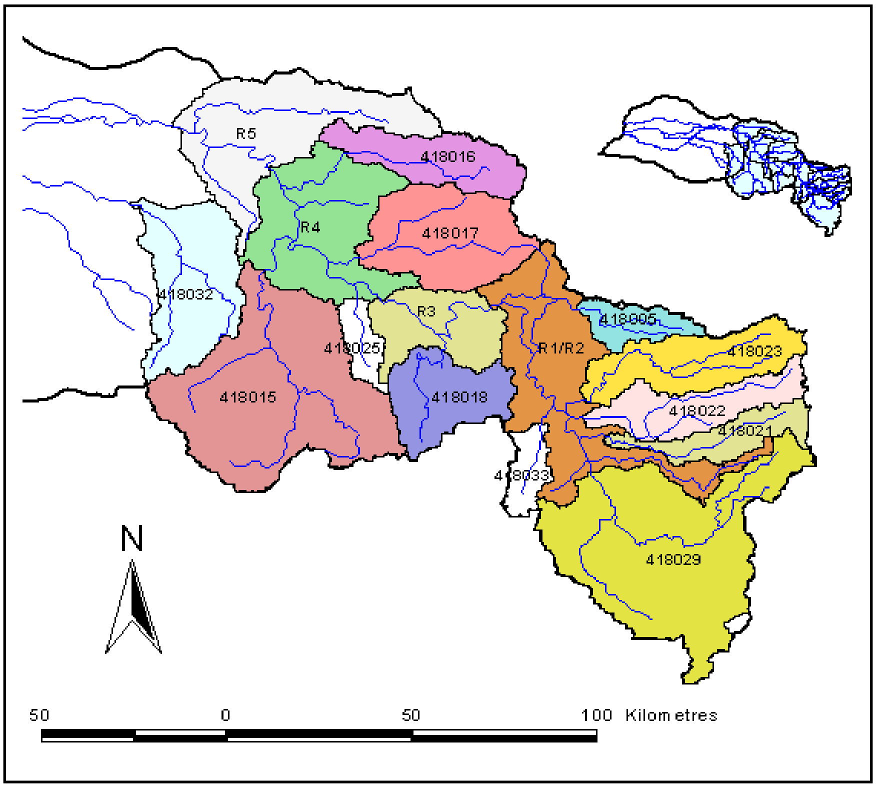


Figure 5.2. Inflow catchments used for 1999 Salinity Audit

Table 5.1. Salt inflow model parameters for gauged catchments

Subcatchment	IQQM inflow node	Audit load flow model			
		Type	η	λ	C_{max} (mg/L)
Gwydir River Upstream of Copeton Dam					
418029	357	IIC	18.1	6.08	350
418021	358	IIC	1.95	6.0	300
418022	359	IIC	1.62	6.73	480
418023	360	IIC	1.62	6.73	450
418033	351	IIC	0.62	3.17	220
418005	352	IIC	0.72	5.58	480
Gwydir River Downstream of Copeton Dam					
418018	006	IID	3.037	0.8291	700
418025	010	IIC	-0.4	61.3	1200
418017	011	IIC	11.8	23.7	2220
418015	012	IIC	19.2	17.0	1000
418016	013	IIC	5.9	12.7	750
418032	069	IIC	7.18	16.3	1000
	205	IIC	2.52	16.3	1000

Table 5.2. Salt inflow model parameters for residual catchments

Subcatchment	IQQM inflow node	Audit load flow model			
		Type	η	λ	C_{max} (mg/L)
R2	353	IIC	12	3.5	500
R3	260	IIC	2.8	26.0	600
	007	IIC	2.8	26.0	600
R4	255	IIC	1.8	10.0	1200
	261	IIC	3.6	10.0	1000
	144	IIC	1.0	10.0	1200
	262	IIC	3.6	10.0	750
R5	021	IIC	5.9	12.7	1000
R6	125	Constant 300 mg/L			300
	066	Constant 300 mg/L			300
	221	Constant 300 mg/L			300
	141	Constant 300 mg/L			300
	196	Constant 300 mg/L			300
	322	Constant 300 mg/L			300
	278	Constant 300 mg/L			300
	335	Constant 300 mg/L			300

5.2. EVALUATION METHOD

5.2.1. Model configuration

The quantity model had to be reconfigured so that model results could be reliably compared against observed data, because the water quality is dependent on water quantity. This is demonstrated by considering Figure 5.3, 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}).

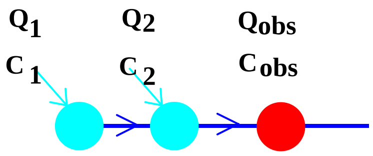


Figure 5.3. Calculating resultant concentration from two tributaries

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

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 Gwydir System IQQM provides good estimates of flow for the parts of the model upstream of Copetone Dam. Downstream of Copeton, the observed flows are impacted by the regulated releases from the storage. Historically, these are a function of varying levels of development and sets of river management policies. However, IQQM is configured with a fixed level of development and set of management policies. This created the problem that it was impossible to match the simulated and observed releases from Copeton Dam.

To overcome this problem, we forced the storage releases to the observed releases. This created another problem in that the modelled extractions used to represent the historical extractions from the system are often an overestimate of the true extractions that occurred (based on 1993/1994 extractions). However, these errors would not significantly effect simulated concentrations, because most of the inflows have already entered the Gwydir River (Figure 4.4) upstream of most of the diversions.

5.2.2. Selection of evaluation sites

A total of fourteen locations have discrete data that could be used for model evaluation (Table 3.2). Neither of the continuous data sets installed in the Gwydir catchment have suitable data for model evaluation (Table 3.3). mainly because they do not have enough data points. The model results were only evaluated at the BSMS target sites and at other key locations that have good data sets.

The BSMS Target sites are at the end of the system:

(i) Station 418031: Gwydir River @ Collymongle

(ii) Station 418058: Mehi River @ Bronte

Additional in-valley target sites were selected based on their proximity and available data:

(iii) Station 418012: Gwydir River @ Pinegrove

(iv) Station 418013: Gwydir River @ Gravesend Road Bridge

(v) Station 418001: Gwydir River @ Pallamallawa

(vi) Station 418002: Mehi River @ Moree

(vii) Station 418053: Gwydir River at Brageen Crossing

The final evaluation location is:

(viii) Copeton Dam (using Station 418026: Gwydir River D/S of Copeton Dam)

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

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 including: total flow; proportion of base flow compared with surface flow; where in the catchment the flow originated; stream-aquifer interactions; degree of regulation; antecedent conditions; season and underlying trend, if any.

For a data set to be representative of the population, it needs to have samples that represent all of these variations. However, each of these cannot be individually quantified so we use surrogate measures to test for representativeness:

(i) how many data points there are;

(ii) what period the data represents;

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

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

Graphs of the full set of screened salinity data (Table 3.2) and observed flow at evaluation locations are shown in Appendix B. Performance measures (i), (ii), and (iii) from above are reported as shown in Table 5.4. The flow ranges referred in this table are based on observed flow as follows:

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

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

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

Time series graphs of the full set of screened salinity data (Table 3.1) and observed flow at evaluation locations are shown at the end of this chapter (Figure 5.24 to Figure 5.31). Performance measures (i), (ii), and (iii) are reported as shown in Table 5.4, and performance measure (iv) from above is reported in Table 5.5.

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)
$V_{t\text{-}1}$ = Volume in storage on previous day (ML)
$C_{t\text{-}1}$ = 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 performance measures (i-iv) are zero, and for performance measure (v) the perfect result is one.

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

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

$$E = \frac{\left| \sum_i S_i - \sum_i O_i \right|}{\sum_i O_i} \qquad (5.5)$$

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

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

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:

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

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

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

5.3. EVALUATION OF SALINITY AUDIT MODEL ESTIMATES

The model was evaluated at eight sites along the main streams of the Gwydir and Mehi River Systems. The basis for selecting these sites is discussed in Section 5.2.2. Time series plots comparing observed and simulated salinity are located at the end of this chapter (Figure 5.32 to Figure 5.39), and discussion of these results with performance measures are presented in Sections 5.3.1 to 5.3.9.

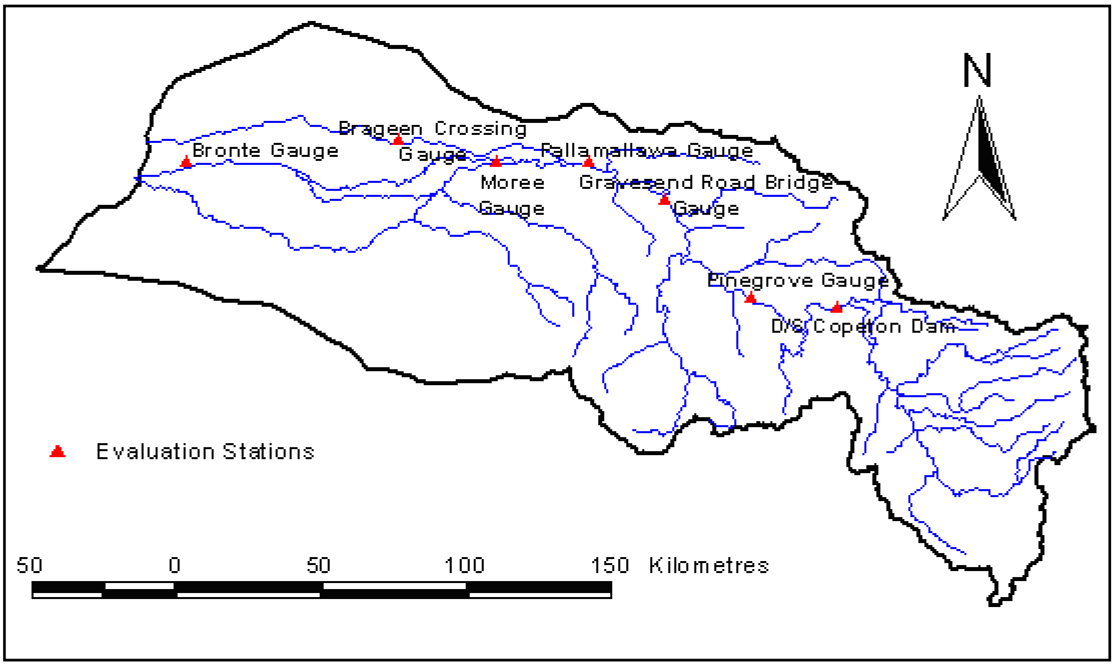


Figure 5.4. Location of evaluation sites

5.3.1. Copeton Dam

Copeton Dam was commissioned in 1972 and salinity data was collected at intervals of approximately 2 months at Station 418026: Gwydir River d/s Copeton Dam (see Table 3.1). The salinity during the model evaluation period ranges from 59-169 mg/L, with a median salinity of 92 mg/L. As expected for storages, the salinity data demonstrates high serial correlation and reasonably low variability.

The simulation using Salinity Audit relationships as inputs on the contributing catchments underestimates the storage salinity (Figure 5.32) The mean of the simulated salinity is 90 mg/L and the corresponding observed mean is 99 mg/L. The pattern of simulated salinity matches the pattern of observed salinity; increasing during periods of stable or decreasing storage volumes (Figure 5.24), and abrupt decreases after significant inflows. The variation in simulated storage salinity is lower than the variation in the observed data.

Results for average error and range appear to be reasonable. By looking at the time series it is evident that these statistics are biased towards the drought between 1993 and 1996. Approximately 40% of the total data used for testing occur within this period. This could be misleading as this period (where the dam almost reaches the “dead storage” volume) is probably less important when calculating end of system salinity percentiles.

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

Performance measure	Result
Pattern match	0.348
Mean match	0.096
Average error	0.124
Range match	0.308
R^2	0.650

5.3.2. Station 418012: Gwydir River @ Pinegrove

The gauging station along Gwydir River @ Pinegrove had data collected consistently within the model evaluation period every 1-2 months from 1980 to 1989, where the dataset ceases. This leaves only 37 points out of the original 145 points suitable for use in model evaluation. The salinity over the whole dataset ranges from about 75-720 mg/L, with a median salinity of 138 mg/L; over 45 mg/L higher than the median salinity of water released from Copeton Dam. The primary cause of this difference is the inflows from Keera Creek catchment.

The results for the simulation using the Salinity Audit relationship for the salt contribution from Keera Ck shows that the observed flow distribution is being maintained (Figure 5.5.a) as would be expected with forced releases from Copeton Dam, but that that observed salinity data is consistently underestimated (Figure 5.5.b) for medium to high flows. This is consistent with underestimating the concentrations in Copeton Dam. Improving Copeton dam concentrations is therefore likely to improve this part of the salinity exceedance plot at Gwydir River @ Pinegrove. The simulated salinity distribution corresponding to the low flow range is underestimating the observed recordings. This is probably due to a poor estimate of the salt being contributed by the two residual catchments in this reach.

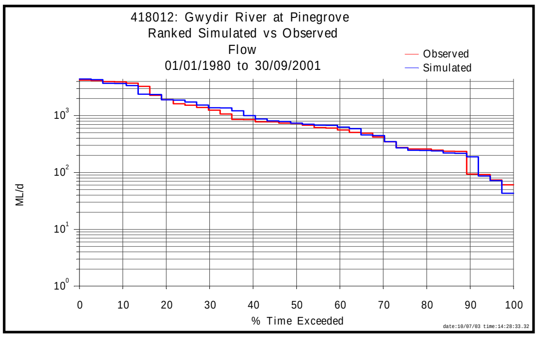
Table 5.4. Distribution of flow with discrete EC across flow ranges and months for Station 418012: Gwydir River @ Pinegrove

Flow range	Period	Number Points	Number of months with data												
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Bias$_{seas}$*
Low	1980-1989	4	0	0	0	0	1	0	1	0	1	0	0	0	0.7
Medium		25	2	1	2	2	2	1	3	2	3	3	2	0	0.4
High		8	2	2	0	0	0	0	0	0	1	0	0	1	1.6
All		37	6	3	2	2	4	1	5	2	5	3	2	1	0.1

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 418012: Gwydir River @ Pinegrove

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	67	21	15	103
	With EC obs	80	16	61	94
Medium	*All*	571	438	104	1,788
	With EC obs	694	410	235	1,618
High	*All*	4,436	4,679	1,789	72,367
	With EC obs	3,431	882	1,900	4,222
ALL	*All*	1,262	2,661	15	72,367
	With EC obs	1,219	1,299	61	4,222

(a)



(b)

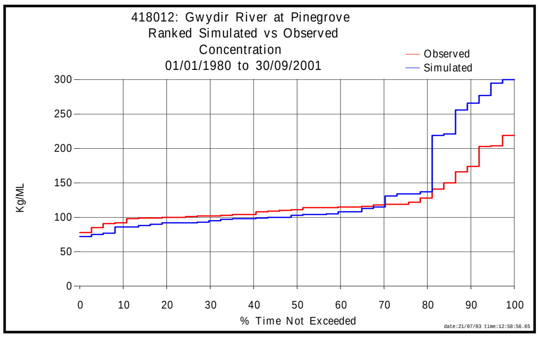


Figure 5.5. Station 418012: Gwydir River @ Pinegrove; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity

Table 5.6. Comparison of statistics within flow ranges of: (i) observed versus simulated flow; (ii) observed discrete versus simulated salinity; and (iii) observed versus simulated load for Station 418012: Gwydir River @ Pinegrove

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*	80	16	61	94	187	31	150	219	73	0.69	15
	Simulated	105	78	43	218	237	90	104	299			28
Medium	*Observed*	694	410	235	1,618	115	25	85	203	20	0.86	77
	Simulated	785	524	189	1,896	123	54	77	297			89
High	*Observed*	3,431	882	1,900	4,222	103	12	78	118	25	0.33	349
	Simulated	3,222	1,024	1,538	4,422	106	51	72	231			310
All	*Observed*	1,219	1,299	61	4,222	120	33	78	219	27	0.80	129
	Simulated	1,238	1,244	43	4,422	132	67	72	299			130

5.3.3. Station 418013: Gwydir River @ Gravesend Road Bridge

The gauging station Gwydir River @ Gravesend Road Bridge has had data collected consistently every 1-2 months over the evaluation period (1980-2001), with the exception of a gap in 1990-1992 (Figure 5.26). The data is uniformly distributed across the flow ranges, as well as throughout the year (Table 5.7). The median salinity at this site is 222 mg/L (Table 3.4). This represents almost a 50% increase on the median salinity at Gwydir River @ Pinegrove, indicating the dominance of tributary inflow in this reach.

The simulated flows match the distribution of the observed well, which is to be expected with the majority of the volume at this station produced from observed inflows. The simulated salinity data also shows a very good match when compared to the observed salinity data (Figure 5.23). Concentrations for medium to high flows are still underestimating, by about 10% on average, and once again this can probably be attributed to the results at Copeton Dam (discussed in section 5.3.2). The highest simulated concentration is approximately 17 % higher than the highest observed recording.

Table 5.7. Distribution of flow with discrete EC across flow ranges and months for 418013: Gwydir River @ Gravesend Road Bridge

Flow range	Period	Number Points	Number of months with data												
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*$Bias_{seas}$*
Low	1980-2001	57	2	2	5	5	5	7	4	3	3	2	2	3	0.4
Medium		113	6	6	13	7	5	7	5	4	7	10	10	5	0.3
High		40	7	6	1	1	0	1	2	1	2	7	1	4	0.8
All		210	12	13	13	11	11	15	10	8	11	15	12	10	0.1

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 Station 418013: Gwydir River @ Gravesend Road Bridge

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	139	59	6	227
	With EC obs	125	63	9	222
Medium	*All*	856	563	228	2,391
	With EC obs	744	534	231	2,309
High	*All*	6,922	10,783	2,393	264,663
	With EC obs	4,746	2,695	2,414	14,600
ALL	*All*	1,946	5,437	6	264,663
	With EC obs	1,365	2,071	9	14,600

(a) (b)

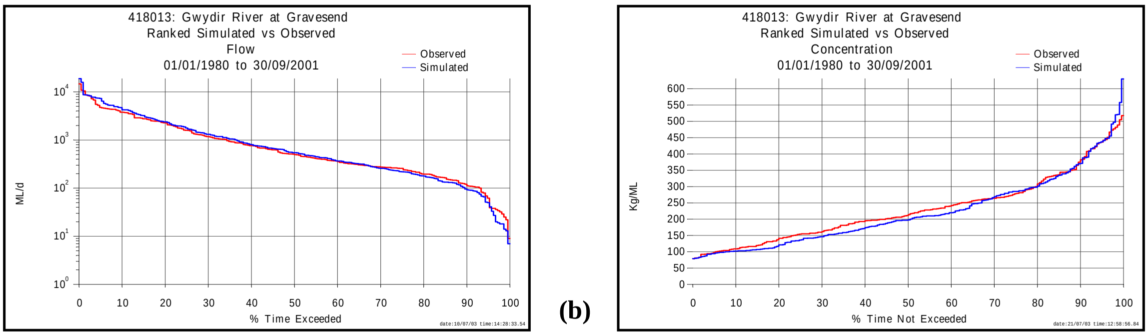


Figure 5.6. 418013: Gwydir River @ Gravesend Road Bridge; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity

Table 5.9. Comparison of statistics within flow ranges of: (i) observed versus simulated flow; (ii) observed discrete versus simulated salinity; and (iii) observed versus simulated load for 418013: Gwydir River @ Gravesend Road 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*	144	74	9	262	284	83	150	482	68	0.39	41
	Simulated	154	121	7	635	321	114	155	632			43
Medium	*Observed*	784	536	264	2,309	233	100	95	518	54	0.49	162
	Simulated	1,007	1,227	103	7,756	201	81	83	447			166
High	*Observed*	4,746	2,695	2,414	14,600	140	58	79	290	25	0.59	657
	Simulated	5,081	3,512	1,313	18,800	135	50	79	238			742
All	*Observed*	1,365	2,071	9	14,600	229	101	79	518	52	0.53	223
	Simulated	1,552	2,488	7	18,800	221	109	79	632			243

5.3.4. Station 418001: Gwydir River @ Pallamallawa

There is only a small amount of discrete data at Pallamallawa during the evaluation period (1980-2001), and all of this data occurs before 1990 (Figure 5.27). The data is spread across all flow ranges, however the months with data in the low flow range is limited to April, May and September, primarily because of the low number of samples available in this range (Table 5.10). The flow on the days on which data was collected has similar statistical characteristics to the flow on all days over the evaluation period, but it misses out on the high and low extremes. The median salinity for Gwydir River @ Pallamallawa is 252 mg/L which is 12% higher than the Gwydir River @ Gravesend Road Bridge. This is a substantial increase considering that there is only a very small residual input between the two stations. This apparent change could be caused by a number of things including sampling non-representativeness and data problems.

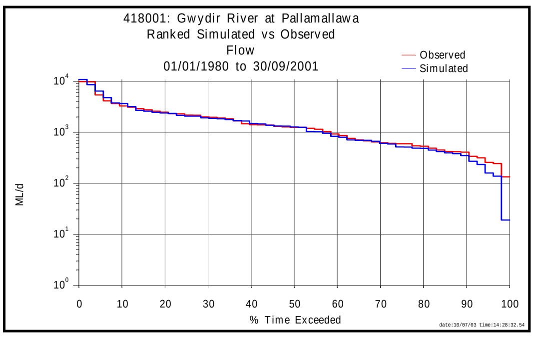
The results show that the match of flow distribution at this site is quite good (Figure 5.7.a), however, simulated concentrations are significantly lower than observed concentrations (Figure 5.7.b). This also supports the above statement of a sampling bias towards higher concentrations at Gwydir River @ Pallamallawa, considering that the calibration at the upstream site was quite good. The simulated difference in median concentrations from 418013 to 418001 is less than 2%.

Table 5.10. Distribution of flow with discrete EC across flow ranges and months for Station 418001: Gwydir River @ Pallamallawa

Flow range	Period	Number Points	Number of months with data												
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Bias$_{seas}$*
Low	1980-1989	3	0	0	0	1	1	0	0	0	1	0	0	0	1.3
Medium		39	1	2	4	2	4	4	0	1	4	5	3	3	0.4
High		11	2	2	1	1	0	0	2	0	0	2	0	0	0.4
All		53	3	5	4	3	5	4	2	1	5	7	3	3	0.3

Table 5.11 Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC* data during evaluation period for Station 418001: Gwydir River @ Pallamallawa

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	148	60	7	236
	With EC obs	N/A	N/A	134	134
Medium	*All*	878	565	237	2381
	With EC obs	1070	634	243	2328
High	*All*	7275	10901	2382	145838
	With EC obs	4540	2739	2470	9880
ALL	*All*	2033	5558	7	145838
	With EC obs	1773	1952	134	9880

(a)


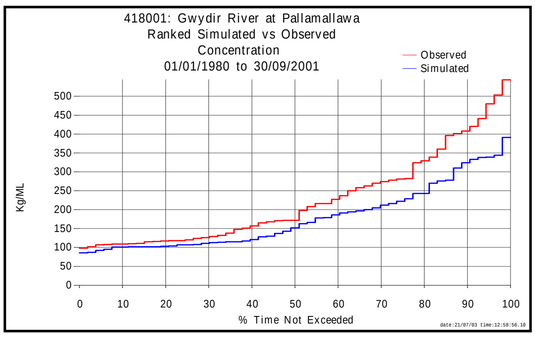
(b)


Figure 5.7. Station 418001: Gwydir River @ Pallamallawa; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity

Table 5.12. Comparison of statistics within flow ranges of: (i) observed versus simulated flow; (ii) observed discrete versus simulated salinity; and (iii) observed versus simulated load for Station 418001: Gwydir River @ Pallamallawa

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	211	67	134	256	247	100	172	360	64	0.47	54
	Simulated	174	136	19	270	261	122	120	338			42
Medium	Observed	1,112	621	317	2,328	241	128	102	543			250
	Simulated	1,080	648	139	2,683	185	84	96	399			177
High	Observed	4,540	2,738	2,470	9,880	161	71	98	282	29	0.84	812
	Simulated	4,632	2,823	2,332	10,780	132	48	86	206			696
All	Observed	1,773	1,952	134	9,880	225	120	98	543	72	0.38	356
	Simulated	1,766	2,019	19	10,780	178	84	86	399			277

5.3.5. Station 418002: Mehi River @ Moree

The gauging station Mehi River @ Moree has had data collected consistently every 1-2 months over the evaluation period (1980-2001), with the exception of two large gaps 1987-1992, and 1995-2001 (Figure 5.28). This represents the flow ranges and months uniformly (Table 5.13), with the exception of April to September for the high flow range. The statistical representativeness within each flow range is reasonable. Flow with salinity data during the model evaluation period is slightly lower compared to all flow for the low and medium regimes, and is slightly higher for the high flow regime. The median salinity at this site is 213 mg/L (Table 3.4).

The simulated salinity appears to represent the observed data reasonably well during the evaluation period (figure 5.6). The exceedance plot illustrates that the simulated data is underestimating the observed data by an average of 10% for the low to medium flow range, and overestimating by about 10% for the medium to high flow range (Figure 5.8.b).

Table 5.13. Distribution of flow with discrete EC across flow ranges and months for Station 418002: Mehi River @ Moree

Flow range	Period	Number Points	Number of months with data												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	$Bias_{seas}$
Low	1980-2000	19	0	1	0	3	2	3	2	1	1	2	1	2	0.3
Medium		42	1	3	5	3	4	3	2	5	5	2	5	0	0.4
High		12	3	2	1	0	0	0	0	0	0	3	0	1	1.1
All		73	6	5	6	6	6	6	4	6	6	7	5	3	0.1

Table 5.14. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC* data during evaluation period for Station 418002: Mehi River @ Moree

Flow range	Data set	Flow (ML/d)			
		Mean	SD	Min	Max
Low	All	49	31	0	104
	With EC obs	40	30	2	97
Medium	All	438	270	105	1,106
	With EC obs	385	277	114	1,038
High	All	2,256	1,543	1,107	26,128
	With EC obs	2,507	2,293	1,230	9,433
ALL	All	725	1,071	0	26,128
	With EC obs	644	1,249	2	9,433

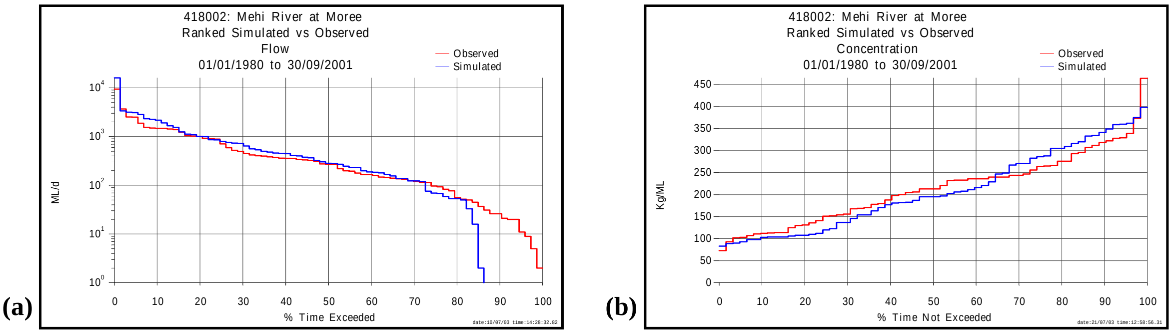


Figure 5.8. Station 418002: Mehi River @ Moree; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.15 Comparison of statistics within flow ranges of: (i) observed versus simulated flow; (ii) observed discrete versus simulated salinity; and (iii) observed versus simulated load for 418002: Mehi River @ Moree

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*	45	32	5	97	245	40	151	312	72	0.02	11
	Simulated	221	141	3	489	247	75	170	401			49
Medium	*Observed*	394	283	114	1,038	225	82	103	464	62	0.37	83
	Simulated	516	454	17	2,260	214	93	92	375			99
High	*Observed*	2,600	2,380	1,230	9,433	124	33	73	180	31	0.03	278
	Simulated	3,477	4,254	215	16,004	112	32	82	175			464
All	*Observed*	702	1,325	5	9,433	212	79	73	464	59	0.39	101
	Simulated	967	2,101	3	16,004	203	92	82	401			151

5.3.6. Station 418053: Gwydir River at Brageen Crossing

The gauging station Gwydir River at Brageen Crossing had data collected consistently every 1-2 months over the evaluation period (1980-2001), with the exception of a two gaps during 1987-1991 and 1994-2001 (Figure 5.30). The data is uniformly distributed across the flow ranges, however, there is some bias in the seasonal representation in the high flows (Table 5.16). The median salinity at this site is 180 mg/L (Table 3.4). This is 15% lower than the median salinity at Mehi River @ Moree. There are no significant inflows in this reach so the observed salinities should be reasonably consistent with the Moree data. For data that was collected on the same day, the values are consistent. Therefore, the overall difference in the median is thought to be due to non-representative sampling at this site.

The results of the simulation are displayed in Figure 5.38 and show that the observed concentrations are reproduced well at the 50th and 80th non-exceedance percentiles and underestimated at the 20th percentile. The observed flow data at this site is not reproduced particularly well (Figure 5.9.a), underestimating for the majority of the regime. This is probably because the simulated extractions (which are based on a fixed level of development set in the model) are greater than the historical extractions over the calibration period. For this reason, the major focus was on getting a good match with the salinity, since extractions do not affect the concentration. The results of the salinity simulation are considered acceptable, given these significant flow differences. Overall, the simulated mean salinity for the full data set is approximately 10% lower than the observed mean based on the discrete samples. (Table 5.18).

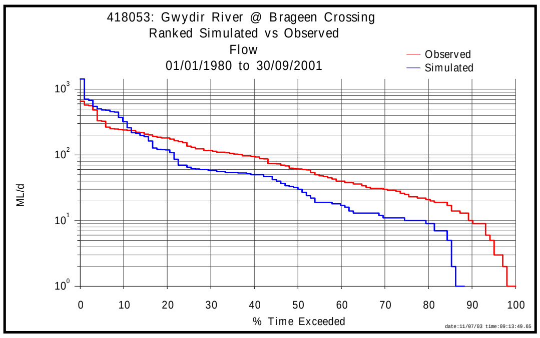
Table 5.16. Distribution of flow with discrete EC across flow ranges and months for Station 418053: Gwydir River @ Brageen Crossing

Flow range	Period	Number Points	Number of months with data												
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Bias$_{seas}$*
Low	1980-1998	21	2	2	1	2	0	0	2	3	3	1	2	0	0.3
Medium		56	4	4	5	2	3	3	1	2	2	7	3	4	0.3
High		25	7	2	2	0	0	1	1	0	0	4	0	4	1.0
All		102	10	5	6	4	3	4	4	5	5	9	4	5	0.2

Table 5.17. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC* data during evaluation period for Station 418053: Gwydir River @ Brageen Crossing

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	9	7	0	21
	With EC obs	11	7	1	21
Medium	*All*	67	35	22	151
	With EC obs	65	35	22	136
High	*All*	629	1,291	152	9,291
	With EC obs	276	140	154	656
ALL	*All*	160	608	0	9,291
	With EC obs	106	124	1	656

(a)



(b)

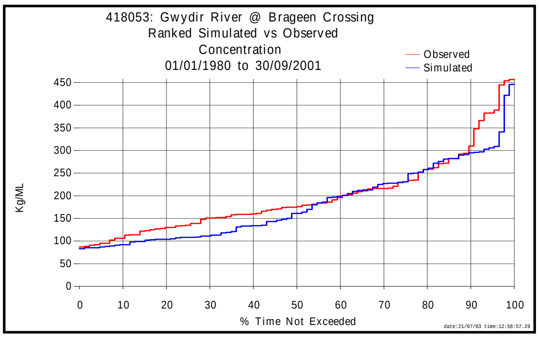


Figure 5.9. Station 418053: Gwydir River @ Brageen Crossing; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.18. Comparison of statistics within flow ranges of: (i) observed versus simulated flow; (ii) observed discrete versus simulated salinity; and (iii) observed versus simulated load for Station 418053: Gwydir River @ Brageen Crossing

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*	8	5	1	14	261	91	152	457	120	0.36	2
	Simulated	28	21	7	58	197	67	102	288			5
Medium	*Observed*	65	37	17	136	195	77	91	454	54	0.45	11
	Simulated	80	125	1	644	196	90	84	446			15
High	*Observed*	281	145	154	656	175	89	88	389	51	0.51	49
	Simulated	256	346	6	1,451	152	72	83	279			41
All	*Observed*	115	129	1	656	198	85	88	457	61	0.29	20
	Simulated	121	218	1	1,451	184	85	83	446			20

5.3.7. Station 418031: Gwydir River @ Collymongle

Although this station is one of the end of system locations for the Gwydir valley, we cannot evaluate the model at this site because there was very limited salinity data available and the modelled flow is significantly different to the historical flow. Of the 37 observed concentration points within the model evaluation period, only one point occurs when there are simulated flows in the river. This is not surprising, considering that this site flows less than 5% of the time during the evaluation period. Considering the small flow volume then the impact of this site on the salinity in the Barwon River would only be small, so our inability to do a comprehensive evaluation at this site is not significant.

5.3.8. Station 418058: Mehi River @ Bronte

The gauging station Mehi River at Bronte has generally had data collected consistently every 1-2 months over the evaluation period (1980-2001), however, the majority of the data available occurs after 1990 (Figure 5.31). The data is uniformly distributed across the flow ranges (but is slightly biased towards the medium and high flow ranges). There is also some seasonal bias present in the high flow range (Table 5.19). The median salinity at this site is 213 mg/L (Table 3.4). This is consistent with median concentration at the upstream site of Mehi River @ Moree.

The results of the simulation appear to match the data well (Figure 5.38), however the historical flow is not simulated particularly well at this location, significantly overestimating the high and medium flow frequency. The modelled flow has a far higher period of no flow than the observed data indicates. Concentrations are slightly underestimated throughout all flow ranges (Figure 5.10.b).

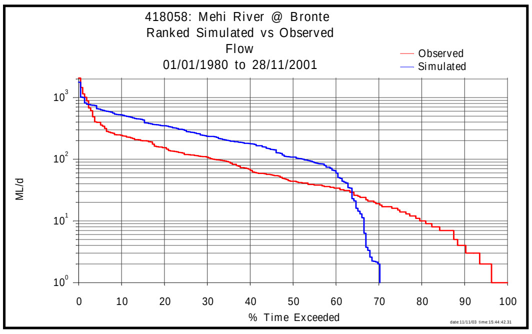
Table 5.19. Distribution of flow with discrete EC across flow ranges and months for Station 418058: Mehi River @ Bronte

Flow range	Period	Number Points	Number of months with data												
			Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*$Bias_{seas}$*
Low	1981-2001	27	4	1	2	2	0	1	1	2	0	1	4	1	0.2
Medium		112	7	7	10	8	4	5	6	4	6	5	5	9	0.2
High		76	11	9	3	1	1	2	1	0	1	2	8	6	0.9
All		215	12	13	12	10	5	8	8	7	7	8	11	12	0.2

Table 5.20. Comparison of statistics within flow ranges of *all observed flows versus observed flows on days with discrete EC* data during evaluation period for Station 418058: Mehi River @ Bronte

Flow range	Data set	Flow (ML/d)			
		Mean	*SD*	*Min*	*Max*
Low	*All*	2	2	0	5
	With EC obs	3	1	1	5
Medium	*All*	35	22	6	87
	With EC obs	34	21	7	86
High	*All*	263	360	88	2953
	With EC obs	271	320	90	2073
ALL	*All*	72	187	0	2953
	With EC obs	114	223	1	2073

(a)



(b)

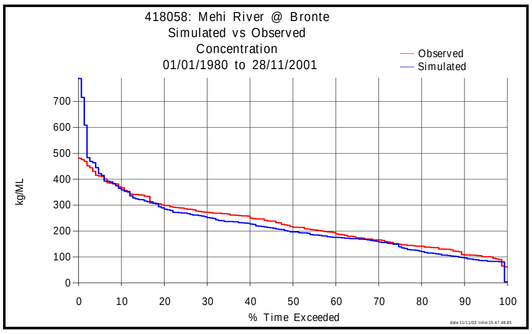


Figure 5.10. Station 418058: Mehi River @ Bronte; (a) Exceedance curve for observed versus simulated flow, (b) Non-exceedance curve for observed discrete versus simulated salinity.

Table 5.21. Comparison of statistics within flow ranges of: (i) observed versus simulated flow; (ii) observed discrete versus simulated salinity; and (iii) observed versus simulated load for Station 418058: Mehi River @ Bronte

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*	*Avg. error (mg/L)*	R^2	
Low	*Observed*	2	1	1	5	303	82	138	444	129	0.00	1
	Simulated	163	153	2	516	286	155	103	760			35
Medium	*Observed*	55	41	7	136	235	90	101	481	84	0.15	12
	Simulated	271	261	1	1766	226	105	82	705			51
High	*Observed*	360	313	146	1455	155	58	62	277	50	0.18	52
	Simulated	392	261	3	997	155	66	80	318			61
All	*Observed*	109	189	1	1455	227	93	62	481	82	0.18	18
	Simulated	282	258	1	1766	219	112	80	760			51

5.3.9. Evaluation of results using Salinity Audit relationships

The results of the simulations using the Salinity Audit relationships to estimate the contribution from the tributaries generally display a good match when compared to the observed data. However, there were two major issues with the calibration achieved during the Salinity Audit. Firstly, the simulated concentrations in Copeton Dam are generally underestimating the observed concentrations at Station 418026: Gwydir River D/S of Copeton Dam. The error is most prominent when the storage is at medium to high volumes. The underestimation of salinity in dam releases is carried down through the system and is evident in the high to medium flows at Station 418012: Gwydir River @ Pinegrove and

Station 418013: Gwydir River @ Gravesend Road Bridge. Improving the simulation at the dam would therefore be expected to improve the results at these locations.

The poor result of observed vs simulated concentrations at station 418001: Gwydir River @ Pallamallawa, was unexpected given that:

- Concentrations were simulated well at the upstream location of Gravesend
- There are no significant inflows between Gravesend and Pallamallawa.
- Concentrations were simulated well at the downstream locations of Brageen Crossing and Moree.
- There are no significant inflows between Pallamallawa and the two downstream stations mentioned above.

Given these facts it was thought that the limited dataset available for assessment at Pallamallawa may be biased towards higher concentrations, and is not representative of the full range of concentrations that can occur at this site. It may also be possible that the upstream site at Gravesend is biased however this seems less likely because there are more samples (210 data points within the model evaluation period) and this site is also consistent with other sites upstream of that.

The median of the observed dataset also supports this conclusion. The median observed concentration at Pallamallawa was 252 mg/L, whilst the medians at Moree and Brageen Crossing were 213 mg/L and 180 mg/L, respectively. It would not be possible for the concentration to decrease this much given, the limited inflow that occurs between these sites unless there is a significant amount of groundwater interaction in this reach.

The simulated flows for the end of system sites display a poor match when compared to observed flows, however the concentrations appear to be reasonable. It was not possible to evaluate the end of system site Gwydir River at Collymongle (418031), as whenever there was an observed salinity data point, the model indicated that there was no flow, and therefore no concentration was available to compare. The model indicated that when the river is flowing at this site concentrations range between 110-300 mg/L

5.4. SALINITY MODEL CALIBRATION

5.4.1. Methods (General)

The model calibration reestimated 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

$$SL = e^{\eta} Q^{\lambda} \tag{5.8}$$

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.

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

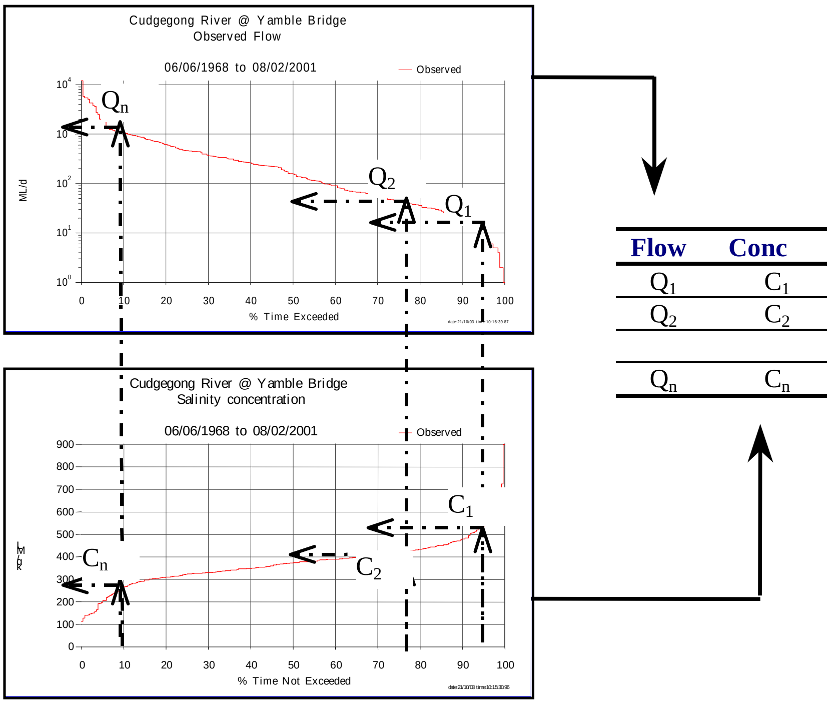


Figure 5.11. Derivation of flow versus concentration LUT from exceedance curves

5.4.1.2. Residual catchments

The salt inflows from residual catchments were calibrated using a procedure as illustrated in Figure 5.12. A target salt load at the calibration point is estimated using the power form of the salt load versus flow relationship (Equation 5.8). The model is run, and the salt load that the residual catchments need to contribute is 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 initial estimate of the flow-concentration look-up table (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.

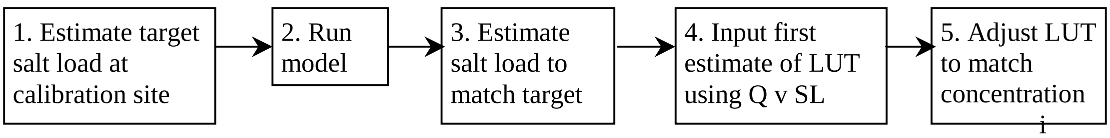


Figure 5.12. Procedure to calibrate salt inflows from residual catchments

5.4.2. Copeton Dam

The simulated concentrations in Copeton Dam probably underestimate the observed data because of the simplistic relationships used to estimate salt inflow accumulating from the six gauged catchments above the storage.

Another factor could be that the evaporation applied to the storage may be underestimating the true evaporation that has historically occurred, given the underestimation during the drought period of 1992-1995. It is also possible that the residual catchment is inputting less salt to the system than it does in reality. It is important to remember that the residual catchment represents all processes that are not otherwise modelled including both ungauged run-off and groundwater interaction. The residual catchment is effectively used to achieve the best possible calibration at the main stream gauge. Therefore, it can be considered as a calibration parameter in itself.

The first step in calibrating the salt inflows was to aggregate the inflows to Copeton Dam, and using the simulated net concentration from the Audit Relationships as a starting point, developing a flow-load relationship, which matched the Copeton Dam salinities. This 'target' relationship is displayed in Equation 5.10

$$SL = e^{3.05}Q^{0.72} \qquad (5.10)$$

This relationship then produced salt load target for calibration, and the procedure discussed in Section 5.4.1 was used. The salt inflows for Station 418029 (Gwydir River @ Stonybatter), Station 418021 (Laura Creek @ Laura), Station 418022 (Georges Creek @ Clerkness), Station 418023: (Moredun Creek @ Bundarra), Station 418033 (Bakers Creek @ Bundarra) and Station 418005 (Copes Creek @ Kimberly) were re-estimated using the power relationship and all available data. The resultant relationships are referenced in Equation 5.11, Equation 5.12, Equation 5.13, Equation 5.14, Equation 5.15, and Equation 5.16, respectively. The Salinity Audit relationship for Residual Catchment R3 was converted to flow-concentration LUTs, and calibrated to the target relationship shown at Table 5.22. The calibrated upstream model vs the target relationship is displayed in Figure 5.13.

The results of the calibrated simulation are displayed in Figure 5.39. The match with observed inflow salinity data is overall quite good, however, the model now overestimates concentrations in the low flow period. This is not considered to be a significant problem given that the concentrations in the dam are all relatively low and therefore the concentrations at the downstream stations are primarily influenced by the tributary inflow concentrations. Improving this range and variation of concentration during the dry periods would involve improving the modelling of evaporation from the storage surface, given the fact that there is little upstream inflow during theses times. Concentrations in the medium to high flow ranges are represented well with the calibrated relationships.

The performance measures displayed in Table 5.23 have been improved relative to the first-cut model run, with the mean match, average error and range and r-squared all improving.

$$SL = e^{2.66}Q^{0.87} \qquad (5.11)$$

$$SL = e^{2.18}Q^{0.77} \qquad (5.12)$$

$$SL = e^{2.19}Q^{0.77} \qquad (5.13)$$

$$SL = e^{2.29} Q^{0.83} \quad (5.14)$$

$$SL = e^{1.57} Q^{0.90} \quad (5.15)$$

$$SL = e^{1.84} Q^{0.84} \quad (5.16)$$

Table 5.22. Calibrated flow versus salinity relationship used for inflows in residual catchment R1/2

Flow (ML/d)	Concentration (mg/L)
0	0
1	370
100	366
400	235
1000	167
5000	100
8500	20
30000	5
80000	0
1.00E+37	0

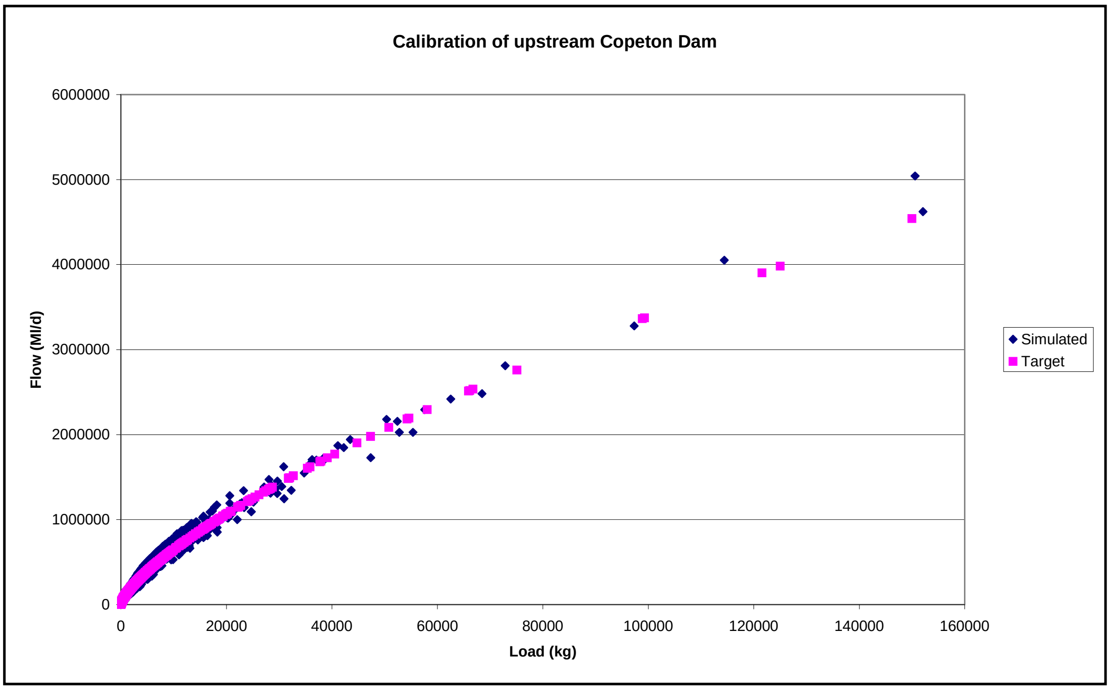


Figure 5.13 Results of calibrated upstream relationships vs target relationship for dam inflow salinity

Table 5.23 Results of performance measures for simulated versus observed salinities in Copeton Dam using calibrated relationship

Performance measure	Result
Pattern match	0.363
Mean match	0.065
Average error	0.132
Range match	0.047
R^2	0.728

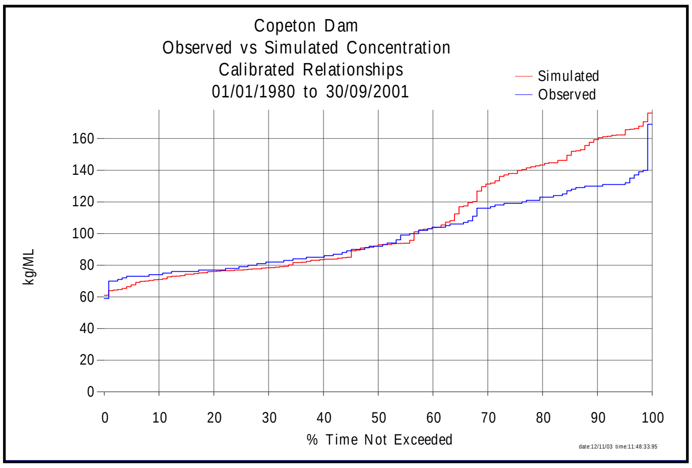


Figure 5.14. Non-exceedance curve for observed versus simulated salinity for calibrated model at Copeton Dam

5.4.3. Station 418012: Gwydir River @ Pinegrove

Improving the results of the salinity simulation in Copeton Dam significantly improved the results at this station, relative to the first-cut model results. Further improvements were made by rederiving the salinity inflow relationship on the two residual catchments between Gwydir River D/S of Copeton Dam and this station (described in Table 5.24). The relationship for the gauged catchment 418018: Keera Creek @ Keera was not altered from the 2D relationship discussed in section B.2.1, and described in equation 5.17.

The results of the simulation are shown in Figure 5.41, and show a close match for most of the points. The simulated vs observed salinity distribution shows an improved match across all flow ranges, however the low to medium flows correspond to concentrations that are slightly below observed recordings (up to 7%).

$$SL = e^{3.04} Q^{0.83} \qquad (5.17)$$

Table 5.24. Calibrated flow versus salinity relationship used for inflows in residual catchment R3

Flow (ML/d)	Concentration (mg/L)
0	0
1	600
8	300
20	210
50	190
200	160
1.00E+37	160

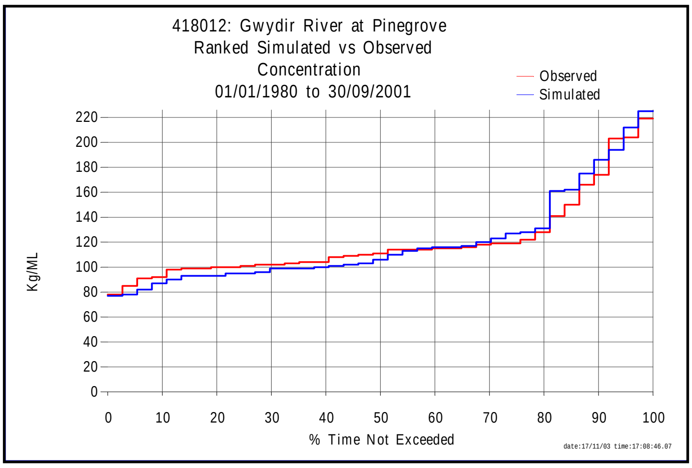


Figure 5.15 Non-exceedance curve for observed versus simulated salinity for calibrated model at Station 418012: Gwydir River @ Pinegrove

Table 5.25Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 418012: Gwydir River @ Pinegrove

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*	187	31	150	219	18	0.86	15
	Simulated	178	51	106	225			20
Medium	*Observed*	115	25	85	203	11	0.75	77
	Simulated	115	30	78	212			85
High	*Observed*	103	12	78	118	12	0.45	349
	Simulated	105	27	77	162			322
All	*Observed*	120	33	78	219	12	0.79	129
	Simulated	119	37	77	225			129

5.4.4. Station 418013: Gwydir River @ Gravesend Road Bridge

The Gravesend results were improved by re-deriving the salt inflows using a flow/concentration LUT or a power relationship of flow vs salt load at each of the contributing catchments. The data at each of the gauged inflow sites was analysed to decide the best representation of the salt load entering from these catchments. For three of the catchments (Myall, Horton and Warialda) a flow/concentration LUT gave the best results. This relationship was based on the original linear audit relationships for salt load vs flow. These relationships were modified at the low end to remove the fixed intercept that results when using a linear relationship. The intercept causes the model to have very high salinities at very low flows since the use of an intercept implies some load is being contributed at zero or near zero flows. Using this modification reduces the incidence of concentrations reaching the maximum allowable concentration which is evident when the linear salinity audit relationships are used. The parameters of the look-up tables for Myall Ck, Horton River and Warialda Ck are shown in tables Table 5.26, Table 5.27 and Table 5.28 respectively.

The relationship for Halls Creek was changed from a linear relationship in the audit (which had a negative intercept) to a power relationship as shown in Equation 5.18.

The Salinity Audit relationships for the residual catchments R4 were converted to flow-concentration LUTs, which were adjusted to achieve the best match possible with the observed non-exceedance curve at Gravesend. The final LUTs are presented in Table 5.29

The final simulation results for observed and simulated salinity is shown in Figure 5.42, which shows a slight improvement compared with the Salinity Audit relationships. The simulated versus observed non-exceedance curve (Figure 5.16) shows a slight improvement compared with the Salinity Audit relationships, but a significant improvement for salinities with a non-exceedance probability above 90%. This is due to the low end modifications on the inflow relationships The comparative statistics for the flow ranges are also quite close across all flow ranges (Table 5.30)

$$SL = e^{3.88} Q^{0.97} \qquad (5.18)$$

Table 5.26 Calibrated flow versus salinity relationship for inflows in Myall Creek

Flow (ML/d)	Concentration (mg/L)
0	0
1	2220
5	2220
15	1000
25	700
50	470
150	315
600	265
5000	250
1e37	250

Table 5.27 Calibrated flow versus salinity relationship for inflows in Horton River

Flow (ML/d)	Concentration (mg/L)
0	0
1	600
3	800
6	520
15	423
80	255
500	196
1e37	187

Table 5.28 Calibrated flow versus salinity relationship for inflows in Warialda Creek

Flow (ML/d)	Concentration (mg/L)
0	0
1	750
10	750
15	500
35	300
70	205
300	155
5000	140
1e37	140

Table 5.29. Calibrated flow versus salinity relationship for inflows in residual catchment R4

Flow (ML/d)	Residual Node			
	255	261	144	262
	Concentration (mg/L)			
0	0	0	0	0
1	720	600	720	450
3	520	800	320	600
6	316	520	208	592
15	267	423	234	442
80	213	255	196	264
500	196	196	187	196
1e37	187	187	187	187

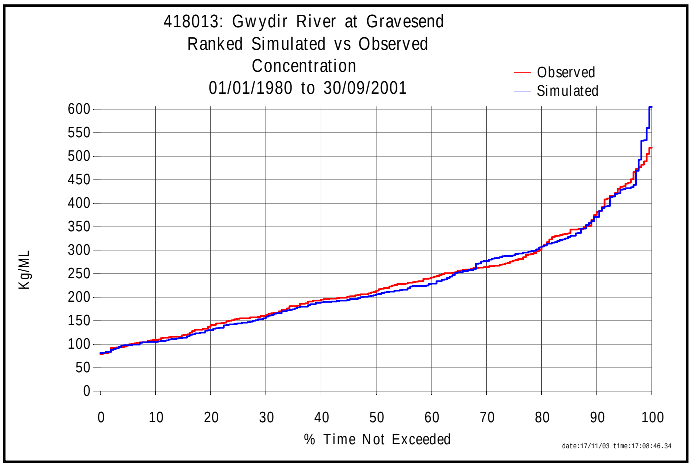


Figure 5.16. Non-exceedance curve for observed versus simulated salinity for calibrated model at Station 418013: Gwydir River @ Gravesend Road Bridge

Table 5.30. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 418013: Gwydir River @ Gravesend Road 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*	284	83	150	482	68	0.34	41
	Simulated	329	103	153	605			45
Medium	*Observed*	233	100	95	518	51	0.49	162
	Simulated	207	76	91	430			173
High	*Observed*	140	58	79	290	23	0.64	657
	Simulated	135	44	81	219			729
All	*Observed*	229	101	79	518	50	0.52	223
	Simulated	226	105	81	605			244

5.4.5. Station 418001: Gwydir River @ Pallamallawa

The calibrated relationships upstream of Gwydir River @ Pallamallawa produce a result that is similar to the result obtained from the audit relationships (Figure 5.43). The simulated concentration is significantly lower than the observed concentration throughout all flow ranges. As previously discussed in Section 5.3.4, there may be a problem with the representativeness of the data collected at this site, however this should not effect the result achieved using a "corresponding points comparison". (i.e. even though the data may be biased to dry periods, we are comparing it with simulated data from dry periods).

Given the fact that there is little modelled inflow or outflow occurring between this site and the upstream site of Gravesend, it was decided that further investigation of the results at Gravesend should be performed to help resolve this issue. This investigation found that the 210 discrete data points at Station 418013 are not representative of the full range of concentrations that can occur at that location. This is best shown in a ranked plot of observed vs simulated salinity, where all data points are used independently of the other variable (Figure 5.18). In this situation, the observed exceedance plot would be based on the 210 discrete data points and the simulated exceedance plot would be based on daily values over the entire comparison period (approximately 7000 data points). The simulated exceedance plot is clearly underestimating the observed exceedance plot throughout all flow ranges, which is definitely part of the reason why a poor result is achieved at Gwydir River @ Pallamallawa.

In an attempt to improve this result, we conducted a sensitivity analysis on the impact of the salt input from residual catchments upstream of 418013 and the concentrations in the dam on the simulated concentrations at Gravesend. It was found that these inflows had little effect on the high flow/low concentration period of the exceedance. In fact, the only way to achieve a better result in this flow range was to add more salt at the gauged catchments. It was decided not to take this approach as the current relationships on these catchments represent the observed data well and any adjustments that increase salt load would therefore not be justified. We therefore concluded that it is inconclusive whether the problems at Pallamallawa are due to non-representative data at this gauge or at Gravesend. If the data is non-representative at Gravesend then the model would have been calibrated to non-representative data.

To deal with the possibility that the Pallamallawa data is non-representative, we decided to “extend” the data-set a Pallamallawa by merging the original data with the data from other downstream sites. In doing this, we hoped we would get a more representative data-set since the other sites had data that was collected at different periods to Pallamallawa. We could then compare the “merged” data-set with the simulated points gain a better understanding of the “actual” error that occurs across the full range of flows (Figure 5.20). We obtained as many additional data points as possible from nearby sites where there is a strong relationship between the concentration at Pallamallawa and the alternate site. Typically, the immediately downstream sites were considered to be most representative of the concentration at Pallamallawa since there is generally small inflows between Pallamallawa and these sites. For example 418004: Gwydir River at Yarraman Bridge displayed a very high correlation with Pallamallawa when salinity data samples on corresponding days were compared. A relationship was developed and used to factor the data at Yarraman so that it was representative of the expected value at Pallamallawa. This factored data was merged into the Pallamallawa data-set. The process was repeated using data from Moree and Gravesend. The final merged data-set had a total of 397 data points as opposed to the 53 data points available in the original Pallamallawa sample.

The results from the comparison with the merged dataset, show that the model is still significantly underestimating the medium to high flow regime, by up to 20% (Figure 5.20). This error is considered to be unacceptable however as previously discussed the gauged inflows above 418013, are the main inflows that effect this part of the flow regime and there is no evidence to suggest that they should be adjusted. The merged data-set also shows that the low flow regime is simulated much better than the original comparison indicated.

Table 5.31. Calibrated flow versus salinity relationship for inflows in residual catchment R5

Flow (ML/d)	Concentration (mg/L)
0	0
1	600
6	600
20	450
80	270
350	170
1e37	135

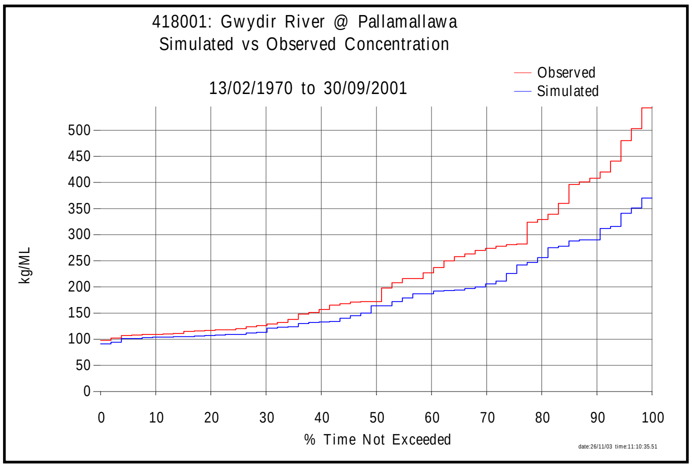


Figure 5.17 Non-exceedance curve for observed versus simulated salinity for calibrated model at Station 418001: Gwydir River @ Pallamallawa

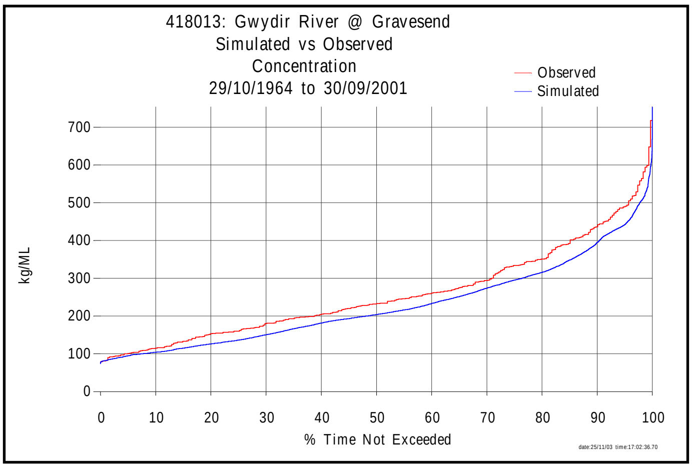


Figure 5.18 Independent non-exceedance curve for observed versus simulated salinity for calibrated model at Station 418013: Gwydir River @ Gravesend

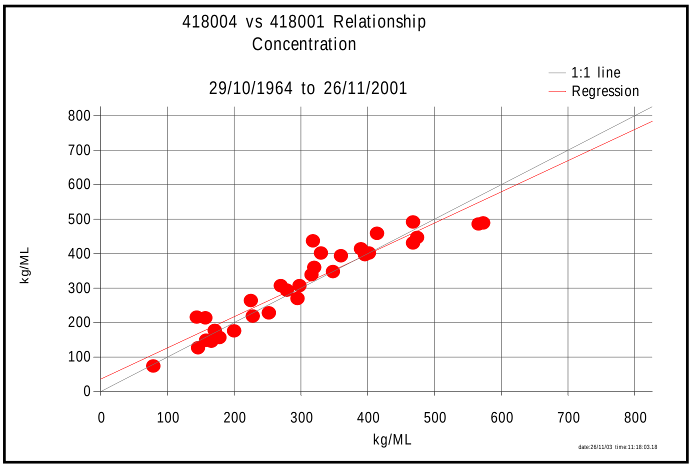


Figure 5.19 Relationship between sites 418004: Gwydir River @ Yarraman Bridge and 418001: Gwydir River @ Pallamallawa, used to derive 'merged' dataset.

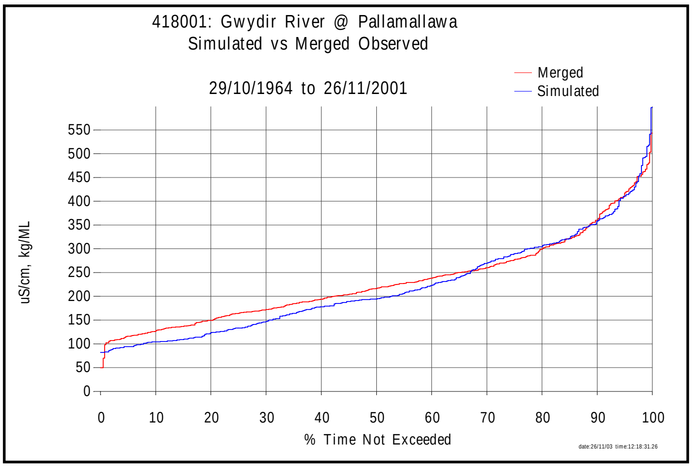


Figure 5.20 Non-exceedance curve for merged observed versus simulated salinity for calibrated model at Station 418001: Gwydir River @ Pallamallawa

Table 5.32 Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 418001: Gwydir River @ Pallamallawa (original data set)

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*	247	100	172	360	54	0.62	54
	Simulated	237	103	121	316			40
Medium	*Observed*	241	128	102	543	79	0.37	250
	Simulated	188	79	101	370			179
High	*Observed*	161	71	98	282	26	0.89	812
	Simulated	136	46	91	197			715
All	*Observed*	225	120	98	543	66	0.44	356
	Simulated	180	78	91	370			282

5.4.6. Station 418053: Gwydir River @ Brageen Crossing

A slightly improved match between observed and simulated data at Gwydir River @ Brageen Crossing occurs from using the calibrated upstream relationships. The residual inflow catchment was re-derived and was based on the nearby Tycannah Creek catchment (Table 5.33, node 141). These relationships replace the constant 300 mg/L that had been used for the first-cut audit relationship run.

The statistics for this site are shown in Table 5.34. Improvements occur across all flow ranges, however the most notable change occurs in the high flow range where the average error has been reduced from 47 mg/L to 36 mg/L. Even with this improvement, it is clear that the underestimation of the high flow salinities at Pinegrove/ Pallamallawa has been transferred downstream to this location (Figure 5.21).

This is the most downstream site on the Gwydir River that can be evaluated with reasonable confidence, before the system joins with the Barwon River. Although the results still display significant errors between the observed and simulated salinity data, it is considered that it will only have a small impact on the simulated salinity in the Barwon-Darling system since the simulated average annual flow at the Gwydir River end of system is only 10GL/yr (over the benchmark period).

Table 5.33 Calibrated flow versus salinity relationship for inflows of residual catchments in the lower Gwydir

Flow (ML/d)	Residual Node 205	125	066	221	141	196	322	278
	Concentration (mg/L)							
0	0	0	0	0	0	0	0	0
1	600	600	600	600	620	450	600	600
4	600	490	600	600	510	350	600	600
20	450	380	450	450	400	300	400	450
50	400	325	400	400	345	250	200	400
350	320	250	320	320	270	240	120	320
2000	260	180	260	260	200	200	100	260
5500	150	150	150	150	170	150	60	150
1e37	130	130	130	130	150	130	60	130

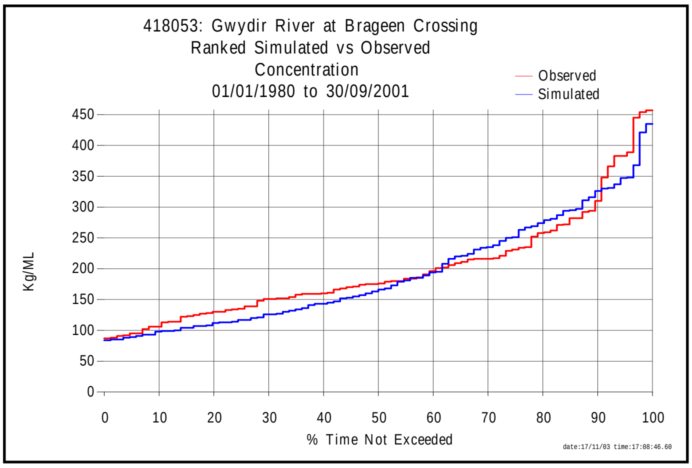


Figure 5.21. Non-exceedance curve for observed versus simulated salinity for calibrated model at Station 418053:Gwydir River @ Brageen Crossing

Table 5.34. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 418053:Gwydir River @ Brageen Crossing

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*	261	91	152	457	123	0.37	2
	Simulated	207	73	99	326			6
Medium	*Observed*	197	78	91	454	54	0.43	12
	Simulated	202	92	88	435			15
High	*Observed*	171	89	87	389	36	0.57	48
	Simulated	158	77	84	331			33
All	*Observed*	198	86	87	457	58	0.29	20
	Simulated	191	87	84	435			19

5.4.7. Station 418002: Mehi River @ Moree

Statistics for the observed vs simulated concentrations at Mehi River @ Moree show that there is little difference between the first-cut audit relationships and the calibrate relationships (Figure 5.35). The only change to the Salinity Audit model in this reach is the inclusion of new flow vs concentration look-up tables for residual inflows in this reach (see Table 5.33, node 125). Although the results appear to be acceptable in both models, there is a higher confidence in the calibrated results, as the simulated storage concentration is much more realistic when compared with the observed data. Therefore the adjustments required using the residual catchment to match the observed data at Moree are probably more realistic. The problem of underestimating concentration at high to medium flows (as previously discussed) is still evident but the magnitude of the error has substantially decreased (Figure 5.22). The simulated is now overestimating the low flow regime by up to 10%, however it was not possible to reduce this error without increasing the error throughout the medium flow range. The mean of the observed and simulated salinity is within 0.5% of each other for corresponding points.

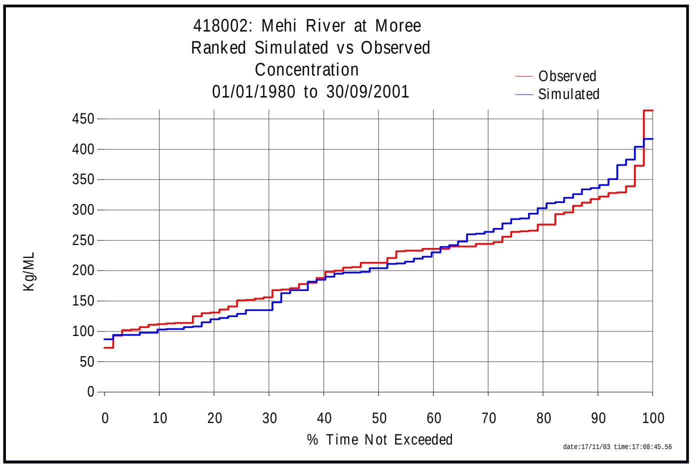


Figure 5.22. Non-exceedance curve for observed versus simulated salinity for calibrated model at Station 418002: Mehi River @ Moree

Table 5.35. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 418002: Mehi River @ Moree

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*	245	40	151	312	66	0.00	11
	Simulated	272	74	195	417			54
Medium	*Observed*	225	82	103	464	59	0.38	83
	Simulated	216	89	94	404			98
High	*Observed*	119	31	73	180	21	0.07	280
	Simulated	125	36	87	190			560
All	*Observed*	213	80	73	464	55	0.39	98
	Simulated	214	91	87	417			162

5.4.8. Station 418031: Gwydir River @ Collymongle

As previously discussed it was not possible to evaluate this site.

5.4.9. Station 418058: Mehi River @ Bronte

The calibrated results for Mehi River @ Bronte demonstrate improvements across all flow ranges, when compared with the results from the first-cut run (as shown in Figure 5.36). Improvements in this reach include the updated relationships for all residual inflows in this reach (see Table 5.33, nodes 066 and 205), as well as using a power relationship for the gauged inflow of Tycannah Creek @ Horseshoe Lagoon (Equation 5.19) as opposed to the linear relationship in the first-cut model. The simulated mean on days corresponding to an observed data point 224 mg/L compared to the observed mean of 230 mg/L.

$$SL = e^{3.26}Q^{0.84} \tag{5.19}$$

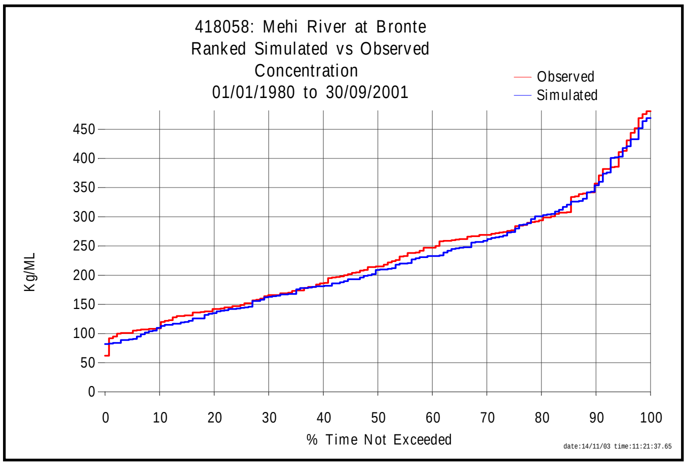


Figure 5.23. Non-exceedance curve for observed versus simulated salinity for calibrated model at Station 418058: Mehi River @ Bronte

Table 5.36. Comparison of statistics within flow ranges of: (i) observed discrete versus simulated salinity; and (ii) observed versus simulated load for Station 418058: Mehi River @ Bronte

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*	302	84	138	444	102	0.00	1
	Simulated	280	92	109	480			35
Medium	*Observed*	238	92	101	481	83	0.12	11
	Simulated	232	95	82	490			52
High	*Observed*	152	59	62	277	47	0.20	51
	Simulated	157	62	82	319			61
All	*Observed*	230	96	62	481	78	0.19	18
	Simulated	224	96	82	490			51

5.5. VALIDATION OF RESULTS

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

As to be expected the calibrated model displays only minor differences in terms of salt load compared to the first-cut model (Table 5.37). The most notable difference occurs at station:418012: Gwydir River @ Pinegrove, where calibrated salt loads show a 8% reduction when compared with the fist cut run.

Compared with the Salinity Audit, there is a range of differences in the annual salt load at the inflow (Table 5.37), as well as those used for the initial model evaluation (column 4 in Table B.8.1). The difference at the catchment as a percentage is in quite significant, although in real terms only usually +/- a couple of thousand tonnes per year. The exception to this is the residual catchments, which can be up to 17,400 tonnes per year different and Station 418018: Keera Creek @ Keera. The differences occurring at the residuals can mostly be contributed to the quantity of flow entering from the residuals. Differences occurring at Keera Creek can be attributed to the new relationship used at this location, which is a much more realistic representation of the observed data available for this site (discussed in section B.2.1)

Comparisons of mainstream gauges show that the annual salt loads reported in the audit are very similar to the results of the calibrated IQQM model. The exception to this is station 418001: Gwydir River @ Pallamallawa, where the simulated salinity in the calibrated model is approximately 17% (average of 26,000 tonnes per year) lower than results from the Salinity Audit model. Table 5.37 shows that the difference between Gravesend and Pallamallawa is approximately 30 tonnes per year. Considering that there are no significant quantity inputs in this reach, we this type of increase was not possible. However, the Salinity Audit model was calibrated to match the discrete data at Pallamallawa, thus reproducing the large increase in salt load between these two sites. We felt that this was not appropriate and underwent a comprehensive investigation into the data at Pallamallawa (as discussed in Section 5.4.5). During this investigation, we concluded that the problem was a combination between non-representativeness of the observed data points at Pallamallawa and at Gravesend. After adjusting the salinity inputs and the calibration at Gravesend as much as possible, the match presented as Pallamallawa was the best we could achieve in the current model.

Table 5.37. 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*	*4*	*Calibrated*
418029	Gwydir River @ Stonybatter	13.7	13.4	15.6
418021	Laura Creek @ Laura	2.5	2.6	2.4
418022	Georges Creek @ Clerkness	3.7	3.8	3.1
418023	Moredun Creek @ Bundarra	6.2	7.1	6.4
418033	Bakers Creek @ Bundarra	0.6	0.5	0.6
418005	Copes Creek @ Kimberley	1.7	1.6	1.4
418026	**Gwydir River D/S Copeton Dam**	**32.4**	**30.2**	**33.7**
418018	Keera Creek @ Keera	9.9	5.7	6.1
418012	**Gwydir River @ Pinegrove**	**53.5**	**55.3**	50.7
418025	Halls Creek @ Bingara	5.1	4.9	4.3
418017	Myall Creek @ Molroy	13.0	12.1	12.5
418015	Horton River @ Rider (Killara)	44.1	42.5	40.6
418016	Warialda Creek @ Warialda No.3	4.7	4.2	4.4
418013	**Gwydir River @ Gravesend Road Bridge**	**119.7**	**121.1**	**119.9**
418001	**Gwydir River @ Pallamallawa**	**149.4**	**123.4**	**124.3**
418032	Tycannah Creek @ Horseshoe Lagoon	9.9	7.3	6.9

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, such as 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 Gwydir IQQM is a robust and reliable water balance model of the Gwydir/Mehi Rivers. The model has been peer reviewed externally, and has been used for a number of years to provide information for developing water sharing policies.

The result of the comparison for salinity and salt loads from the tables in Section 5.4 are summarised in Table 5.38. 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 all evaluation points in each flow range was matched within ±10% with six, three of which can be attributed to Pallamallawa. This result was addressed in detail in Section 5.4.5. The other three are the low and medium flow ranges at the Gwydir River @ Gravesend Road Bridge, and the low flow range at the Gwydir River @ Brageen Crossing.

The match of simulated salt loads to observed data was good for the total flow at the Gwydir River @ Pinegrove, Gwydir River @ Gravesend Road Bridge and Gwydir River @ Brageen Crossing (all within ± 10%). However, the salt load results within the respective low, medium, and high flow ranges are variable. All remaining sites have significant difference in load, primarily the result of modelled diversions not representing reality.

In summary, the model appears to simulate the salinity behaviour in the river system well. The matches for the non-exceedance curves reported in Section 5.4, the corresponding consistency of behaviour of continuous and daily behaviour, and the close match of mean concentrations across all flow ranges at all evaluation sites gives us confidence in this. The exception to this is concentrations in the high to medium flow range for Pallamallawa.

Table 5.38. 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%**	
	Copeton Dam	-	-	-	1	-	-	-	-
418012	Gywdir River @ Pinegrove	1	1	1	1	3	1	1	1
418013	Gywdir River @ Gravesend Rd Bridge	2	2	1	1	1	1	1	1
418001	Gwydir River @ Pallamallawa	1	3	2	3	3	3	2	3
418002	Mehi River @ Moree	1	1	1	1	3	2	3	3
418053	Gwydir River @ Brageen Crossing	3	1	1	1	3	2	3	1
418058	Mehi River @ Bronte	1	1	1	1	3	3	2	3

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.

Given the above results, the model would be suitable for simulating relative changes in concentration at all sites. Absolute values for concentration in all flow ranges for Pallamallawa, the low flow range for Brageen Crossing should be used with caution. The same applies for absolute values of load at all locations.

5.6.3. Water management scenarios

The relative impacts of various water sharing scenarios on salinity can be simulated with confidence.

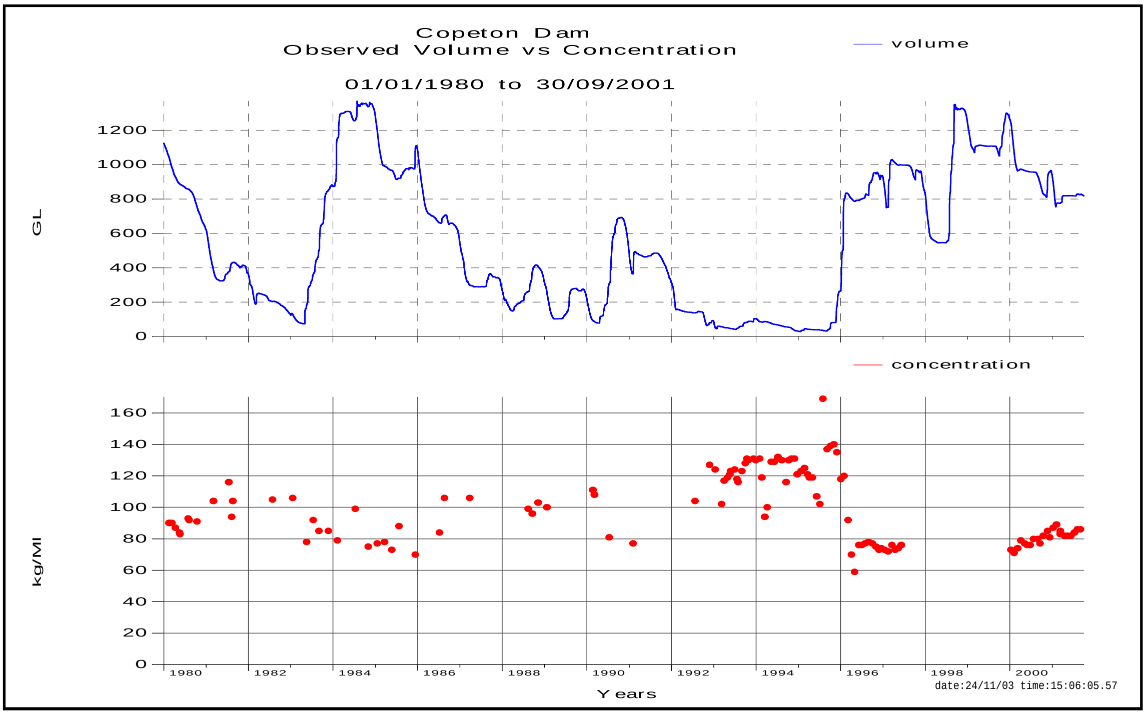


Figure 5.24. Copeton Dam storage volume and concentration data

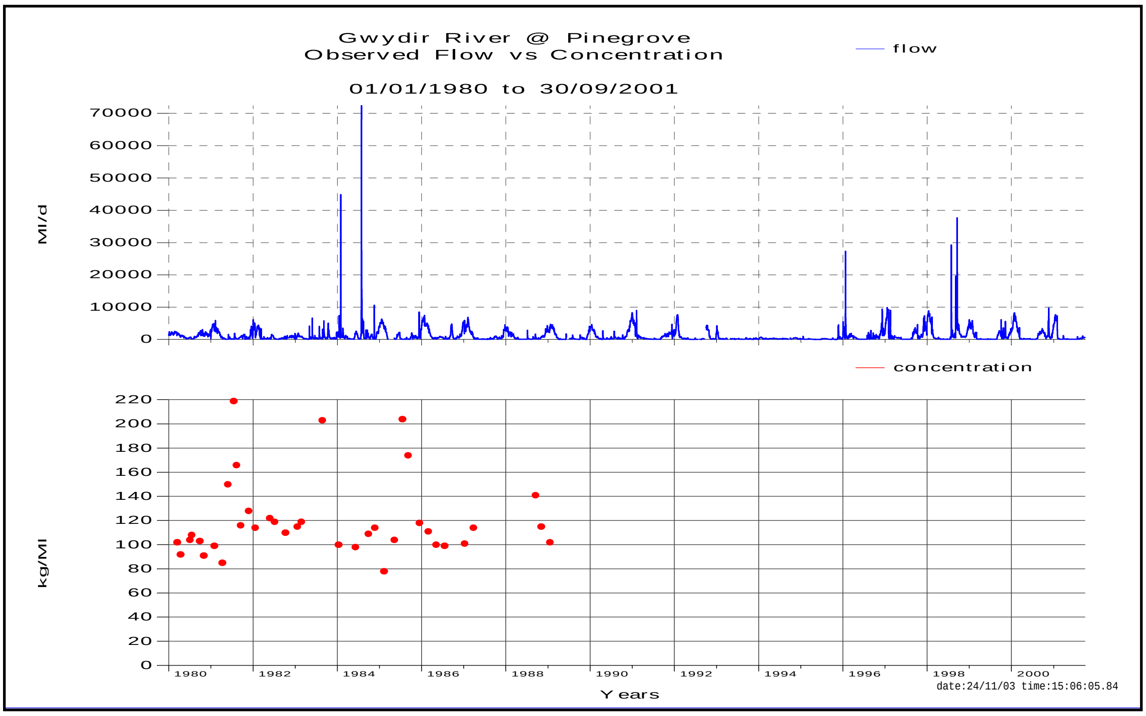


Figure 5.25. Station 418012: Gwydir River @ Pinegrove flow and concentration data

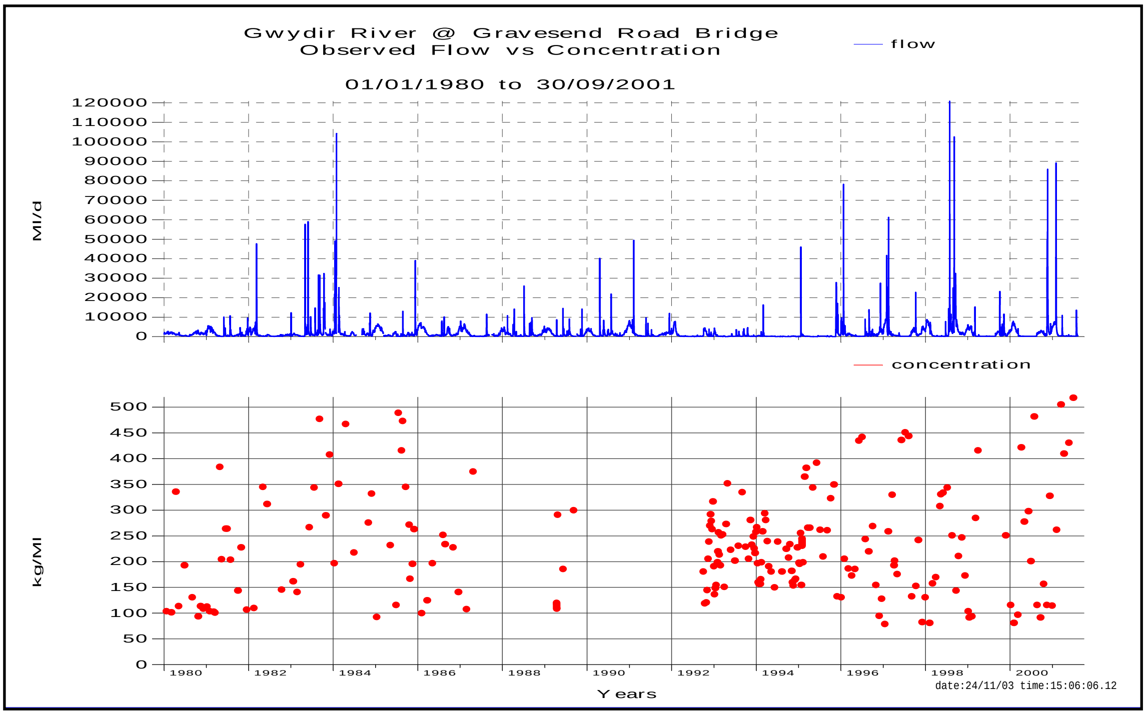


Figure 5.26. Station 418013: Gwydir River @ Gravesend Road Bridge flow and concentration data

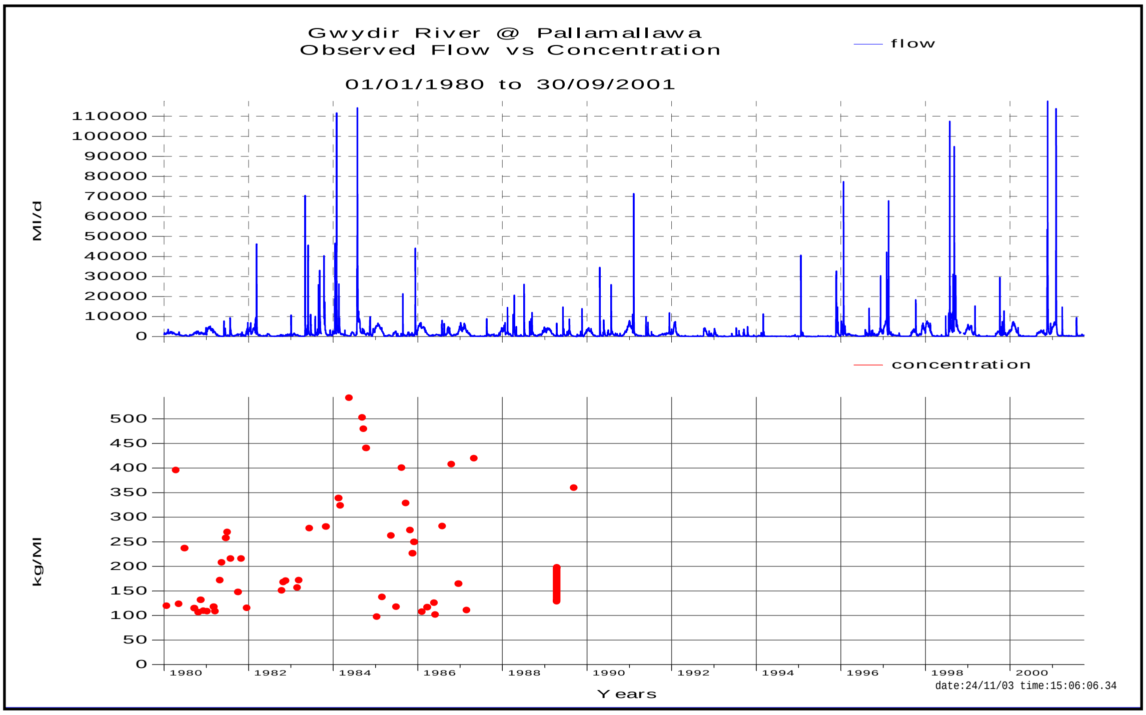


Figure 5.27. Station 418001: Gwydir River @ Pallamallawa flow and concentration data

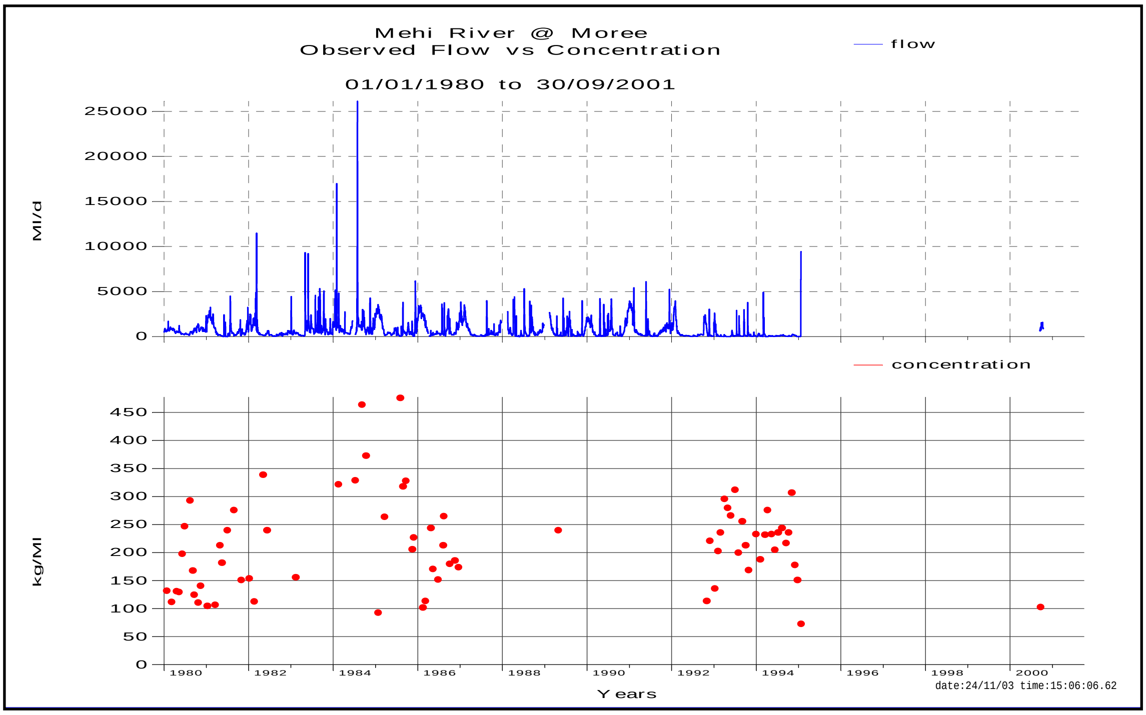


Figure 5.28. Station 418002: Mehi River @ Moree, flow and concentration data

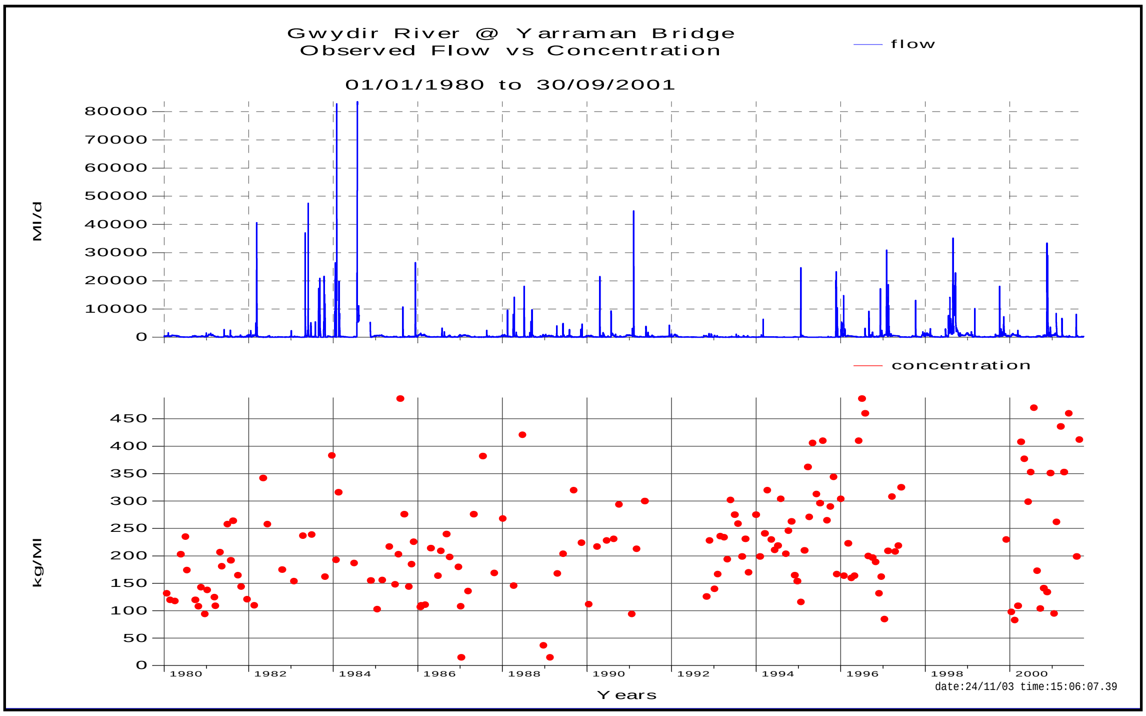


Figure 5.29. Station 418004: Gwydir River @ Yarraman Bridge, flow and concentration data

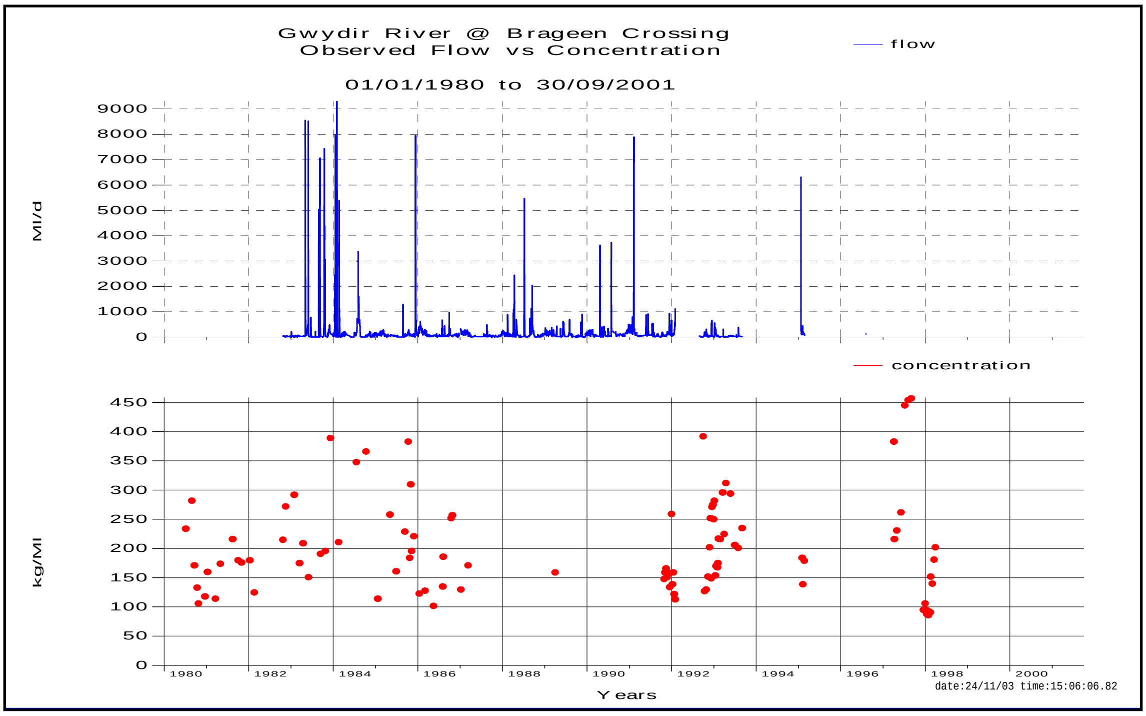


Figure 5.30. Station 418053: Gwydir River @ Brageen Crossing

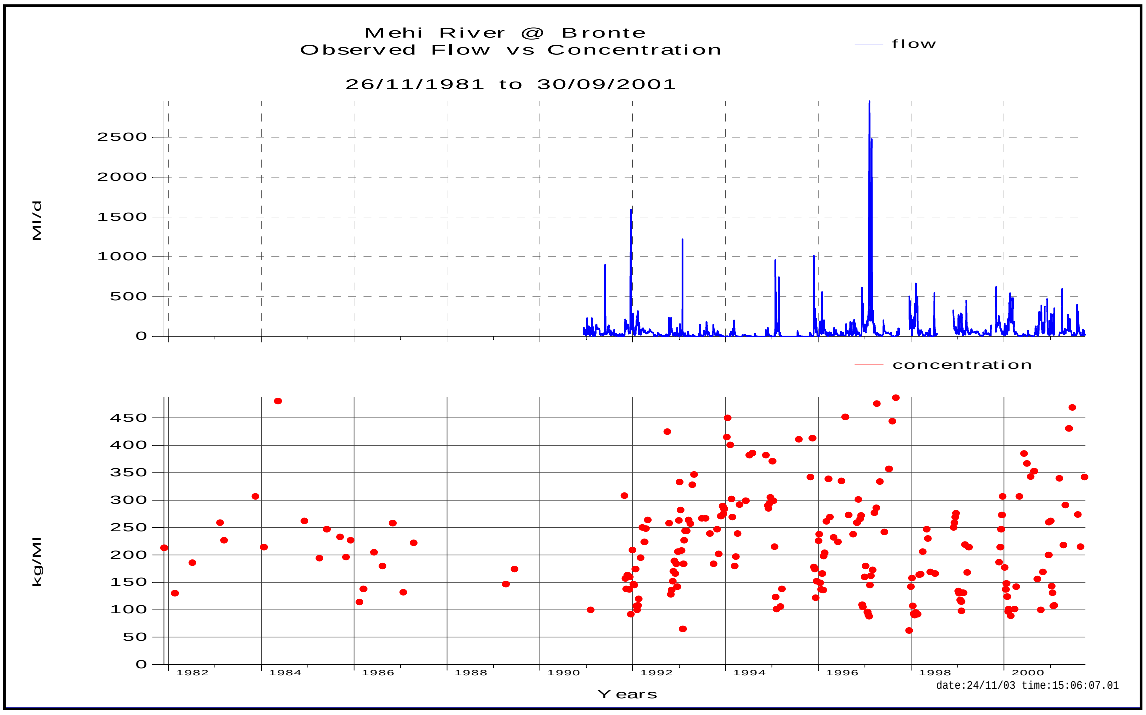


Figure 5.31. Station 418058: Mehi River @ Bronte observed flow and concentration

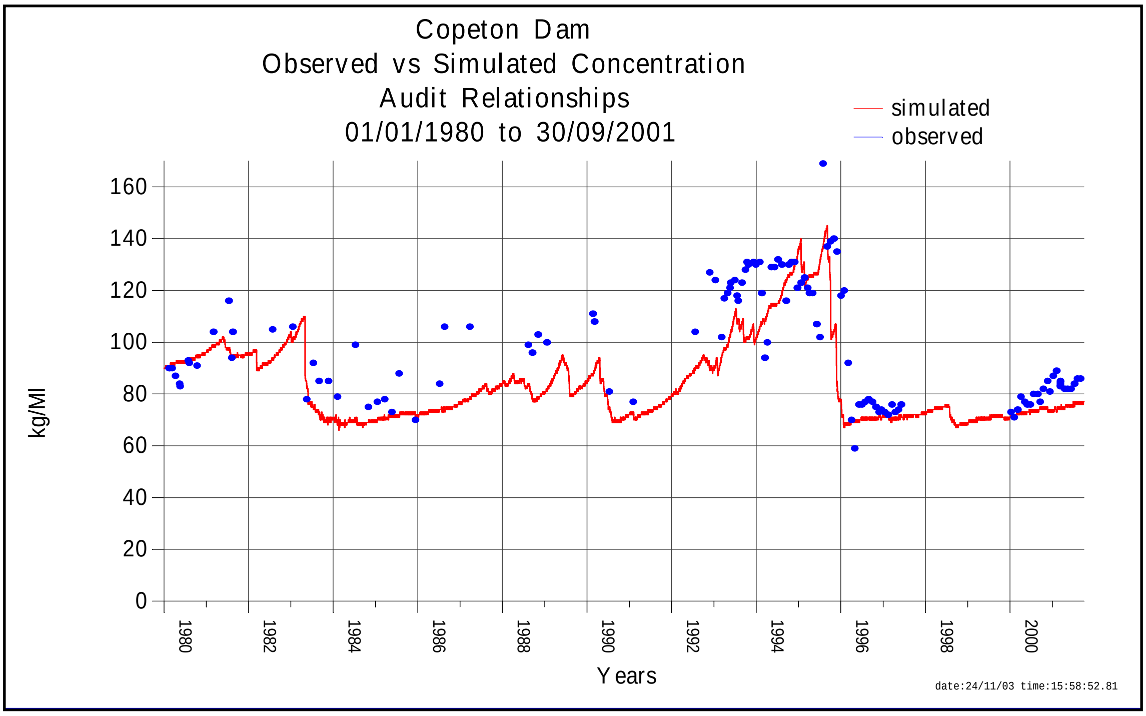


Figure 5.32. Simulated versus observed concentration at Copeton Dam, using Salinity Audit relationships.

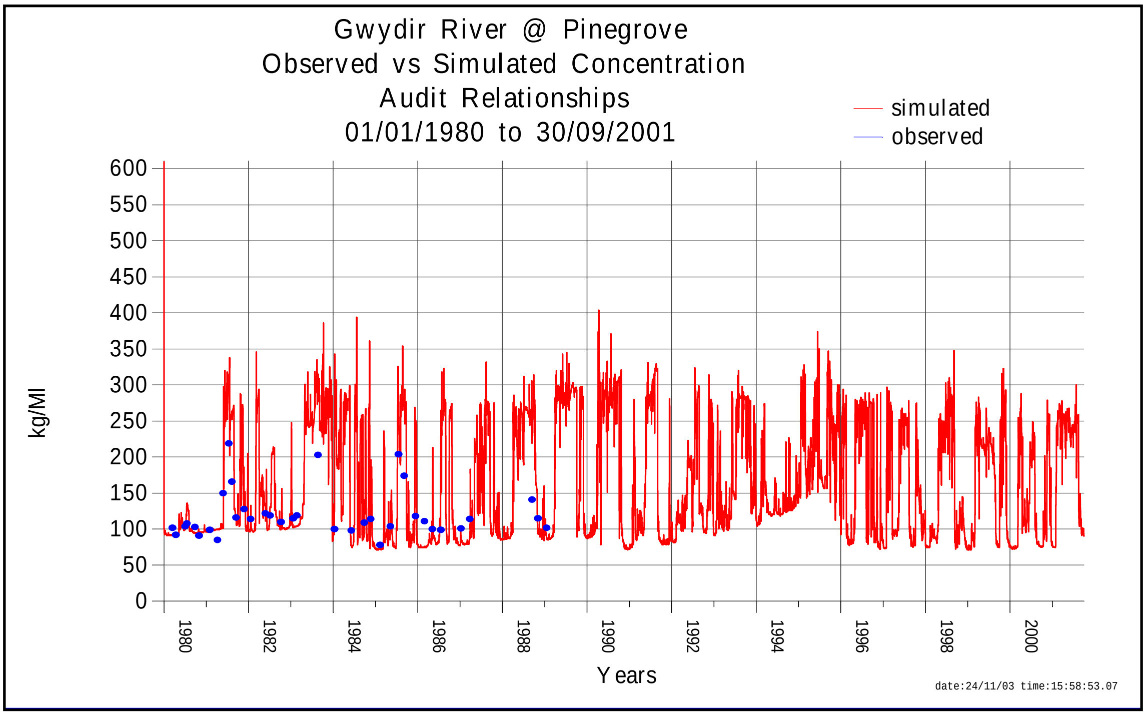


Figure 5.33. Simulated versus observed salinities at Station 418012: Gwydir River @ Pinegrove, using Salinity Audit relationships.

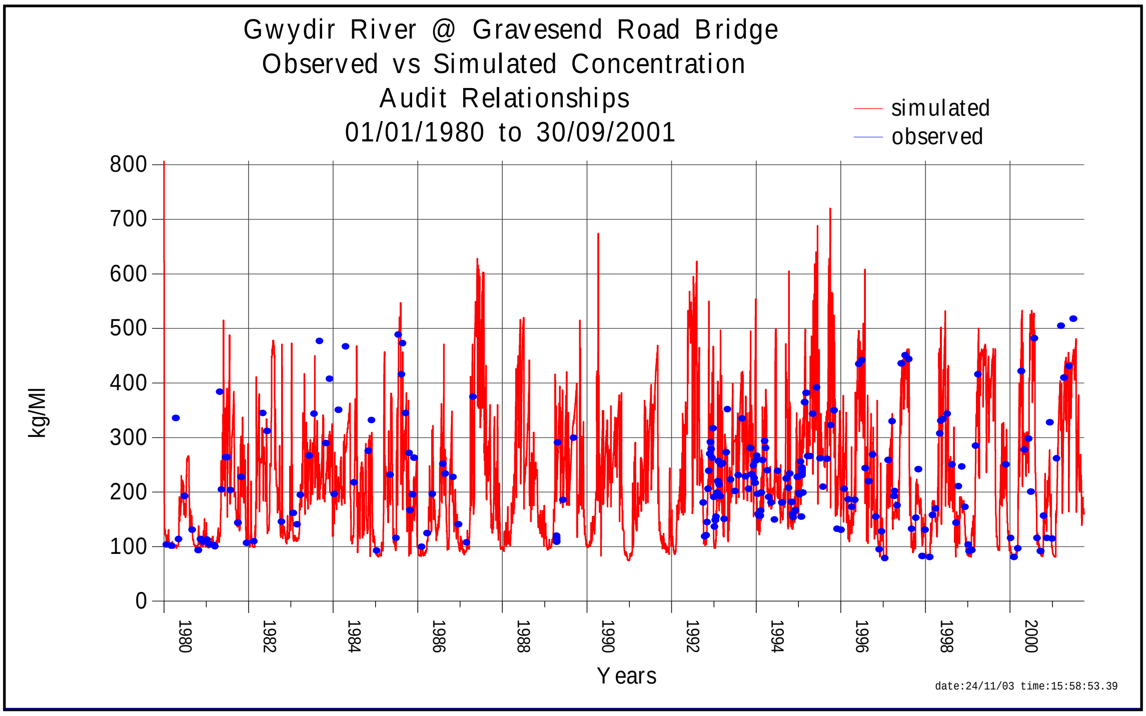


Figure 5.34. Simulated versus observed salinities at Station 418013: Gwydir River @ Gravesend Road Bridge, using Salinity Audit relationships.

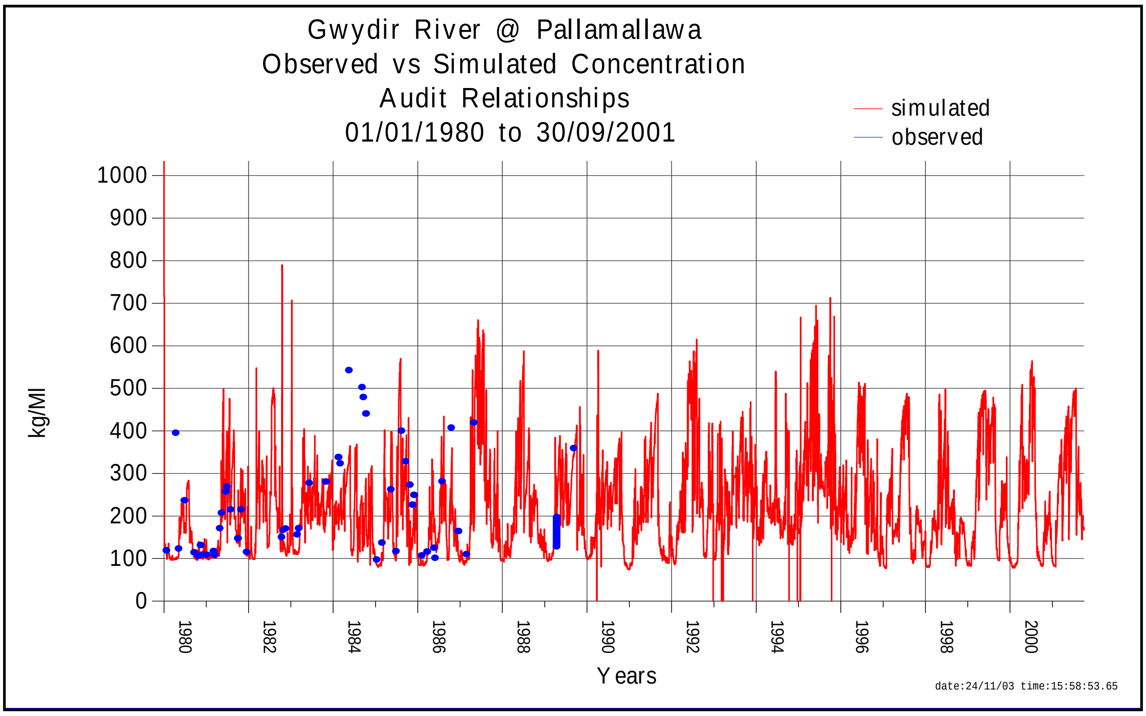


Figure 5.35. Simulated versus observed salinities at Station 418001: Gwydir River @ Pallamallawa, using Salinity Audit relationships.

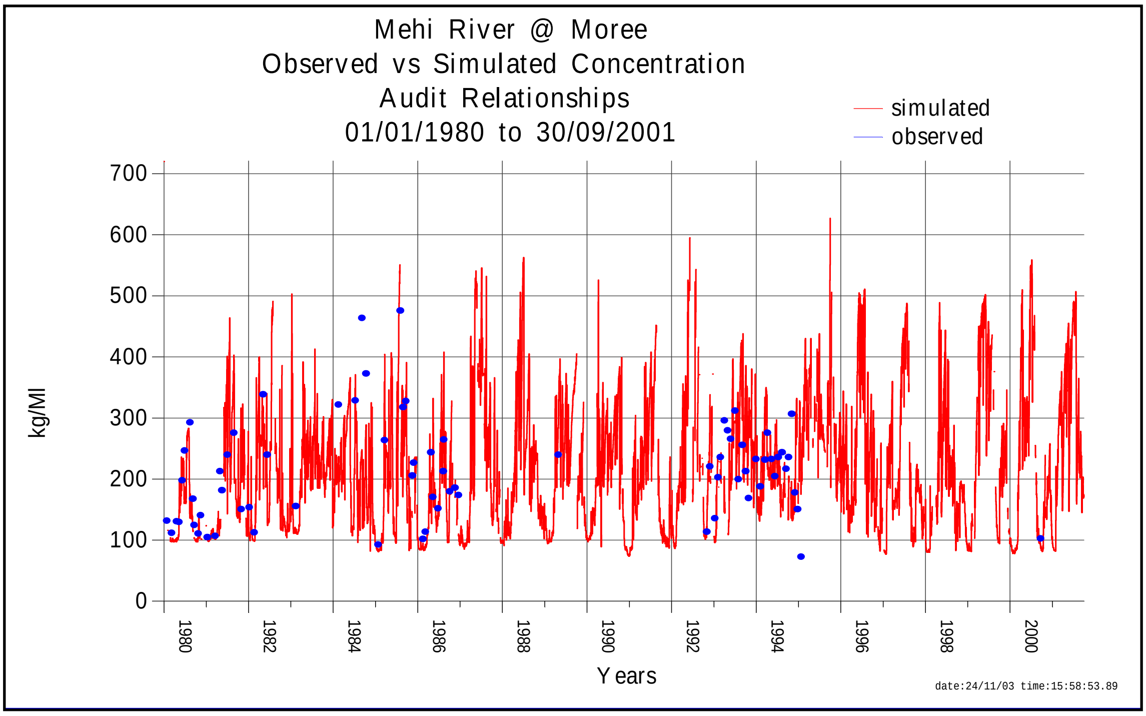


Figure 5.36. Simulated versus observed salinities at Station 418002: Mehi River @ Moree, using Salinity Audit relationships.

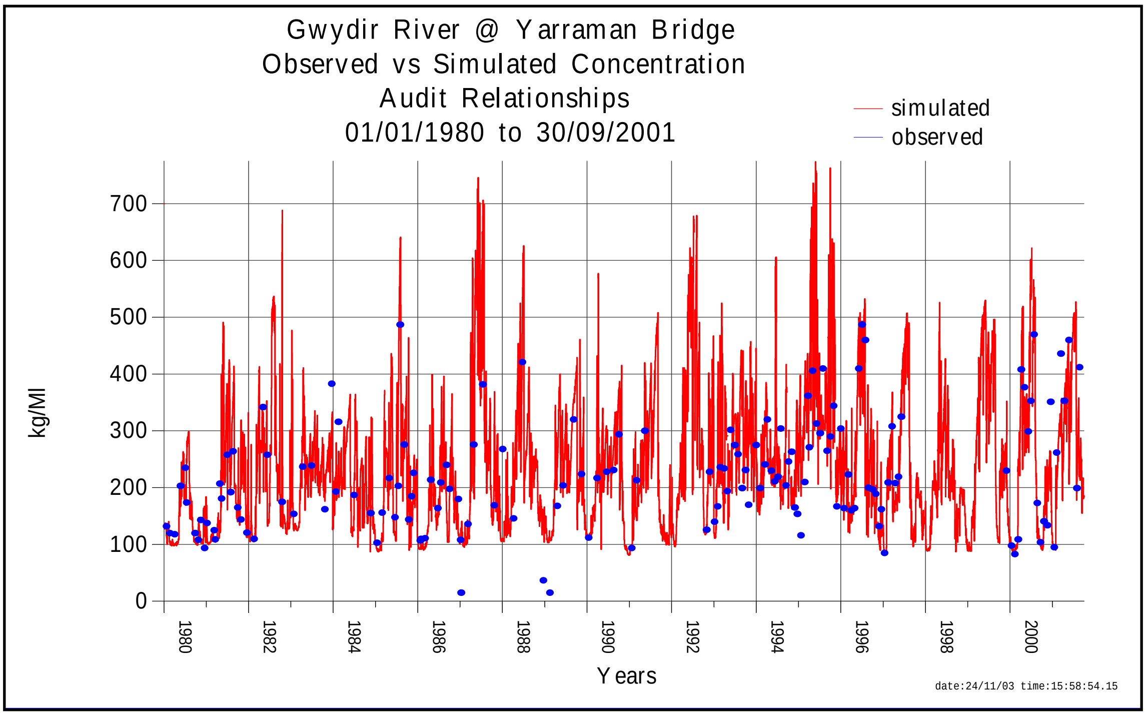


Figure 5.37. Simulated versus observed salinities at Station 418004: Gwydir River @ Yarraman Bridge, using Salinity Audit relationships.

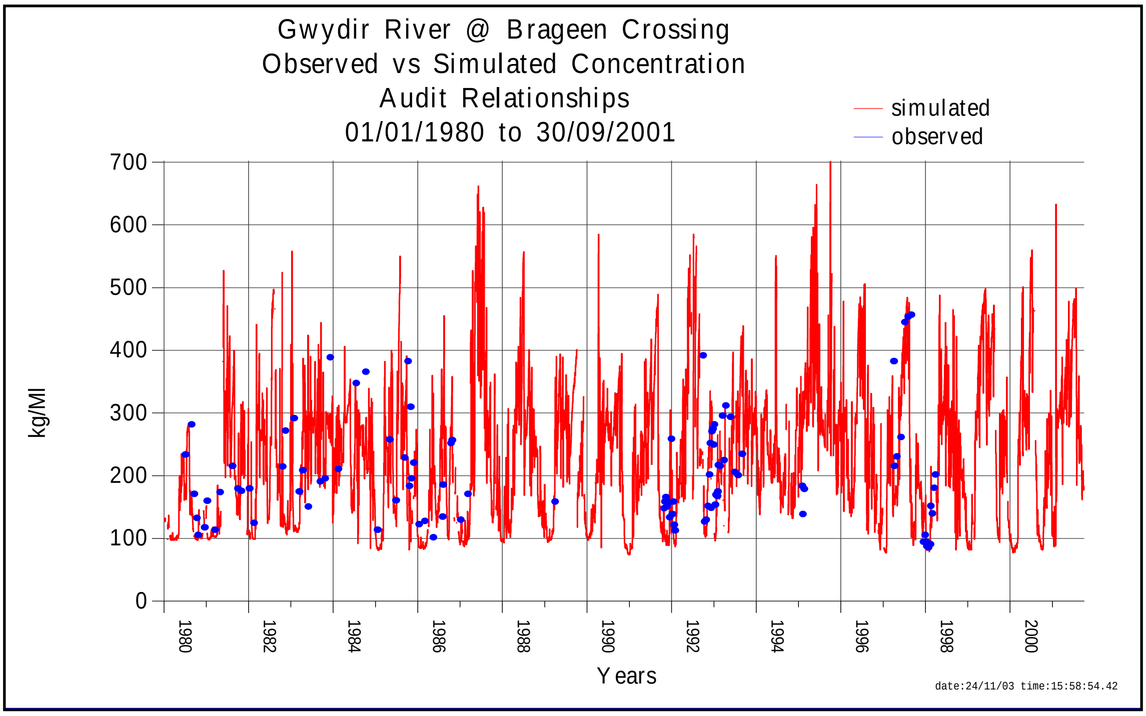


Figure 5.38. Simulated versus observed concentration at Station 418053: Gwydir River @ Brageen Crossing, using Salinity Audit relationships.

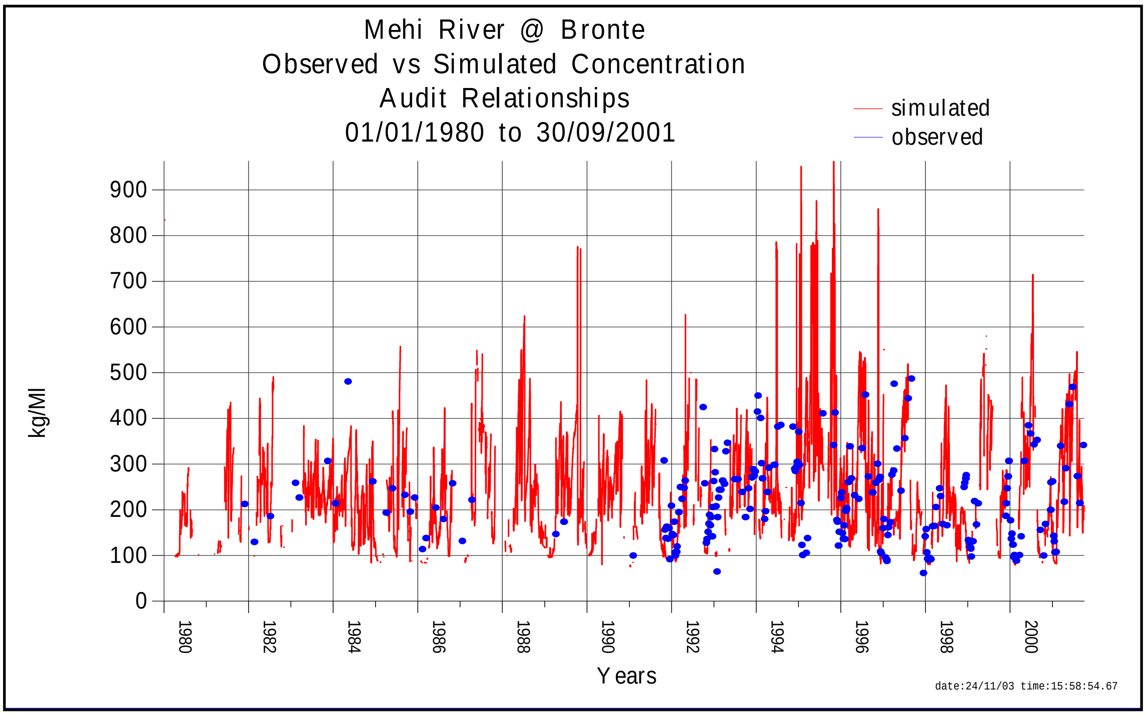


Figure 5.39. Simulated versus observed concentrations at Station 418058: Mehi River @ Bronte, using Salinity Audit relationships.

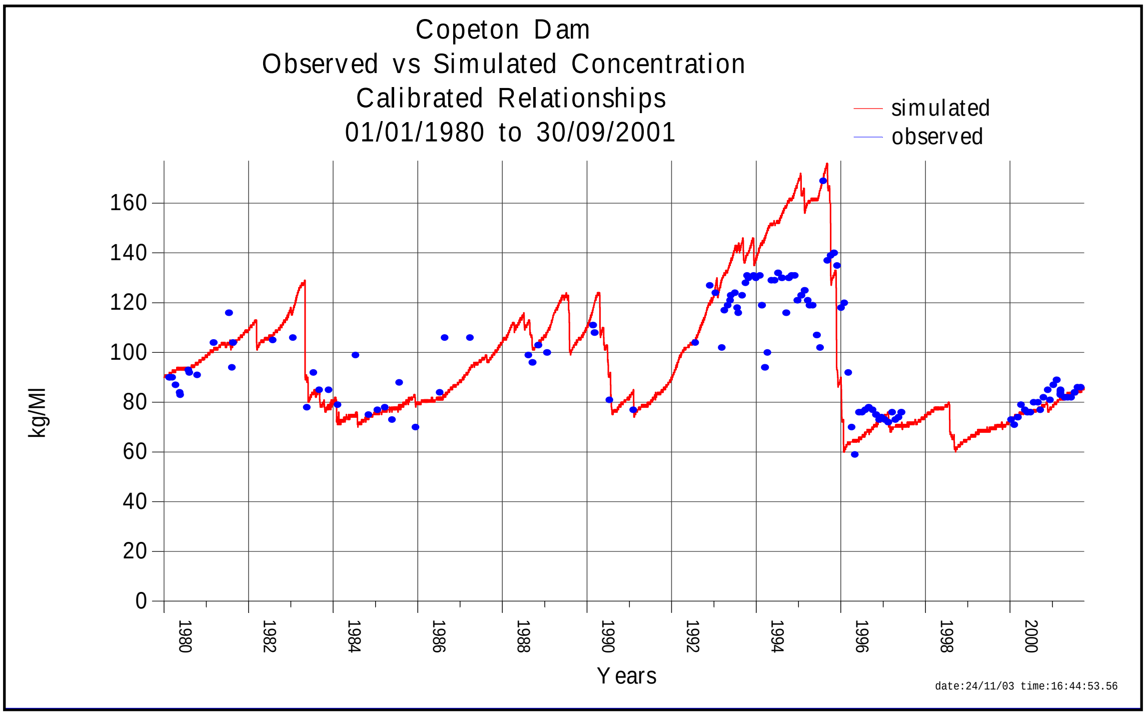


Figure 5.40. Simulated versus observed salinity at Copeton Dam, using calibrated relationship.

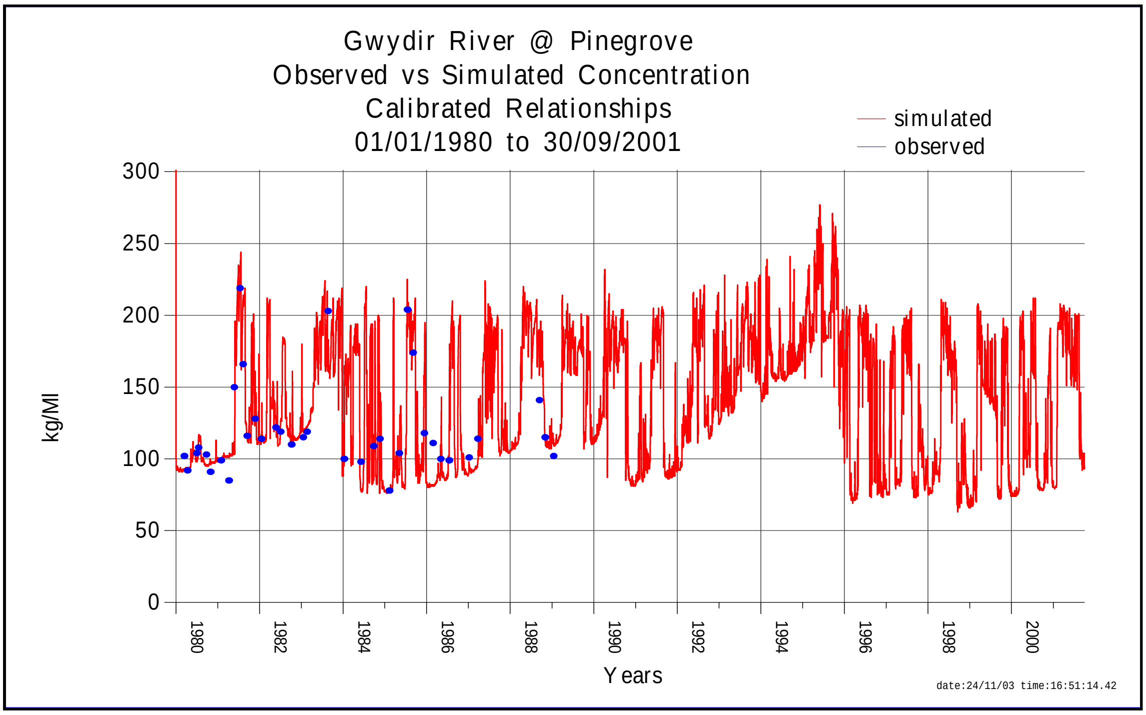


Figure 5.41. Simulated versus observed salinity for Station 418012: Gwydir River @ Pinegrove, using calibrated relationships.

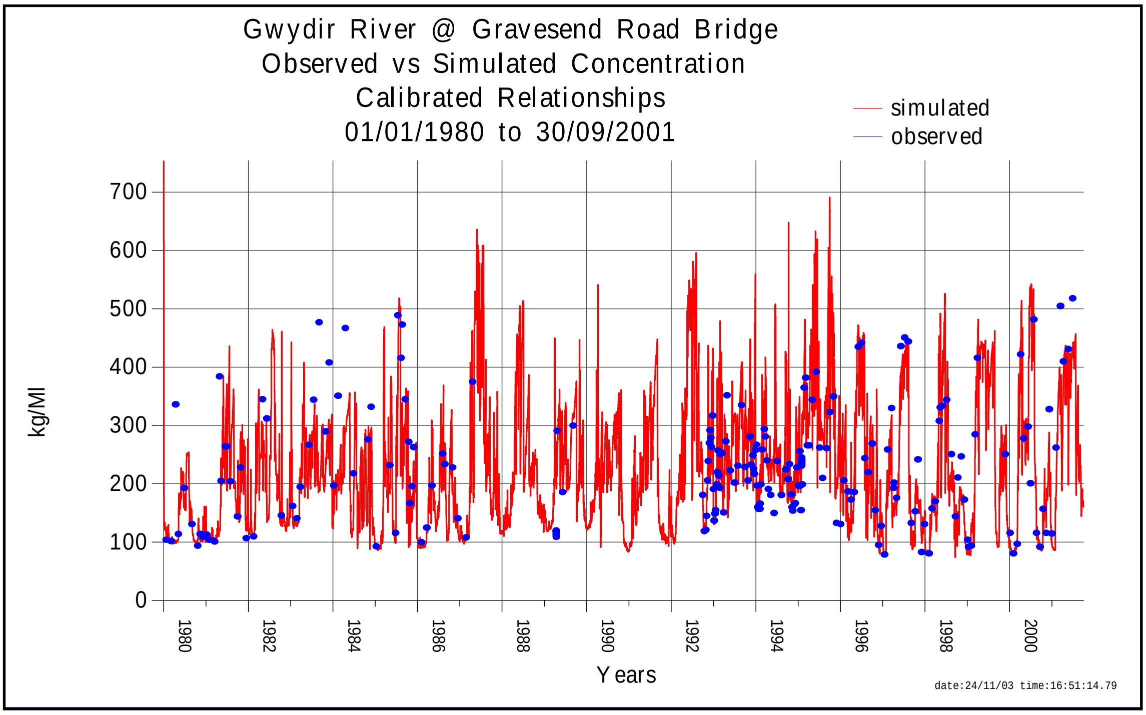


Figure 5.42. Simulated versus observed salinity for Station 418013: Gwydir River @ Gravesend Road Bridge, using calibrated relationship.

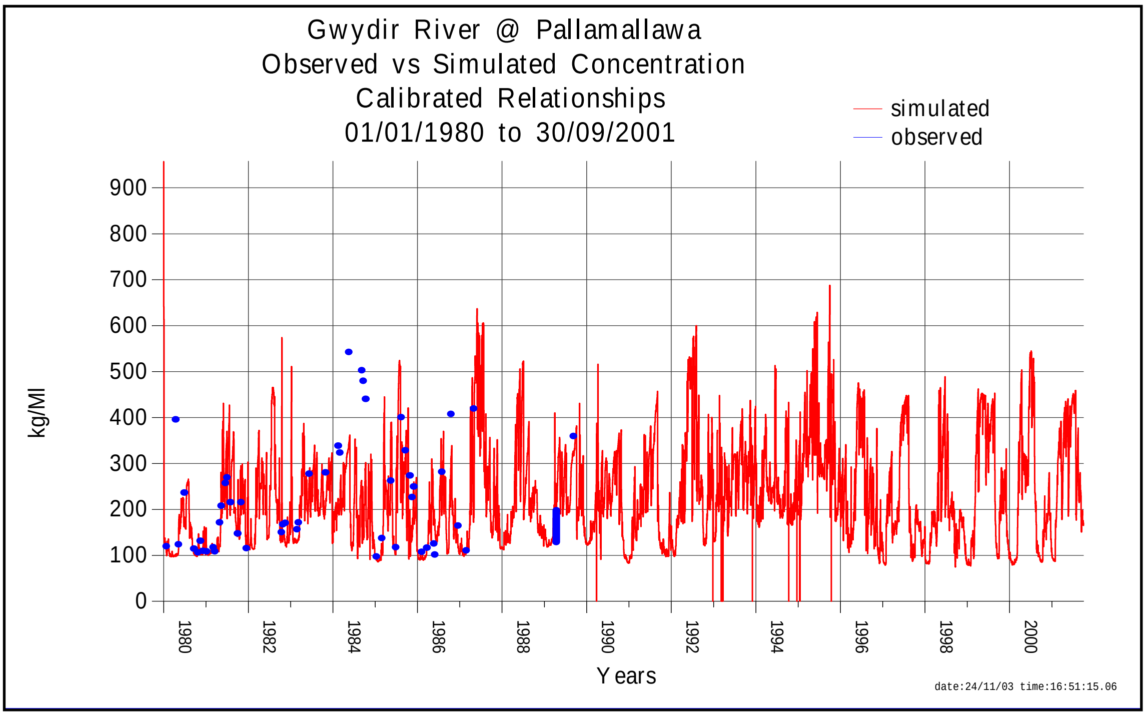


Figure 5.43. Simulated versus observed salinity for Station 418001: Gwydir River @ Pallamallawa, using calibrated relationship.

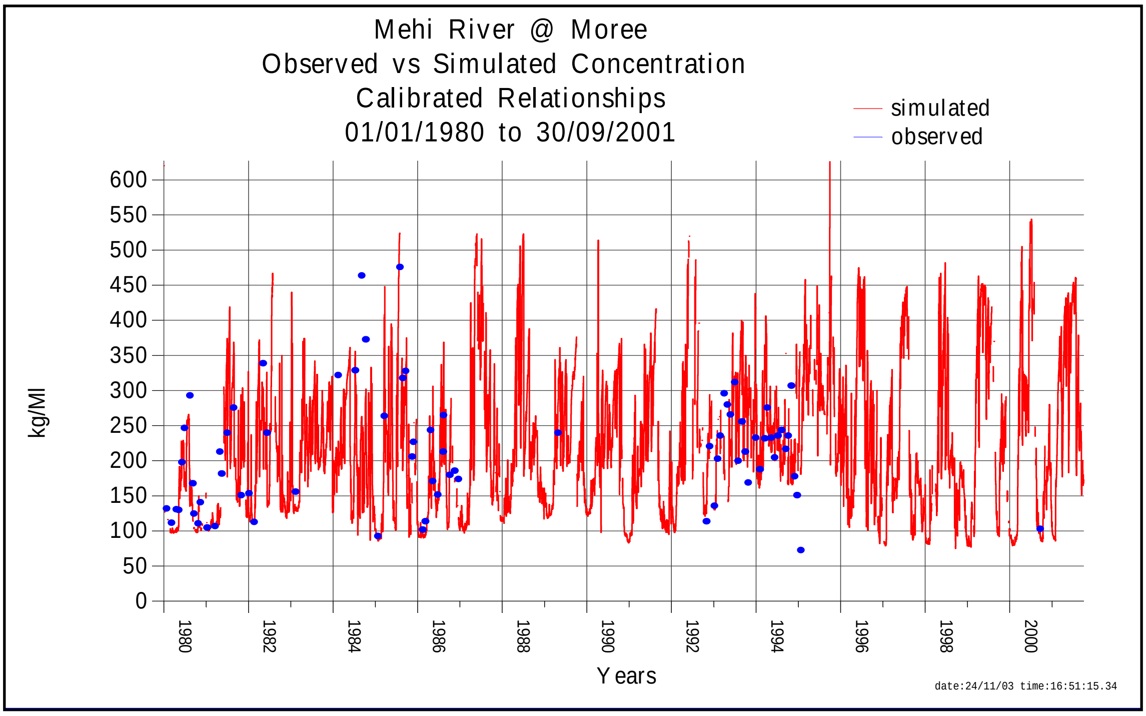


Figure 5.44. Observed versus simulated concentrations for Station 418002: Mehi River @ Moree using calibrated relationship.

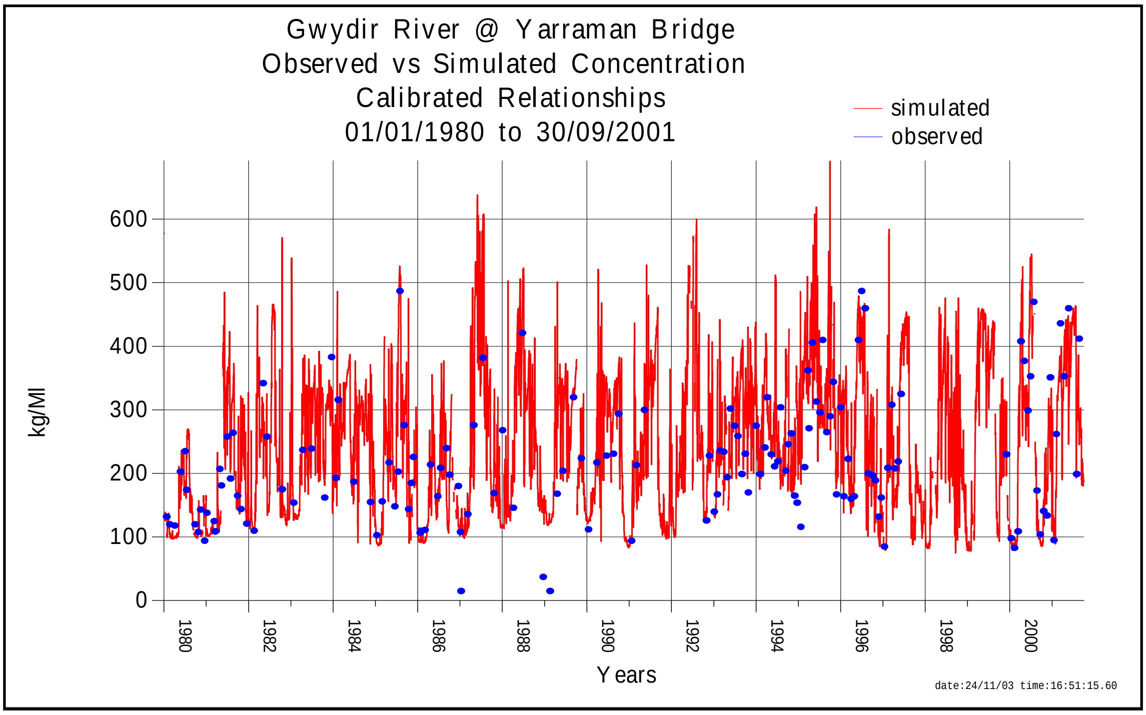


Figure 5.45. Observed versus simulated concentrations for Station 418004: Gwydir River @ Yarraman Bridge, using calibrated relationships

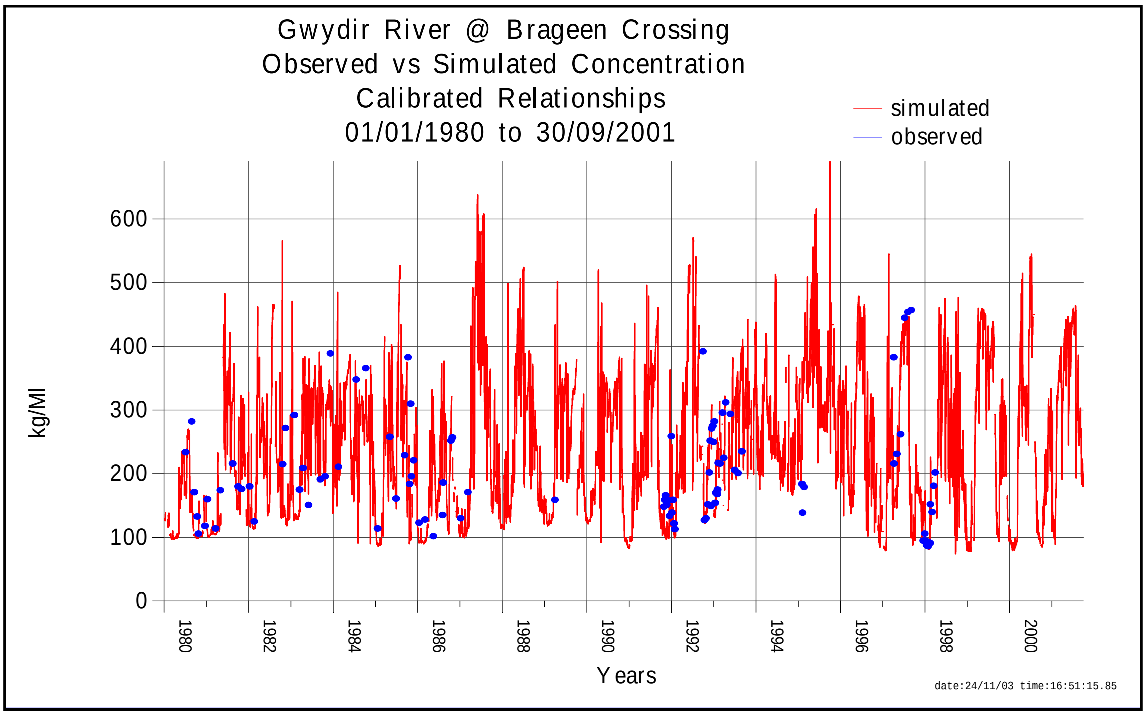


Figure 5.46. Observed versus simulated concentrations for Station 418053: Gwydir River @ Brageen Crossing, using calibrated relationships.

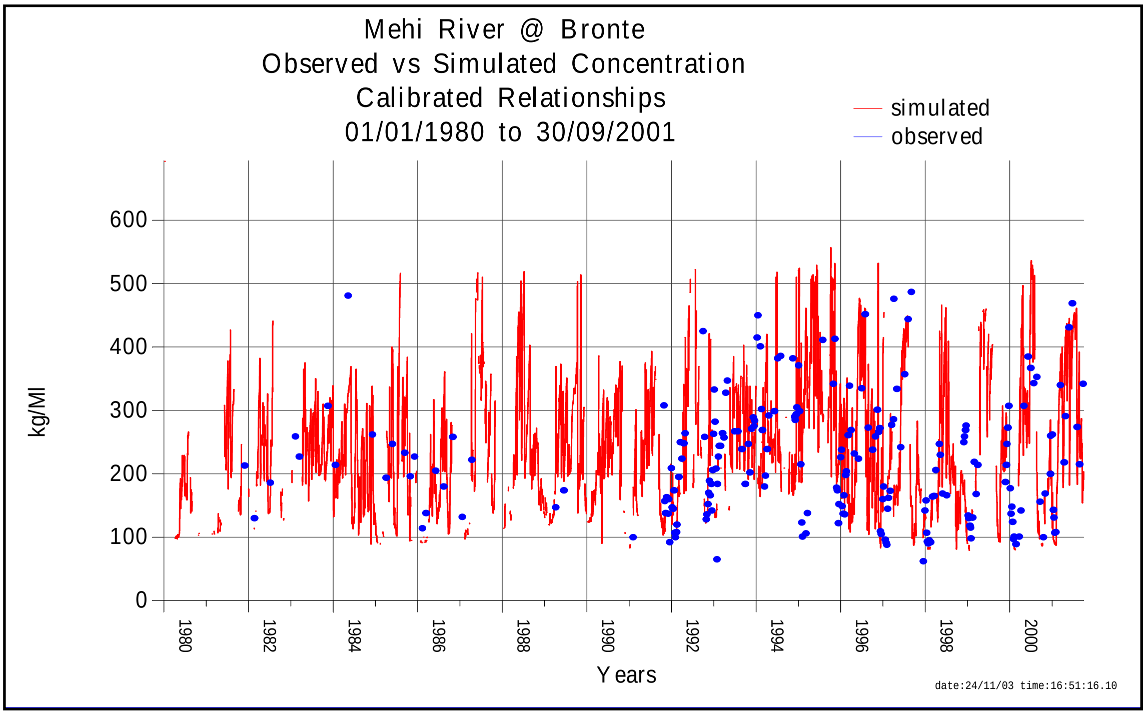


Figure 5.47. Observed versus simulated concentrations for Station 418058: Mehi River @ Bronte using calibrated relationships.

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 also 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 arising 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, e.g.; geology, topography, landuse; as well as characteristics that change in time, such as climate and groundwater levels. The aggregate response to all these characteristics is measured at the catchment outlet. Unfortunately, these salinity measurements are sparse for tributaries, and cannot currently be used to separate out the effects that change over time. This situation will improve as the catchment modelling studies capture and analyse the catchment data, and additional continuous data.

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

More information is available to define water use and river operating regimes in the Gwydir River. This information has been collected, or developed in the process of setting up the IQQMs over the years. This information is summarised in Table 6.1 and Table 6.2.

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

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

Water Balance Component (see Table 4.1)	Value	Units
Inflows		
Copeton Dam Inflows	394	GL/year
Gwydir/Mehi below Copeton	642	GL/year
Storages		
Copeton		
Active storage	1,343	GL
Storage reserve	70	GL
Transmission and operation losses	155	GL
Irrigation		
General security licences	515	GL/year
High security licences	13	GL/year
Proportion licences active	100	%
Maximum allocation	100	%
Maximum irrigable area	122,000	Ha
Pump capacity	22	GL/day
On-farm storage capacity	472	GL
Crop types (See Table)		-
Surplus flow entitlement	N/A	GL/year
Town water supply		
Bingara	0.7	GL/year
Gravesend	0.1	GL/year
In-stream water supply		
Lower Gwydir	1	GL/year
Gwydir River @ Wandoona	4	GL/year
Carole Creek @ Gallaway	4	GL/year
Mehi River @ Collarenebri	4	GL/year
Gwydir Wetlands	11	GL/year
Thalaba Creek	2	GL/year
Gingham Creek	1	GL/year
Mallowa Creek	6	GL/year
Ballinboora Creek	<1	GL/year

Table 6.2 Crop types, proportions, and irrigation factor

Crop type	% of total	Irrig. factor	Average crop factor for month											
			J	F	M	A	M	J	J	A	S	O	N	D
Cotton	84	0.80	0.80	0.60	0.40	0.00	0.00	0.00	0.00	0.00	0.50	0.20	0.50	0.75
Lucerne	<1	0.80	0.95	0.90	0.80	0.80	0.70	0.55	0.55	0.65	0.75	0.85	0.95	1.00
Pasture	0	0.75	0.70	0.70	0.60	0.60	0.50	0.45	0.40	0.45	0.55	0.65	0.70	0.70
Summer Cereal	1	0.63	0.70	0.70	0.60	0.30	0.20	0.00	0.00	0.00	0.30	0.40	0.52	0.65
Winter Cereal	<1	0.72	0.00	0.00	0.00	0.20	0.70	0.70	0.71	0.71	0.64	0.40	0.00	0.00
Wheat	3	0.63	0.00	0.00	0.00	0.00	0.07	0.28	0.58	0.74	0.70	0.70	0.34	0.00
Others	11	0.75	0.66	0.70	0.70	0.60	0.60	0.52	0.45	0.50	0.41	0.53	0.56	0.76

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 6.3. The results for the mean and percentile non-exceedance annual salt load at all evaluation points are reported in Table 6.4.

The patterns of the concentration results are consistent with observed data (Figure 3.4), showing low concentrations released from Copeton Dam. Salinity gradually increases down to Gravesend, and then remains reasonably consistent through to the end of system sites for the Gwydir and Mehi Rivers. The simulated concentration results for Bronte are consistent with the mean and distribution of observed salinities at Bronte (20th, 50^{th} and 80^{th} percentiles are within 6%)(Table 6.5).

The results for salt loads show that load released from Copeton Dam increase rapidly down to Gravesend due to major tributary inflows from Keera, Horton, Warialda, and Myall catchments. The average annual salt load decreases downstream of Pallamallawa as water and salt is removed from the system by irrigation diversions (Figure 4.3) and also by groundwater losses (Figure 2.10 and Figure 4.4).

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

Target Site		**Concentration (mg/L)**				**Salt Load (T/day)**				**No Flow Days**
Number	Name	*Mean*	*Percentile non exceedance*			*Mean*	*Percentile non exceedance*			*(%)*
			20	*50*	*80*		*20*	*50*	*80*	
418026	Gwydir River d/s Copeton Dam	95	80	90	110	90	0	17	120	0
418012	Gywdir River @ Pinegrove	150	100	130	200	140	18	52	190	0
418013	Gywdir River @ Gravesend Rd Bridge	210	130	200	280	330	53	120	390	0
418001	Gwydir River @ Pallamallawa	210	130	200	290	340	53	130	360	0
418002	Mehi River @ Moree	210	130	200	290	130	14	53	190	2
418053	Gwydir River @ Brageen Crossing	220	130	210	300	59	7	22	62	1
418031	Gwydir River @ Collymongle	190	170	190	210	5	0	0	0	89
418058	Mehi River @ Bronte	250	160	240	330	19	1	11	26	16

- Note: In Bewsher (2004) it has been recommended that the Gwydir 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. 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*
418026	Gwydir River d/s Copeton Dam	33	13	38	50
418012	Gywdir River @ Pinegrove	50	26	54	68
418013	Gywdir River @ Gravesend Rd Bridge	119	56	106	152
418001	Gwydir River @ Pallamallawa	124	62	114	154
418002	Mehi River @ Moree	46	23	50	62
418053	Gwydir River @ Brageen Crossing	21	11	16	29
418031	Gwydir River @ Collymongle	2	0	1	3
418058	Mehi River @ Bronte	7	4	5	10

- Note: In Bewsher (2004) it has been recommended that the Gwydir 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 6.5 Statistics of observed data for flow, salinity and salt load (1975-2000) at Mehi River @ Bronte

Parameter	Units	Mean	Percentile non-exceedance		
			20	50	80
Flow*	(ML/d)	81	4	29	86
Salinity**,+	(mg/L)	220	130	210	280
Salt load**	(Tonnes/d)	17	2	9	26

* Observed flow data set at 418058 only covers the period 11/12/1990 – 30/04/2000
** Salinity/Salt load based on 192 data points between 1981-2000
+ Only 2 significant figures shown

Figure 6.1to Figure 6.9 show the Baseline results compared to observed information at Mungindi.

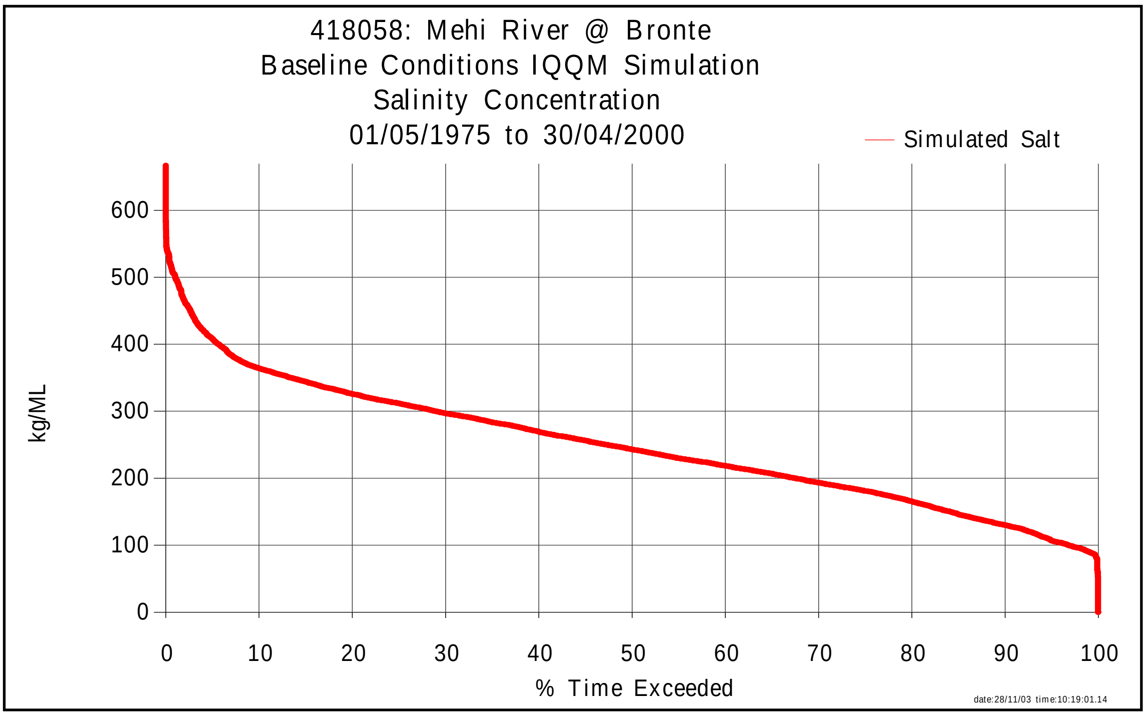


Figure 6.1 Frequency of exceedance of simulated salinity for Baseline Conditions scenario (1/5/1975-30/4/2000) for Mehi River @ Bronte

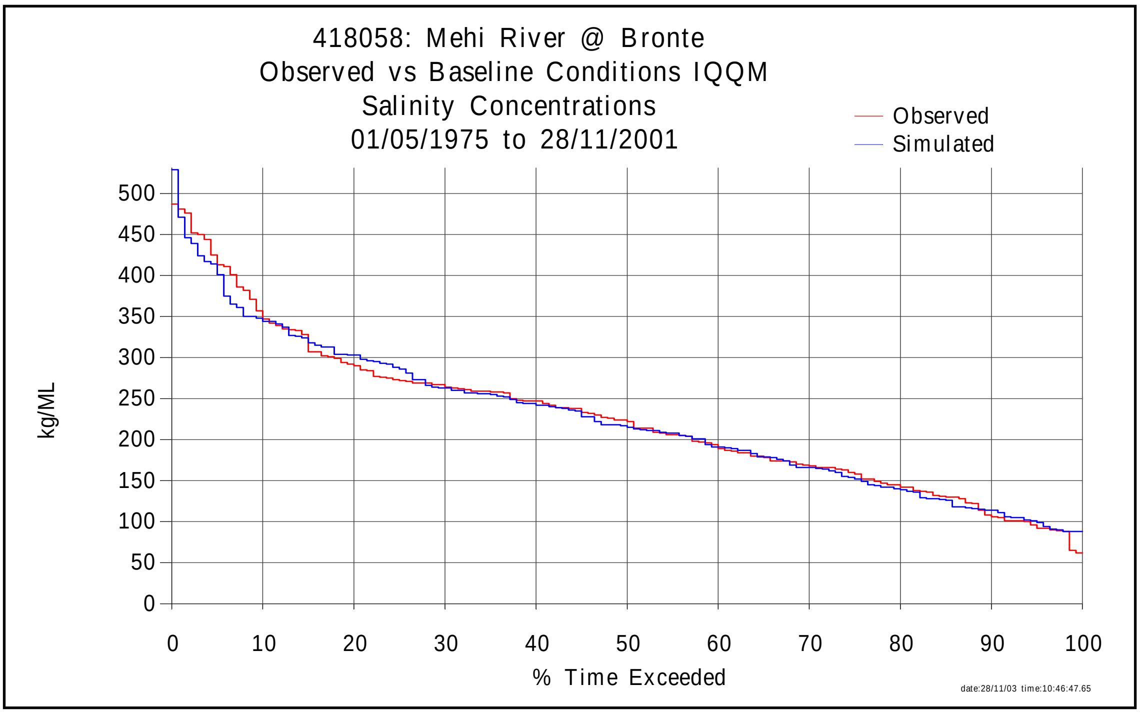


Figure 6.2 Frequency of exceedance of simulated salinity for Baseline Conditions scenario on days with salinity observations (1/5/1975-30/4/2000), compared with salinity observations for Mehi River @ Bronte

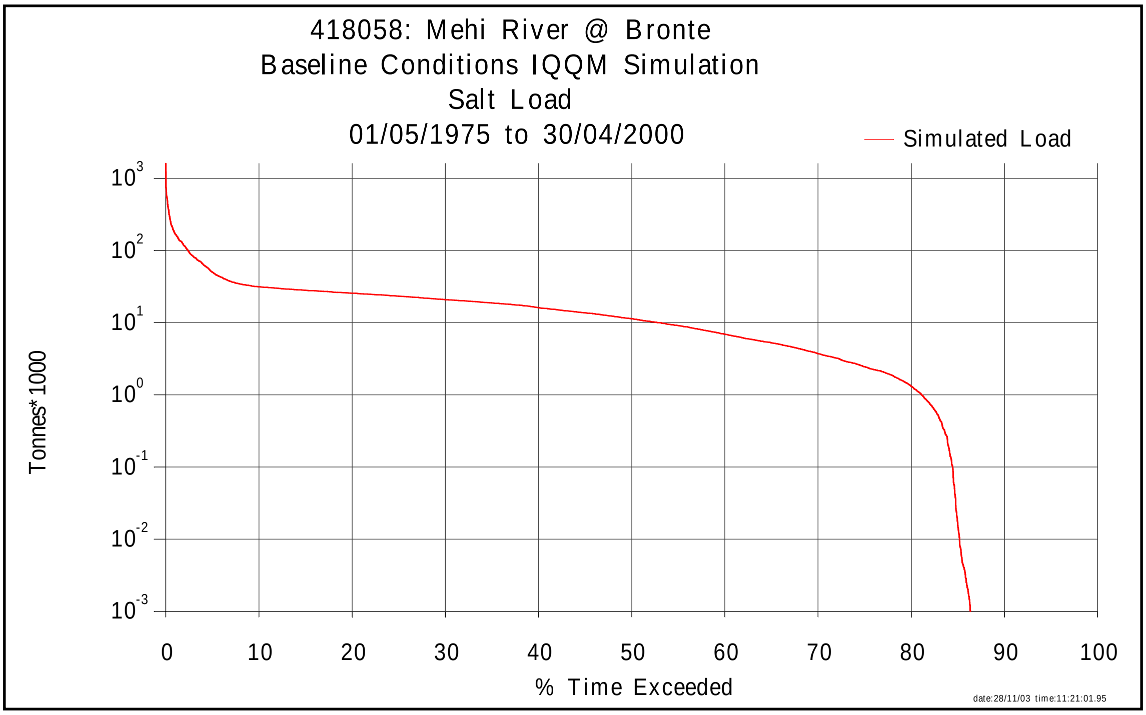


Figure 6.3 Frequency of exceedance of simulated salt load for Baseline Conditions scenario (1/5/1975-30/4/2000) for Mehi River @ Bronte

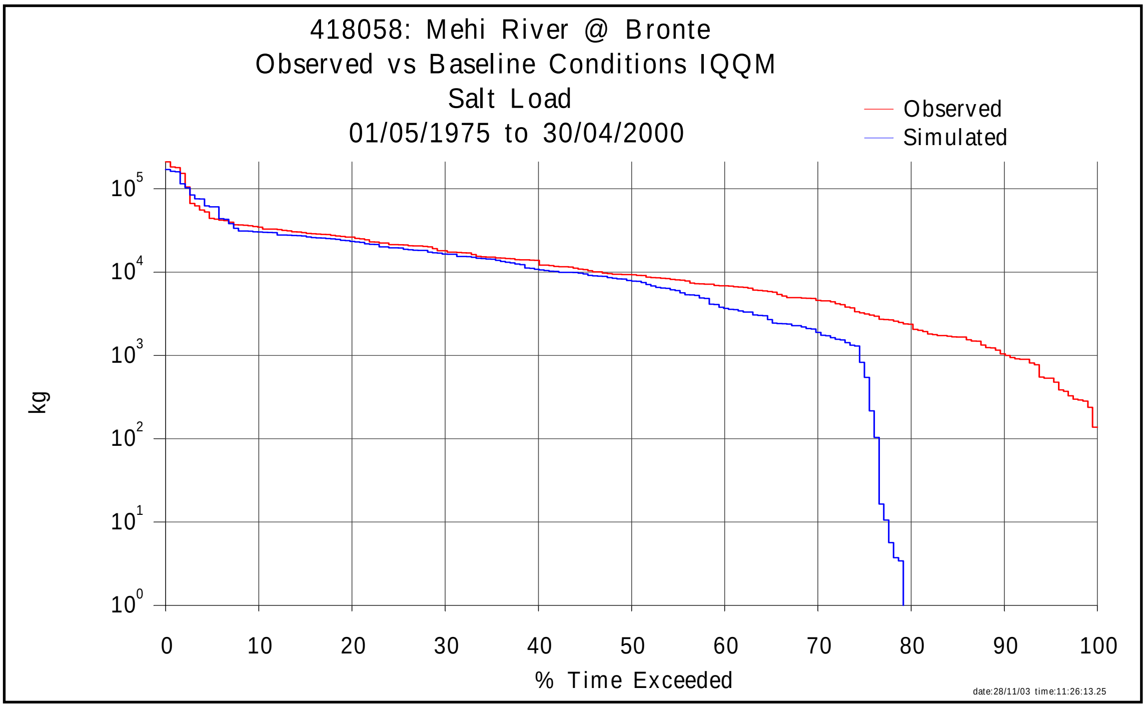


Figure 6.4 Frequency of exceedance of simulated salt load for Baseline Conditions scenario on days with salinity and flow observations (1/5/1975-30/4/2000), compared with salinity observations for Mehi River @ Bronte

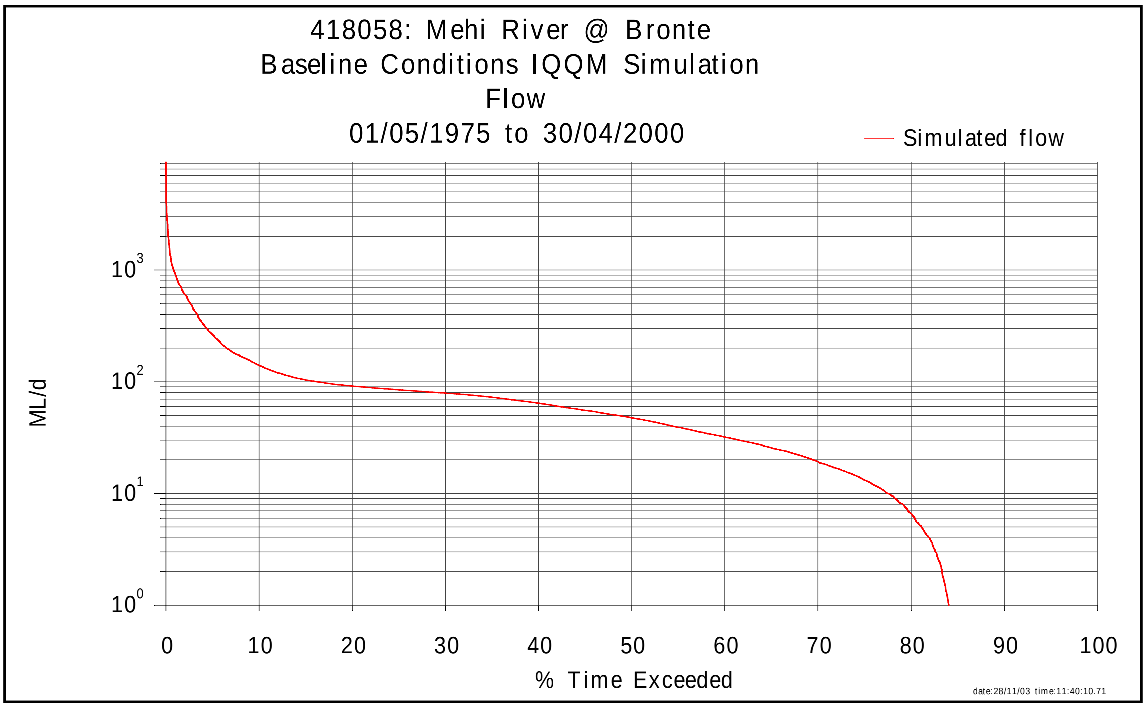


Figure 6.5. Frequency of exceedance of simulated flow for Baseline Conditions scenario (1/5/1975-30/4/2000) for Mehi River @ Bronte

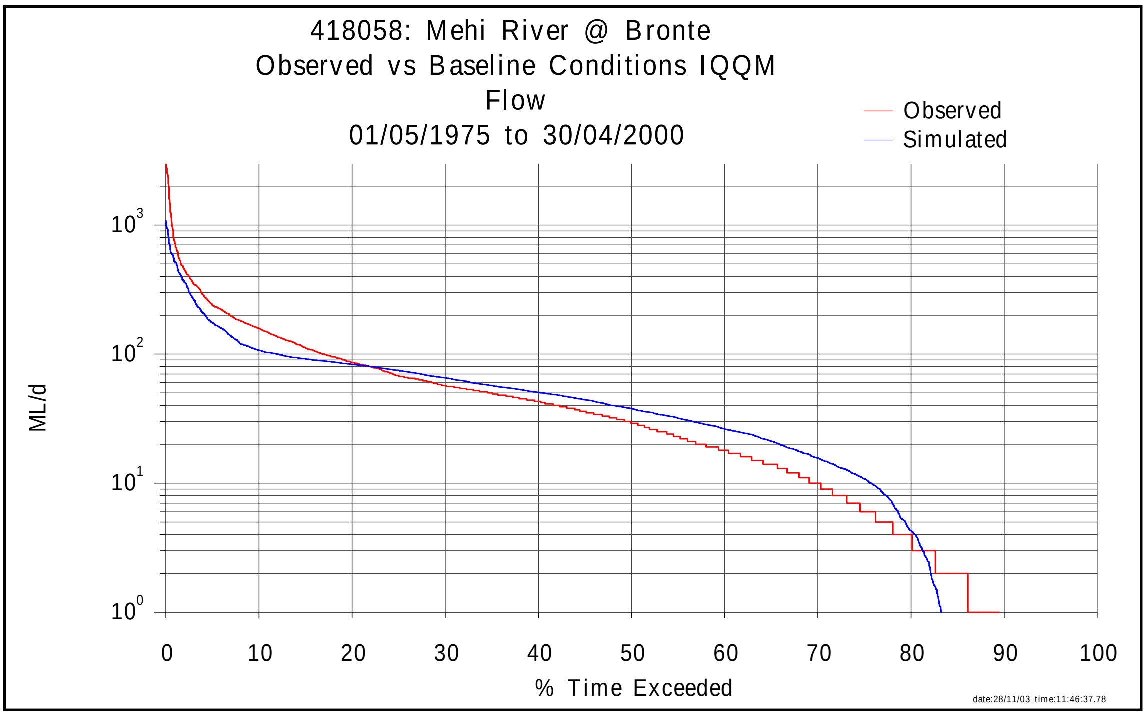


Figure 6.6 Frequency of exceedance of simulated flow for Baseline Conditions scenario on days with flow observations (1/5/1975-30/4/2000), compared with observed flow for Mehi River @ Bronte .

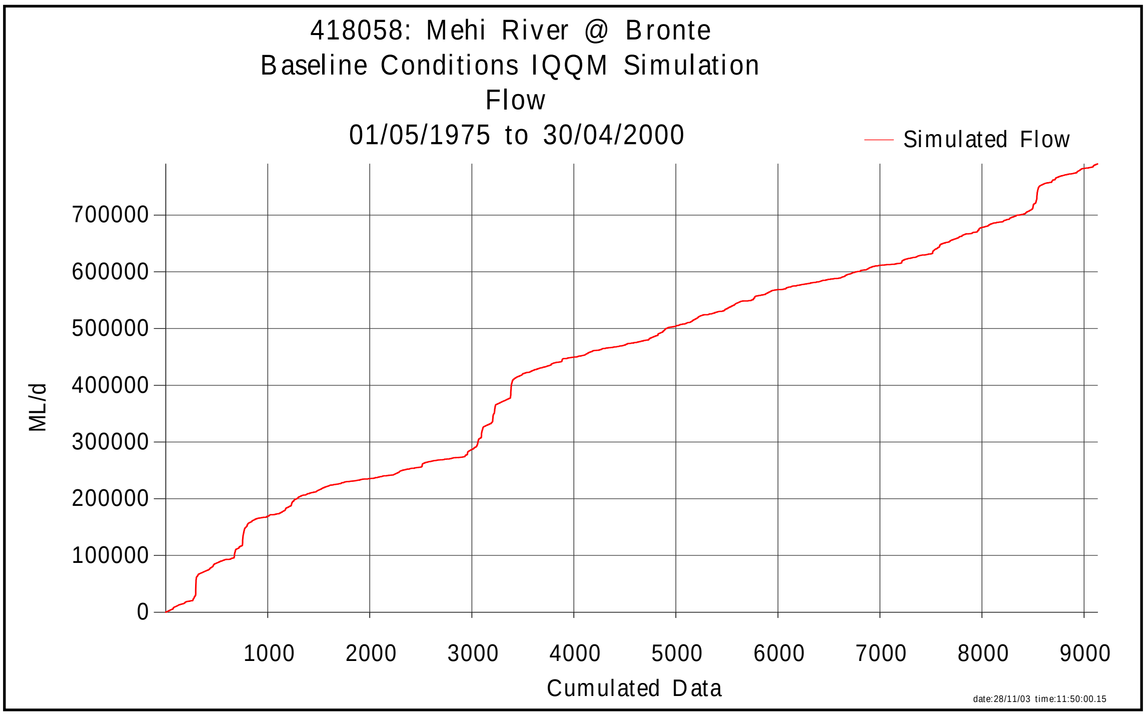


Figure 6.7 Cumulative simulated flow for Baseline Conditions scenario (1/5/1975-30/4/2000) for Mehi River @ Bronte

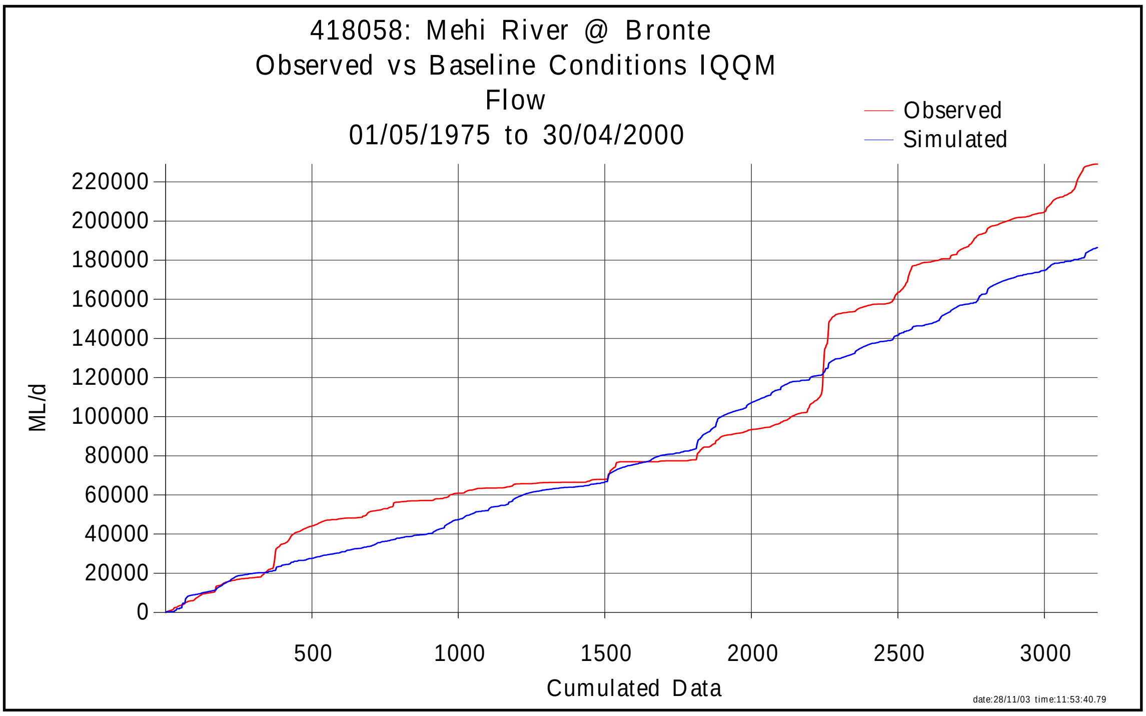


Figure 6.8 Cumulative simulated flow for Baseline Conditions scenario for days with observed flow, and observed flow (1/5/1975-30/4/2000) for Mehi River @ Bronte

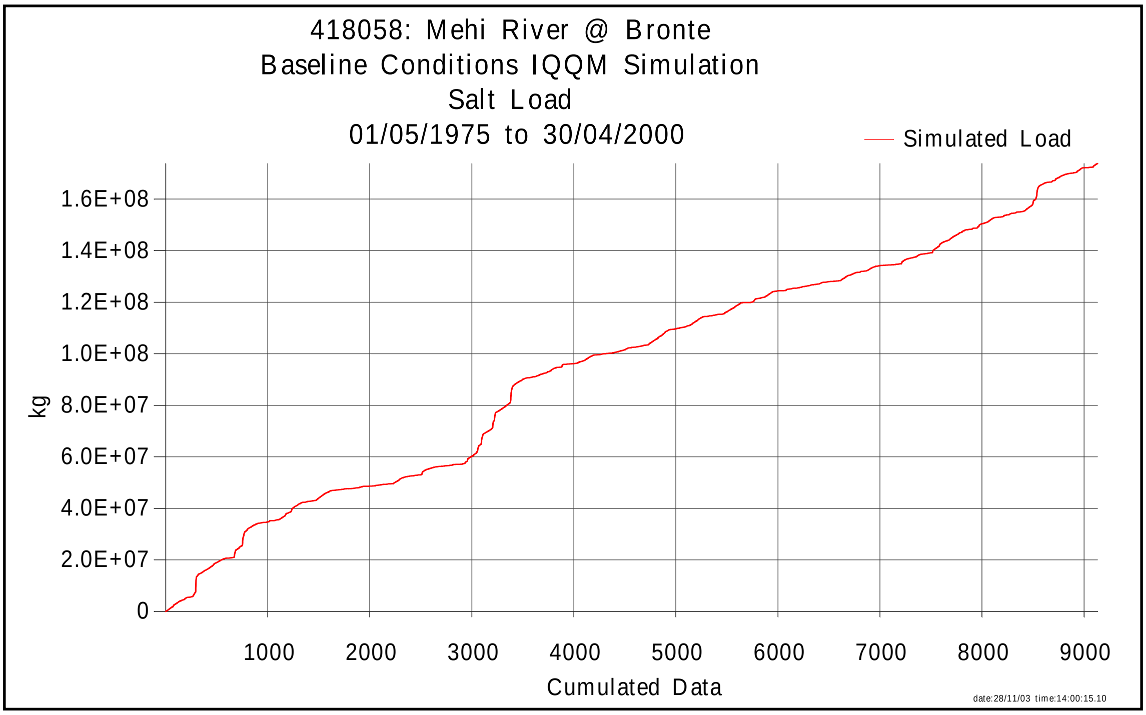


Figure 6.9 Cumulative simulated salt load for Baseline Conditions scenario (1/5/1975-30/4/2000) for Mehi River @ Bronte.

7. Recommendations

7.1. CONCLUSION

The Gwydir Rivers IQQM salinity calibration produced simulated concentration within 10% of the observed at most flow ranges in most of evaluation points. The salt loads are higher than observed especially at high flow range due to over estimation of high flow volumes. The Gwydir Rivers IQQM is capable of estimating the flow and salinity impacts of water sharing policies.

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.

- Sacramento models and residual catchment upstream of Copeton Dam to be re-estimated and extended to allow for 100 years of simulation so that the quantity and quality models are compatible. The re-calibration of these Sacramento models is likely to have little effect on the results reported for the baseline scenario.
- Further investigation to the underestimating of concentration at high flows at key locations such as Gravesend and Pallamallawa. Improvement is likely to be constrained until more observed data is available.
- Better estimates of EOS flows.
- Improvements could be made to the methods used to estimate salt loads under Baseline Conditions. The flow versus salt load and flow versus concentration relationships do not on their own reproduce the variability in the salt load generation. Catchment process based modelling and continuous data should go some of the way to better salt export relationships.
- Modelling reaches where there are large surface area should be checked to examine the effect of rainfall and evaporation in salinity.

7.3. RECOMMENDED FUTURE DATA COLLECTION

7.3.1. Main stream salinity data

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

Discrete data

Discrete data coverage in the Gwydir catchment is reasonably adequate, with collection sites located at regular intervals along the mainstream channels. The modelling is somewhat limited by the length of the data sets, the majority of EC sites having between 1 and 30 days of data (Figure 3.1). Fortunately most of the discrete sites with low amounts of data are located on minor tributaries and watercourses and do not directly affect the quality of the modelling. Continual collection of data at key locations will ensure that the modelling of the catchment can be further improved, and allow for reliable validations of the results achieved in this project. Table 7.1. outlines the sites that should be considered a priority for regular data collection in the Gwydir.

Table 7.1Main stream priority sites for discrete salinity data collection

Station Code	Station Name
418029	Gwydir River @ Stonybatter
418008	Gwydir River @ Bundarra
418026	Gwydir River D/S of Copeton Dam
418012	Gwydir River @ Pinegrove
418013	Gwydir River @ Gravesend Road Bridge
418001	Gwydir River @ Pallamallawa
418004	Gwydir River @ Yarraman Bridge
418031	Gwydir River @ Collymongle
418002	Mehi River @ Moree
418058	Mehi River @ Bronte

Continuous data

The continuous data coverage in the Gwydir valley is poor. There are only two continuous data sites currently available (Figure 3.2). One of the stations (418069) can not be used in the project due to its location within the catchment, while the other (418058) currently does not have enough data to be used for any relevant analysis. It is recommended that continuos salinity data recorders be installed at all key locations in the Gwydir catchment. Initial priority should be given to the locations outlined in Table 7.2.

Table 7.2Main stream priority sites for continuous salinity data collection

Station Code	Station Name
418026	Gwydir River @ D/S Copeton Dam
418013	Gwydir River @ Gravesend Road Bridge
418001	Gwydir River @ Pallamallawa
418002	Mehi River @ Moree

Continuous data at these locations would allow for significant improvements in the modelling of this catchment, and eventually eliminate the data sampling problem discussed in section 5.4.5.

7.3.2. Inflow salinity data

Improved salinity inflow relationships will results from the continuation of salinity data collection at the sites listed in Table 7.3. Where it is possible continuos data probes should be installed.

Table 7.3 Main stream priority sites for salinity data collection

Station Code	Station Name
418021	Laura Creek @ Laura
418022	Georges Creek @ Clerkness
418023	Moredun Creek @ Bundarra
418033	Bakers Creek @ Bundarra
418005	Copes Creek @ Kimberly
418018	Keera Creek @ Keera
418017	Myall Creek @ Molroy
418015	Horton River @ Rider
418016	Warialda Creek @ Warialda
418032	Tycannah Creek @ Horseshoe Lagoon

7.3.3. Storages and other supporting data

It is recommended to increase the salinity concentration sampling within the Copeton dam storage, to gain a better understanding of the processes occurring within the storage. Continuous EC data together with storage inflows and at outflows will assist in modelling salinity behaviour in the storage.

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. Availability of salinity data

Table A1. data in the Gwydir River valley

Station number	Station name	Lat (S)	Lon (E)	Data type	Period collected	Number of data days
416027	Gil Gil Creek @ Weemelah	149.1667	-29.0333	Discrete	1969-1989	80
416052	Gil Gil Creek @ Galloway	148.9844	-29.1286	Discrete	1989-2002	145
418001	Gwydir River @ Pallamallawa	150.1333	-29.4667	Discrete	1970-1989	132
418002	Mehi River @ Moree	149.8500	-29.4667	Discrete	1976-2002	162
418004	Gwydir River @ Yarraman Bridge	149.8500	-29.4167	Discrete	1964-2002	296
418005	Copes Creek @ Kimberley	151.1167	-29.9167	Discrete	1970-1990	93
418007	Gwydir River @ Camurra (Boolooroo Bridge)	149.9167	-29.4167	Discrete	1982-1982	1
418008	Gwydir River @ Bundarra	151.0639	-30.1725	Discrete	1964-2002	278
418009	Gwydir River @ Gravesend	150.3667	-29.5667	Discrete	1976-1977	7
418011	Carole Creek @ D/S Regulator(Bells Crossing)	149.8833	-29.3833	Discrete	1979-1989	62
418012	Gwydir River @ Pinegrove	150.6333	-29.8833	Discrete	1964-2002	166
418013	Gwydir River @ Gravesend Road Bridge	150.3667	-29.5833	Discrete	1964-2002	333
418014	Gwydir River @ Yarrowyck	151.3617	-30.4686	Discrete	1971-2002	92
418015	Horton River @ Rider (Killara)	150.3500	-29.8333	Discrete	1968-2002	268
418016	Warialda Creek @ Warialda No.3	150.6167	-29.6333	Discrete	1972-2002	86
418017	Myall Creek @ Molroy	150.5833	-29.8000	Discrete	1976-2002	67
418018	Keera Creek @ Keera	150.7811	-30.0206	Discrete	1969-1988	112
418020	Boorolong Ck @ Yarrowyck	151.4264	-30.4800	Discrete	1968-1987	87
418021	Laura Creek @ Laura	151.1853	-30.2297	Discrete	1969-2002	97
418022	Georges Creek @ Clerkness	151.1381	-30.1867	Discrete	1969-1988	95
418023	Moredun Creek @ Bundarra	151.1425	-30.1428	Discrete	1976-1987	55
418024	Roumalla Creek @ Kingstown	151.1456	-30.4806	Discrete	1976-2002	59
418025	Halls Creek @ Bingara	150.5750	-29.9083	Discrete	1970-1989	110
418026	Gwydir River D/S Copeton Dam	150.9000	-29.9167	Discrete	1968-2002	235
418027	Horton River @ Horton Dam Site	150.4281	-30.2081	Discrete	1971-1989	92
418029	Gwydir River @ Stonybatter	151.1422	-30.3225	Discrete	1970-1989	85
418030	Copes Creek @ Tingha	151.2483	-29.9500	Discrete	1968-1989	104
418031	Gwydir River @ Collymongle	148.8167	-29.4000	Discrete	1971-1989	20
418032	Tycannah Creek @ Horseshoe Lagoon	150.0500	-29.6667	Discrete	1971-1989	87
418033	Bakers Creek @ Bundarra	151.0250	-30.2056	Discrete	1972-1990	91

Station number	Station name	Lat (S)	Lon (E)	Data type	Period collected	Number of data days
418034	Boorolong Creek (North Arm) @ Black Mountain	151.6361	-30.2967	Discrete	1974-1991	93
418036	Gwydir River @ D/S Boolooroo Weir (Carole Ck)	149.8850	-29.4167	Discrete	1972-1989	21
418037	Mehi River @ D/S Combadello Weir	149.6500	-29.5667	Discrete	1977-1989	60
418040	Gwydir River @ D/S Mehi Offtake (Weir Site 3)	150.0333	-29.4500	Discrete	1972-1973	5
418041	Mehi River @ D/S Gundare Regulator	149.3167	-29.5833	Discrete	1979-1989	41
418042	Gwydir River @ D/S Tareelar01 Weir	150.0333	-29.4333	Discrete	1976-1989	85
418044	Mehi River @ D/S Tareelaroi Regulator	150.0333	-29.4333	Discrete	1976-1989	54
418046	Mallowa Creek @ Kamilaroi West	149.1833	-29.6167	Discrete	1979-1987	3
418048	Moomin Creek @ Combadello Cutting	149.6539	-29.5642	Discrete	1932-1989	56
418049	Mallowa Creek @ Regulator	149.3333	-29.5833	Discrete	1978-1989	12
418052	Carole Creek @ Near Garah	149.5517	-29.1300	Discrete	1980-2002	45
418053	Gwydir River @ Bragеen Crossing	149.5475	-29.3983	Discrete	1979-2002	281
418054	Moomin Creek @ Iffley	148.8906	-29.5561	Discrete	1980-2002	197
418055	Mehi River @ Near Collarenebri	148.7233	-29.5133	Discrete	1980-2002	119
418056	Gwydir River @ Tyreel (Gwydir Pool)	149.7764	-29.4394	Discrete	1981-1986	28
418058	Mehi River @ Bronte	148.8833	-29.4667	Discrete	1981-2002	257
418058	Mehi River @ Bronte	148.8833	-29.4667	Continuous	2001-2001	168
418060	Moomin Creek @ Glendello	149.4772	-29.6953	Discrete	1984-2002	25
418061	Moomin Creek @ Alma Bridge (Derra Road)	149.1559	-29.6910	Discrete	1985-1989	9
418063	Gwydir River (South Arm) @ D/S Tyreel Offtake Regulator	149.7764	-29.4394	Discrete	1987-1989	4
418064	Gingham Watercourse @ Willowlee	149.6683	-29.3914	Discrete	1989-1989	2
418065	Gwydir River @ Tyreel Storage Gauge	150.7769	-29.4378	Discrete	1989-1989	1

Station number	Station name	Lat (S)	Lon (E)	Data type	Period collected	Number of data days
418066	Gwydir River @ Millewa	149.3683	-29.3631	Discrete	1989-1989	1
418067	Moomin Creek @ Clarendon Bridge (Heathfield)	149.3139	-29.6910	Discrete	1989-1989	2
418068	Mehi River @ U/S Ballin Boora Creek	149.1167	-29.4667	Discrete	1989-1989	2
418069	Box Hill Watercourse Near Inverell	150.9264	-29.6936	Continuous	1994-2001	35
418076	Gingham Channel At Tillaloo Bridge	149.4514	-29.2731	Discrete	2000-2002	2
418077	Gingham Channel At The Waterhole	149.3050	-29.2450	Discrete	2000-2002	9
418078	Gwydir River At Allambie Bridge	149.4303	-29.3478	Discrete	2000-2002	8
41810001	Copeton Dam (Dam Wall) Station 1	150.9261	-29.9019	Discrete	1977-2002	143
41810002	Copeton Dam Station 2	150.9700	-29.9028	Discrete	1980-1991	73
41810003	Copeton Dam Station 3	151.0742	-30.1683	Discrete	1980-1991	64
41810004	Copeton Dam Station 4	150.9953	-29.9400	Discrete	1980-1991	68
41810005	Copeton Dam Station 5	150.9861	-29.9819	Discrete	1980-1990	26
41810006	Laura Creek U/S Bundara	151.1286	-30.2339	Discrete	2002-2002	1
41810034	Big Leather @ Old Dromana	149.3000	-29.3347	Discrete	2000-2002	4
41810035	Gingham Channel @ Rookery	149.3311	-29.2475	Discrete	2000-2002	7
41810036	Big Leather @ Troy 'Wet Patch'	149.2764	-29.3492	Discrete	2000-2002	8
41810038	Gingham Channel @ Crinolyn	149.1469	-29.2103	Discrete	2000-2002	8
41810039	Gwydir River U/S Copeton Dam	150.9886	-30.0136	Discrete	2000-2002	27
41810101	Thalaba Creek At Merrywinebone	151.0742	-30.1683	Discrete	1991-2002	212
41810111	Carole Creek On Mungindi Road	149.8125	-29.3783	Discrete	1991-2002	229

Appendix B. Comparison with Salinity Audit

The flow and salt load results from the ‘first cut’ model are 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 Gwydir System IQQM, that it can reliably reproduce the peer reviewed and published results from the Salinity Audit, that have been used to develop Salinity Targets (NSWG, 2000).

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

The flow and salt load results from the model were extracted for all the nodes listed in Table 5.1 and Table 5.2, as well as for all gauge nodes corresponding to the balance points used for the Salinity Audit. Prior to the comparison, reporting some results had to be combined. In cases where more than one inflow node represented a Salinity Audit as was the case for several of the residual catchments, the results were added. For all the residual catchments the results of flow and salt loads removed at the calibration nodes were subtracted to produce net flow and salt load for that catchment.

These results are summarised in Table B.8.1. The shaded rows in the Table represent Salinity Audit balance points, and the other rows represent inflow points.

Table B.8.1. Salt transport model results compared with Audit results

Audit inflow	Average annual flow (GL/y)					Average annual salt load ('000 t/y)				
	Audit (75-95)	*1*	*2*	*3*	*4*	*Audit (75-95)*	*1*	*2*	*3*	*4*
418029	122.2	133.3	149.0	149.0	149.0	13.7	13.1	14.3	15.3	13.4
418021	30.0	29.4	33.7	33.7	33.7	2.5	2.5	2.9	2.7	2.6
418022	41.8	40.8	46.4	46.4	46.4	3.7	3.6	4.0	3.8	3.8
418023	72.2	80.6	91.8	91.8	91.8	6.2	6.8	7.7	7.2	7.1
R1	47.8	N/A	N/A	N/A	N/A	4.0	N/A	N/A	N/A	N/A
418008	**271.3**	**N/A**	**N/A**	**N/A**	**N/A**	**27.0**	**N/A**	**N/A**	**N/A**	**N/A**
418033	11.1	10.4	11.0	11.0	11.0	0.6	0.6	0.6	0.6	0.5
418005	21.9	22.2	23.6	23.6	23.6	1.7	1.7	1.8	1.6	1.6
R2	36.6	N/A	N/A	N/A	N/A	5.0	N/A	N/A	N/A	N/A
R1 + R2	84.4	37.4	43.4	43.4	43.4	9.0	1.4	1.4	1.3	0.7
418026	**372.0**	**350.0**	**371.9**	**384.1**	**384.1**	**32.4**	**30.5**	**31.7**	**32.6**	**30.2**
418018	27.0	34.3	37.1	37.1	37.1	9.9	5.7	6.1	5.7	5.7
R3	26.4	62.6	63.5	63.5	63.5	9.8	20.8	21.1	19.8	19.4
418012	**421.7**	**447.1**	**472.5**	**484.7**	**484.7**	**53.5**	**57.0**	**58.9**	**58.1**	**55.3**
418025	7.0	7.4	7.6	7.6	7.6	5.1	5.1	5.3	4.9	4.9
418017	32.8	34.8	35.2	35.2	35.2	13.0	13.3	13.5	12.6	12.1
418015	189.6	195.7	198.5	198.5	198.5	44.1	45.3	45.9	43.0	42.5
418016	22.0	24.2	23.3	23.3	23.3	4.7	5.1	5.0	4.7	4.2
R4	136.5	28.5	28.5	28.5	28.5	19.5	2.2	2.2	1.9	2.1
418013	**705.3**	**737.4**	**765.0**	**777.2**	**777.2**	**119.7**	**128.0**	**130.6**	**125.2**	**121.1**
R5	43.5	21.5	17.4	17.3	17.3	7.9	4.7	4.2	3.8	3.8
418001	**725.7**	**749.0**	**772.3**	**784.4**	**784.4**	**149.4**	**130.9**	**133.0**	**127.3**	**123.4**
418032	38.1	33.6	31.3	31.3	31.3	9.9	9.1	8.7	8.2	7.3

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

R1 & 2 = Inflows (353) – Losses (361, 354)

R3 = Inflows (260 + 007) – Losses (150)

R4 = Inflows (255 + 370 + 371 + 262) – Losses (16)

R5 = Inflows (21) – Losses (140)

B.1. FLOW

B.1.1. Direct comparison

The direct comparison of the flows reported in the Salinity Audit and those used in IQQM show that there are differences in nearly all the inflow balance points. Of the sixteen inflow points, five are within 5% of the reported Salinity Audit results, five within 10%, and six are over 10%. There is some bias toward IQQM results underestimating the comparable Salinity Audit results, particularly where differences are greater than 5%.

These results are not what were expected, as the flows should have been the same. Possible explanations for some inflows include:

(i) IQQM uses all sacremento data for Moredum Creek, whereas the Audit would have used observed data.

(ii) Some of the residual catchment inflows were revised compared with the model version used for the Salinity Audit.

The reasons for discrepancies for the gauged inflows are not apparent. Possible explanations for these would include:

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

(iv) 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).

(v) 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.1.2. Climatic period

The mean annual flows for the BSMS climatic period (01/05/1975-30/04/2000) are higher for eleven of the sixteen 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 Gravesend (Figure 2.7). The overall modelled difference in water at the end of the system is approximately 3%.

B.2. SALT LOADS

B.2.1. Direct comparison

The direct comparison of the salt loads reported in the Salinity Audit and those calculated in IQQM flows shows that there are differences for many the inflows and balance points. However, these differences are relatively minor with some notable exceptions. Of the sixteen IQQM inflow points, nine are within 5% of the reported Salinity Audit results, with five of these less than 2%. A further two are within 10%, and the remaining four are over 10% different.

The two salt load inflow points with 5-10% difference are the Moredun Creek @ Bundarra, and Warialda Creek @ Warialda. The difference for the Moredun Creek salt load inflow could be attributed the different flow data used (as discussed in section 4.3.2.1.1). The difference for the Warialda Creek salt load inflow is in the same proportion as the flow difference for this site.

The five salt load inflow points with greater than 10% difference are all residual catchments, with the exception of Keera Creek @ Keera. The salt load for this site shows that IQQM is contributing less than the audit (43% lower). The reason for the difference is that the relationship for this catchment in the audit was identified as a poor representation early in the project. The audit used a linear relationship that was based on another catchment. This was generally the process applied for inflows that do not have any observed data however there is observed data available for this catchment (see Table A.1.). After identifying this as a problem a new 2D relationship was derived for IQQM that uses observed data. This new relationship produces a lower salt load input than the audit, but is a much more realistic representation of the catchment (Note running the audit relationship in IQQM produces 12100 t/y for comparison 1, which is within 20% of the audit value. This difference is explained by the difference in flows).

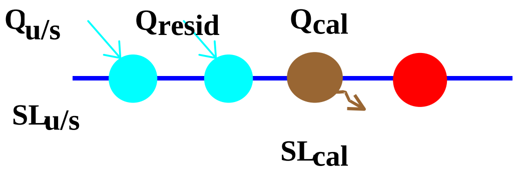
The probable reason for these differences is that the Salinity Audit relationships are applied to different time series. The basic equation for Model IIC calculates salt load using a linear relationship with flow (Equation 4.1). Referring to Figure B.1, the Salinity Audit relationship would have been 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 is 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.

$$SL = \eta + \lambda Q \tag{4.1}$$

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

$$SL_{resid} = \eta + \lambda Q_{resid} - SL_{cal} \tag{4.3}$$

Where: η, λ are salt load relationship parameters



SL__, *Q__* are shown in Figure B.1.

Figure B.1. Schematic for calculating net salt load inflow from residual catchments in IQQM

The comparison of salt loads at the balance points in IQQM against those reported in the Salinity Audit shows a mixed result. This is in part because of the incompatible configurations of the residual catchments and calibration nodes. The net effect at Gywdir River @ Pallamallawa is a 14% decrease in salt loads compared with that reported in the Salinity Audit. By comparing the IQQM results at this station against the observed data it appears likely that the model is significantly underestimating the true result, and the audit is a more accurate estimate. The result in IQQM is likely to be greatly improved after the calibration of the model

B.2.2. Climatic period

The mean annual salt loads for the BSMS climatic period (01/05/1975-30/04/2000) are higher for ten of the nineteen inflow points than the mean annual salt loads for the Salinity Audit climatic period (01/01/1975-31/12/1995). The salt load inflows that increased are for the same catchments where flows increased, with the exception of Keera Creek @ Keera. In this case the difference can be put down to the new relationship that was derived for the catchment (as discussed in section 4.3.2.2.1). This relationship is an improvement to the modelling of this inflow and the difference when compared to the audit is not a concern. The net difference at Pallamallawa is a 2% increase compared with that reported in the previous section.

B.2.3. Conversion factor

Applying a lower EC→salinity conversion factor has a predictable effect, with the results shown in Column 3 of Table B.8.1 a constant ratio of 0.9375 (or 0.60/0.64) lower than those in Column 2 of Table B.8.1.

B.2.4. Concentration cap

Capping the concentration has had quite a significant effect on the total salt loads for most of the inflow points, with reductions compared with column 3. These changes are mostly within the range of 0-10% lower than those in Column 3. One major exception to this is the result for catchment R4, where unexpectedly the average annual salt load increased. This latter result was investigated, and was found to be caused by the method used to calculate the net residual. The calibration node at the mainstream gauge removes flow that is a combination of the residual and all upstream inflows. This result highlights an area that needs attention when reporting results.

B.3. 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 showed some differences. The net difference at Gwydir River @ Pallamallawa is approximately 3%. Some possible reasons for this were put forward, and can be confirmed by reviewing the data and calculations used to report the Salinity Audit results.

The direct comparison of mean annual salt loads reported in the Salinity Audit and those from IQQM showed some differences. The net difference at Gwydir River @ Pallamallawa is approximately -14%. 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 at Gwydir River @ Pallamallawa for the BSMS Benchmark climate period were 3% higher than that used in the Salinity Audit. These higher flows resulted in a 2% increase in mean annual salt loads compared with the IQQM results used in the direct comparison. These mean annual salt loads were then reduced by 5% using the lower EC→ Salinity conversion factor and a further 3% by adopting a realistic maximum concentration for the salinity inflows.

The net difference Gwydir River @ Pallamallawa in mean annual salt loads of all the modifications is -6% compared with the IQQM used for the direct comparison, and –14% compared with those reported in the Salinity Audit.

Appendix C. Model Details

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

- IQQM version = 6.76.1
- System file = GwyBL01.sqq (all other files needed are detailed in this system file).