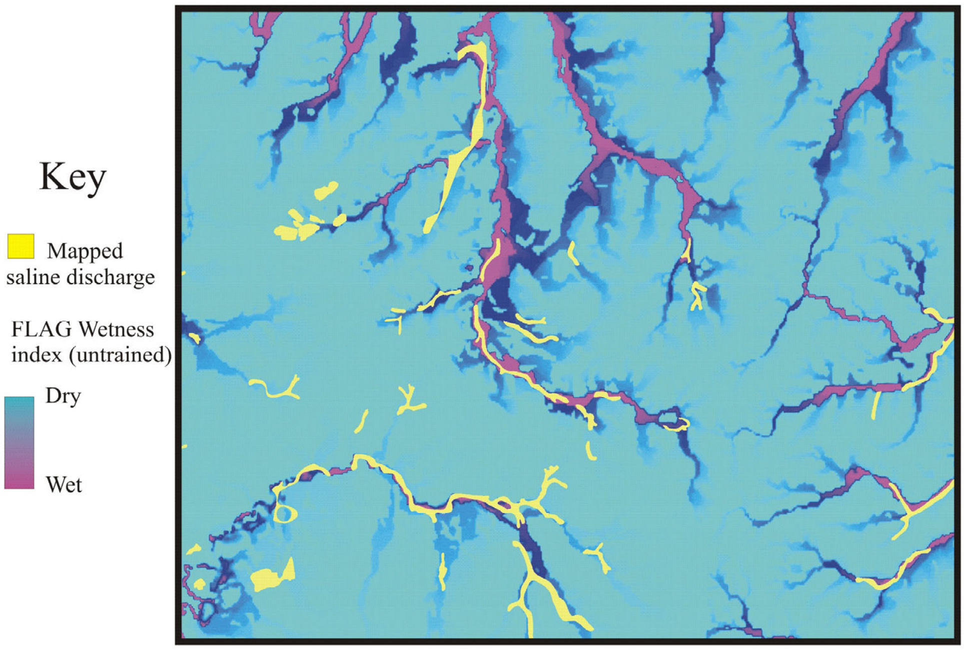
Department of
Infrastructure, Planning and Natural Resources

NSW coastal salinity audit



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NSW coastal salinity audit

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Contents

Page

Figures

Page

Tables

Executive summary

This audit examines the salinity status of coastal New South Wales (NSW). Together with the salinity audit of the Hunter River (Beale et al. 2001) this report completes Action 1.3 of the NSW Salinity Strategy: to audit salt-affected areas outside the Murray-Darling Basin (MDB). It is limited to examining the primary data sources held within the Department of Infrastructure, Planning and Natural Resources (DIPNR). The main focus of this report is the North and South Coast, plus the Manning River, Karuah River and Lake Macquarie and Tuggerah Lake basins, which were not included in the Hunter audit.

The MDB and Hunter River audits assessed the impact of dryland salinity on stream salinity and river basin salt loads, and predicted future stream salinity based on groundwater level trends. The audits did not address land salinisation. Likewise, this audit focussed on stream salinity; however, there was insufficient groundwater data for coastal river basins, except for the Hunter, to be able to make salinity trend predictions.

The audit process adopted in this study was to document the status of primary salinity information for the coast. This took the form of reviewing available data within DIPNR, analysis of historic stream salinity and flow records for coastal river basins, salinity hazard mapping and analysis of historic groundwater salinity data. It should be noted that as the hazard mapping process did not have sufficient input data to give an accurate picture of hazard, to avoid confusion the resulting maps have not been published.

Fuzzy Landscape Analysis GIS (FLAG) maps are presented in this report as they indicate likely discharge sites and have been useful for indicating salinity outbreaks elsewhere in the State.

All other analytical results for each river basin covered in this audit are listed in the appendices. The reader is encouraged to look at these results to avoid confusion when interpreting the broad statements contained in the report.

It should be noted that urban salinity in western Sydney is the subject of separate investigations by DIPNR, as a part of the Local Government Salinity Initiative and Urban Salt Action Team work, also established under the Salinity Strategy. Therefore, to avoid duplication, urban salinity in western Sydney was not a major focus in this audit, beyond the draft hazard mapping and stream salinity analysis.

The general findings of the audit are that:

- median salinity values for most coastal rivers and tributaries are low
- stream salt loads are not currently a major threat in coastal regions
- agricultural practices currently present a low risk for stream salinisation across the coastal basins
- major salinity problems on the coast are associated with infrastructure in salinity hazard areas.

Salinity is recognised as a problem in western Sydney with the potential to affect large areas of new development in the near future. To a lesser extent, salinity is identified as a problem in the Hunter coal mining areas of the Manning and Karuah basins and the southern tableland areas around Braidwood and Goulburn.

Other than these areas, salinity is not generally a major issue in coastal areas at the current time. This is supported by the actions and targets in the Catchment Blueprints, as well as reports by the Healthy Rivers Commission and in discussion with regional DIPNR staff. The stressed rivers reports (e.g.

DLWC 1999a, 1999b, 1999c) generally do not mention salinity as an issue. The Independent Inquiries into coastal rivers (e.g. HRC 1999a,b) also do not list salinity as an issue. *Prima face* this does not exclude the possibility that an unrecognised hazard may exist and that small outbreaks of dryland salinity are not locally important. Bradd (1996), using a weights-of-evidence GIS approach, predicted a moderate salinity hazard in some parts of the northern and southern tablelands. Minor investigations in the Grafton and Casino areas have also recorded some salinisation.

Based on the findings of this audit, it is recommended that baseline spatial data sets such as the 1:25 000 scale geology should be progressively upgraded, as well as groundwater monitoring networks and knowledge of groundwater flow systems.

1. Introduction

In 1998 an audit of the Murray-Darling Basin Salinity and Drainage Strategy focusing on predicted impacts of dryland salinity on river health (MDBC 1999 and Beale et al. 2000) found that rates of salinisation were likely to increase dramatically. In August 2000, the NSW Government released the NSW Salinity Strategy in response to the need for an integrated approach to Salinity in NSW. Action 1.3 of the strategy called for an audit of the major salt affected NSW Catchments outside the Murray-Darling Basin to set interim end of valley salinity targets for the Hunter, North Coast and South Coast catchments.

Salinity is not listed as an issue for the majority of Catchment Blueprints for the coastal rivers. However, outside of these major areas of community focus smaller areas of land salinisation are sporadically documented up and down the coast, mainly in the areas around Braidwood and Goulburn in the South and Casino and Grafton in the North. The audit of the Hunter River and its tributaries upstream of Greta (excluding the Manning River, Karuah River and Lake Macquarie and Tuggerah Lake basin) was completed in 2000. This used the same methodology as the Murray-Darling Basin study, with enhancements to account for topographic effects (Beale et al. 2001). An audit of the remaining coastal catchments commenced in 2001. The findings of the coastal audit are summarised in this report. It collates the available knowledge on groundwater, geology, soils and salinisation for the coastal regions. The report is organised on a regional basis and a summary of the information for each catchment is presented in the Appendices.

1.1 THE AUDIT PROCESS

In previous salinity audits in NSW for the Murray-Darling Basin and Hunter River (Beale et al. 2000 and Beale et al. 2001), predictions were made in regard to future stream salinity based on observed trends in groundwater level. Insufficient data are available for the remainder of the coastal catchments to adequately describe groundwater level trends or establish a reliable surface water and salt mass balance on which to base similar predictions. Therefore, the audit process adopted in this study is to document the status of primary salinity information for the coast.

The audit presented here consists of the results of four primary tasks:

1. A review of available data based on discussion with regional staff.
2. Analysis of the historic stream salinity and flow record for the coastal river basins.
3. Salinity hazard mapping for the whole coast.
4. Analysis of the spatial distribution of the available historic groundwater salinity data.

1.1.1. Review of available data

One of the key tasks of this audit was to document the primary salinity information (hydrogeology, surface hydrology and GIS spatial data) for coastal regions of NSW and an extensive literature review was conducted. Ten district offices were visited in November and December 2001 to draw on local staff experience and collate all salinity-related publications. While there appears to be some detailed project work in specific locations, there was no overall assessment of the threat of salinisation.

1.1.2. Analysis of stream salinity and flow

Surface water salinity information was modelled for both stream salinity and salt load. For stream salinity, the model used stochastic relationships between flow and salt load. This information was used to model the median and 80th percentile (non-exceedance) salinity range (EC) for the coastal catchments. Stream salt loads were generated as a daily time series by applying regression relationships for discrete flow and EC data. From this, annual average salt loads were calculated to determine the relative contribution of the drained areas as a salt source.

1.1.3. Salinity hazard mapping

Salinity hazard mapping is based on identifying the relative probability that salt stores associated with other mappable attributes exist within the landscape. If mobilised, salinity hazards have the potential to create ecological/social salinity problems. Salinity hazard is a static structural view of salinity potential in the landscape rather than a dynamic process of assessment of risk.

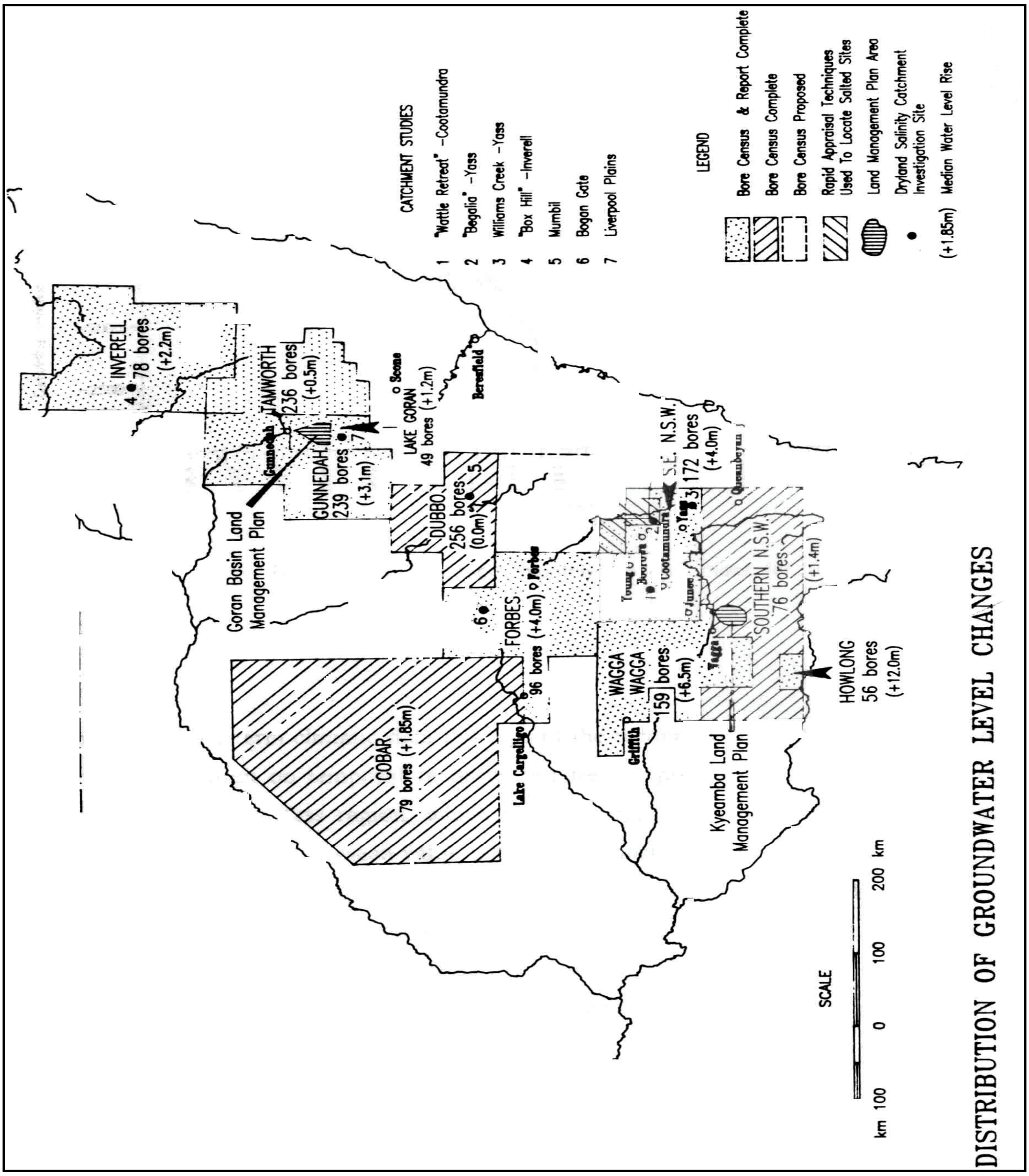
The generalised draft salinity hazard map was constructed using a weights-of-evidence approach. That is, an evidence layer of known salinity outbreaks was analysed in respect of combined layers of predictive landscape attributes such as geology and soils to assess the probability of further hazard extending beyond known outbreaks.

Stream salinity recorded at gauging stations and groundwater salinity data at individual bores give information on the hydrological responses of the catchment. However, there were considerable gaps in the available data and the gauging station and the groundwater salinity data from bores was therefore unsuitable for inclusion as salinity evidence layers in the hazard mapping process. However, they provide an objective, though incomplete, means of checking the draft hazard mapping predicted from other landscape attributes.

1.1.4. Analysis of groundwater salinity data

The map published in Bradd and Gates (1995) highlights the lack of groundwater studies for the coastal region (Figure 1). This paucity of groundwater data prevented the calculation of groundwater trends. However, the available groundwater data was extrapolated and groundwater salinity values assigned to geology polygons to provide a spatial coverage of groundwater salinity (Figures 11 to 13).

Figure 1. Map of groundwater studies for NSW (Bradd and Gates 1995)



2. Data availability / review

In the previous NSW salinity audits for the Murray-Darling Basin and Hunter River (Beale et al. 2000 and Beale et al. 2001), predictions were made about future stream salinity based on observed trends in groundwater level. Insufficient data were available for the remainder of the coastal catchments to adequately describe groundwater level trends or establish a reliable surface water and salt mass balance from which to base similar predictions. Therefore, the audit process adopted in this study was to document the status of primary salinity information for the coast.

A literature review for coastal basins is presented. The previous Murray-Darling Basin and Hunter audits relied heavily on groundwater, surface water and Geographic Information Systems (GIS) spatial data. In this audit, groundwater data were used to find the average groundwater salinities associated with the spatial geology coverage of the coastal catchments. Surface hydrology data were used to determine the statistical structure of river flow and salt loads for tributaries and mainstream locations throughout each river basin. GIS spatial data were used to develop a draft salinity hazard map of the coastal catchments and produce maps displaying the results of the surface and groundwater analyses. Specific project investigations also provided a detailed insight into local and regional salinity issues. The following section provides an overview of information availability.

2.1 HYDROGEOLOGY DATA

Groundwater salinity data were sourced from the TRITON water quality database maintained by DIPNR. All data were converted to consistent electrical conductivity units before use in the analysis. Where total dissolved solids (TDS) and corresponding EC data were available, EC ($\mu S.cm^{-1}$) was used. Where necessary TDS data was converted to an equivalent electrical conductivity using a factor of 0.65. This conversion factor was the average value used in the database. While differences in water chemistry may require a range of conversion factors, the number of records with only TDS was a small proportion of the total sample size and results were statistically valid.

There was a considerable spread in the time of measurement for all records with some records extending back into the 1940s and others of very recent origin.

2.2 SURFACE HYDROLOGY DATA

Surface hydrology and salinity data for stream gauging stations across all basins was obtained from the DIPNR HYDSYS and TRITON databases. Total daily flows were obtained from HYDSYS and, where applicable, instantaneous flows were also obtained. Only discrete salinity samples were available for the coastal gauging stations examined. These were obtained from TRITON along with data on instantaneous flows. Where no instantaneous flow value was available from TRITON but a time of sampling was given, instantaneous flows were obtained from HYDSYS. Generated salt load time series were calculated from the complete observed daily flow time series obtained from HYDSYS.

There are both temporal and spatial gaps in the surface hydrology data. The status of gauging stations varies from long term monitoring sites to discontinued or recently established sites. Therefore, the time periods of the data analysed were not necessarily concurrent. Wherever possible stochastic relationships determined for discrete salt load and flow were applied to the period 1975 to 2000 to generate salt load time series. As flow data was often incomplete and rainfall-runoff modelling unavailable, it was not possible to augment the observed flow data and this limited the time series generated.

2.3 GIS SPATIAL DATA

Spatial data were used to create derivative maps as well as for input into the spatial analysis of salinity hazard. All data layers are held by DIPNR Centre for Natural Resources (Queanbeyan, Wagga Wagga and Parramatta) or by GIS units in the DIPNR regional Offices (Newcastle, Wollongong and Grafton).

A Digital Elevation Model (DEM) with a 25 x 25 metre pixel resolution was available for the whole of the coast. The DEM was reviewed and anomalies such as drainage sinks removed. The DEM was used to produce derivative products using various modelling techniques including:

- FLAG model Wetness Index, Pressure Accumulation Index, Lowness Index and Plan Curvature Index
- FLAG model landform classes
- elevation bands
- slope classes
- catchment boundaries
- Compound Topographic Index (CTI).

A ‘best’ soils map was compiled from a combination of 1:100 000 scale soil landscape maps and 1:250 000 scale comprehensive resource assessment (CRA) mapping.

Geology mapping was used at two scales: the 1:9 000 000 Broad Atlas Geology and 1:250 000 (CRA) scale. The Groundwater Flow Systems map produced by BRS at a national scale (1:5 000 000) was used. ESOCLIM rainfall distribution maps were used both as raw input and to produce a derivative rainfall seasonality distribution map. The Agricultural Land Cover Change (ALCC) land-use layer was also obtained.

Salt outbreak mapping previously compiled for the National Land and Water Audit was used as the primary source of known extent of salinity. This was augmented with point data on soil salinity and sodicity from the DIPNR Soil and Land Information System (SALIS) database.

2.4 COASTAL BASINS NORTH OF THE HUNTER RIVER

2.4.1. Existing information

Bell (1997) noted some isolated and localised salinity around Grafton. Seven of the 13 sites noted were identified in Tenayr and South Grafton. However, this survey was based on visual assessment of a large area from a moving car and adjacent stream salinity measurements. Bell (1997) found that outbreaks of salinity were isolated, localised events, distributed across a small percentage of the study area. Most saline sites identified were on cleared land above the Grafton sandstone formation, which contains relatively saline water reserves.

Williams (1997) investigated salt scalds in a study area of 312 km^2 within the Richmond River Valley (Casino, Coraki, Rappville). He concluded that ‘preliminary investigations indicate there are considerable areas with potential for salinity problems to occur; however, further work is required to validate these findings’. A salinity hazard map based on overlaying ‘depth to watertable’, aquifer salinity and Sodium Adsorption Ratio was produced for the study area. Page (1997) continued this work; however, while some fieldwork was included, references were mainly based on existing agency pamphlets.

Rumpf and Bradd (1997) noted 'the potential for land salinisation to occur on the lower slopes of the Tweed and Brunswick catchments', and recommended that a dryland salinity hazard map be produced. Some minor land salinisation occurs on the tablelands. Eighty-two saline/alkaline sites were located from a landholder survey in the Uralla, Wollun and Walcha districts (Murray 1996). However, no further information was found about this survey.

2.4.2. Water quality

Surface water quality monitoring in the North Coast commenced in the 1970s with DWR (EPA, 1996) monitoring for EC, pH and turbidity linked with the river gauging program. The EPA also conducted water quality monitoring in the 1980s (Williams 1987a-h), but this was focused on the lower river reaches. Results from both the DWR and EPA programs were summarised, as averages, by the EPA (1996).

The statewide Key Sites monitoring program commenced in 1992 to assess trends in salinity, turbidity and total phosphorus (Preece 1998) and includes ten sites located within North Coast basins. Over the period 1992–97, salinity levels (not adjusted for flow) appeared to decline at two sites, increase at three sites, with no trend being apparent for the other sites. When allowance was made for changing flow conditions over this five-year period, one site (the Nambucca River) showed a declining EC trend, while two sites (the Richmond River downstream of Casino, and the Bellinger River at Thora) appeared to increase. The remainder had no significant trend. However, rising trends in the Bellinger River at Thora do not appear to be associated with any land-use change (P & M Rongen pers. comm. 2002) and therefore are likely to represent a short-term climatic response.

Further assessment of salinity trends by Morton and Henderson (2002) over a nine-year record found that salinity decreased at two sites and increased at one site, with no trend apparent at the other sites.

Continuous EC monitoring has recently been installed on the Orara River at Karangi, and on the Nymboida River at Nymboida (Parsons, pers. comm. 2002) and results can be used to assess short-term variability in salinity, and flow-salinity relationships.

2.4.3. Hydrogeology

Approximately 9400 bores were listed in the DIPNR groundwater database for the North Coast basins. Of these, only 932 bores had corresponding salinity records in the TRITON water quality database, and the majority of these bores have only a single EC value recorded. Multiple time series records exist for only a limited number of bores. After extracting duplicate records there were 2042 data records available for the North Coast basins.

Drury (1982) conducted extensive investigations in the Richmond Valley, though this was mainly to look for water supply sites. This included a summary of all bores, wells, spearpoints and excavations located in the Richmond River Valley. The report also describes results of aquifer evaluation and groundwater chemical analysis (cations and anions). It also includes useful information on geology, regional groundwater flow systems within the river alluvium, and groundwater chemistry. The stratigraphic cross-sections across the Richmond Valley with aquifers, piezometer and bore locations are particularly useful in assessing salinity hazard and reclamation measures.

Lytton (1995) noted that while some geological information was available (in the Richmond Valley and the Alstonville Plateau), 'preliminary assessment revealed critical data deficiencies in some areas'.

McKibben (1995) reviewed groundwater information for the Tweed, Brunswick, Richmond and Clarence Rivers. The main aim of this work was to quantify the groundwater resource but the review can also be used to assess salinity hazard. He found 'no evidence of regional watertable use causing adverse impacts such as dryland salinisation, notwithstanding that localised areas of this form of land degradation have been recorded.' He also estimated a total annual recharge of 1.7 million ML for these valleys (based on a simple water balance approach) as well as noting the occurrence of better quality groundwater on coastal sand beds, fluviatile alluvium and Tertiary basalts.

Useful outputs from McKibben (1995) include a major aquifer map (1:250 000), available on DIPNR GIS, summary sheets for each aquifer (which include an estimate of recharge/discharge) and a summary of salinity levels for main aquifer systems and localities.

Rumpf et al. (1998) produced groundwater vulnerability maps for the Richmond Catchment and his report details methodology including the weighting and ranking used. GIS layers are available and could be further developed for salinity hazard mapping or recharge assessment. The Groundwater Vulnerability mapping GIS layers complement information available from the Northern Comprehensive Regional Assessment (CRA) project.

In the Hunter, 1065 bores were listed in TRITON with EC data, out of approximately 6700 bores listed in the Groundwater Database.

Other hydrologic investigations have mainly focused on water supply. These include examination of potential groundwater supplies in the Wauchope area (WCIC 1974), assessment of groundwater supply in the Alstonville Plateau (DWR 1987) and the Lower Manning River Hydrogeological investigation (Gates 1978).

Other information sources include CSIRO work such as Walker (1961), who conducted a limited survey of shallow watertables in the Kempsey District in 1959 (a wet year) and 1960. However, this work focused on the lower river reaches, where acid sulfate soils present more of an issue.

2.4.4. GIS data sources

GIS data on soils, vegetation and cadastral information was available from NCRIU (2001). The northeastern CRA project (NSW Government 1999a, b) collated a range of information that was based largely on 1:100 000 topographic maps and 1:100 000 soil landscape mapping. The products include maps of effective rooting depth and estimated plant available water-holding capacity, which can be adapted for further modelling at the regional scale.

2.5 COASTAL BASINS SOUTH OF THE HUNTER RIVER

2.5.1. Existing information

A number of reports, detailing specific instances of salinity, were located following discussion with local and regional staff. Smith (undated) notes that about 700 ha are salt affected in the Upper Nepean/Wollondilly catchment, and urban salinity has been noted at some locations in Goulburn (McGhie pers. comm. 2002). Armstrong (1997) noted that Millend Springs had a history of dryland salinisation from 1941, with continuous scalds along the main creek-line observed in 1967 and 24 ha affected by 1974. This area had expanded to 35–40 ha (10 ha severely scalded) by 1985. This site has been extensively monitored since 1990, with monthly groundwater monitoring and six monthly salinity assessment.

Grant (1999) reported localised salting in the Braidwood locality and Norman (1999) noted that Landcare groups (including Braidwood Urban, Bombay, Mongarlowe Urban and Windellama Urban) have also had limited involvement in Streamwatch. The stressed rivers reports (DLWC 1999a to f) assessed four sub-catchments (Boro Ck, Braidwood Ck, Bungonia Ck and Nerriming Ck) as 'high stress' due to salinisation and the Mangarlowe River as 'moderate' salinity stress. However, the Independent Inquiry into the Shoalhaven River System (HRC 1999a, b) did not rate salinity as an issue in the Shoalhaven.

Laffin (undated) used the FLAG model and geological information to assess the salinity hazard of the Upper Snowy Catchment. He concluded there was a limited salinity threat around Bombala, but for most of the catchment there was a low risk of salinisation.

There is some minor salting around Moruya (but this may be more associated with acid sulfate soils) and salinisation is not an issue in the Nowra District (Zarrafa pers. comm. 2002), apart from minor outbreaks west and south of Nowra.

Jenkins (1996) mentions salinity as a soil limitation for a number of soil landscapes in the Braidwood area and Talau (1994) mentions salinity as a soil limitation for the Schofields Creek and Slacks Creek soil landscapes on the Cooma map sheet.

2.5.2. Water quality

Surface water quality monitoring in areas south of the Hunter River commenced in 1968 with field testing (EC, pH and temperature) by hydrographers during routine gauging every 8–10 weeks (Clark 1996; Jain 1999). This data was stored in HYDSYS, though it is now also in TRITON. Clark (1996) assessed eight sites and provided a starting point for salinity trend analysis. The statewide Key Sites monitoring program commenced in 1992 to assess trends in salinity, turbidity and total phosphorus (Preece 1998) with nine sites located in areas south of the Hunter River. Over the period 1992–97, four sites showed a declining EC trend, with no trend being apparent for the other five sites. When allowance was made for changing flow conditions over this five year period, five sites showed a declining EC trend, with two sites having no significant trend and a further two sites not analysed due to a poor flow-salinity relationship. Trends are currently being reassessed over the nine-year record by CSIRO (Morton & Henderson 2002).

Gippel (1997) noted that there were no consistent or meaningful trends in EC in the Bega Valley, and the Independent Inquiry into the Bega River (HRC 2000) and the Shoalhaven (HRC 1999a, b) also did not rate salinity as an issue.

Turner et al. (1996) describe some 'snapshot' water quality monitoring undertaken across the Towamba catchment for 103 sites stratified on geology and land-use, with each site sampled six times over a four-day period. A similar approach was applied to the Bega valley, where 175 sampling points were each sampled three times at 12-hourly intervals by 50 trained volunteers during the week of 11 August 1997 (Turner et al. 1998). It was found that EC was largely related to land-use but that overall, salinity was not an issue.

Boey and Jones (1992) reviewed EC data for the period 1970–90 for the Shoalhaven catchment. They summarised the previous water quality data and found 'no statistically significant long-term trends were detected for any indicator. Uncontrolled data collection resulting in irregular sampling frequency and a paucity of records for many sites has made analysis for trends inconclusive…' (p50). They concluded that there were 'no significant long-term trends in conductivity at any site' (p16). Their report includes EC time series plots for all monitored stations. Continuous EC monitoring has only recently been installed at six sites across the region (Jain 1999) and results can be used to assess short-term variability in salinity and flow-salinity relationships.

2.5.3. Groundwater

The DIPNR groundwater database for Sydney South Coast basins indicated that the majority of bores had only single EC records. Of the approximately 9400 bores listed on the Groundwater Data System there are 1018 corresponding bores in TRITON with EC data and 3536 data records available for analysis.

McKibbin and Little (1994) provide a generalised geology overview for the region that is also documented in the CRA report (NSW 1999). Few regional groundwater reconnaissance surveys have been conducted for the Sydney South Coast basin (Russell 2001). Some sporadic monitoring was available, mainly around Bega for seven sites associated with town water supply bores (Jain 1999) and Araluen (nine sites).

Sundararamayya (1983) provides an overview of geology and hydrogeology in the Bega Valley, but focuses on the Bega town water supply. The survey of upland wetlands in the Bega Valley (Green 1999) may be useful in identifying how groundwater seepage sites have changed over time (a map is included in the report).

2.5.4. GIS data sources

Bradd (undated) has prepared a number of GIS layers (ArcView®) for Groundwater Vulnerability mapping in the Bega Catchment. Rumpf et al. (1998) have also completed Groundwater Vulnerability mapping in the Hawkesbury-Nepean Catchment. The accompanying report to Rumpf et al. (1998) details the DRASTIC approach used, and outlines the weightings and rankings used for the Hawkesbury-Nepean. GIS layers are available and could be further developed for salinity hazard mapping or recharge assessment. Krummins et al. (1997) provide additional information on groundwater availability in the Hawkesbury-Nepean Catchment. The Groundwater Vulnerability mapping GIS layers complement information available from the Southern Comprehensive Regional Assessment (CRA) project.

3. Methodology

The 1999 Murray-Darling Basin audit was able to draw on extensive groundwater and surface water information that allowed estimation of groundwater, surface water and salt flux trends. The second audit in the series on the Hunter valley (Beale et al. 2001) was also able to source groundwater and surface water information. Ideally the information for all audits should be comparable. However, lack of detailed salinity and groundwater information for the remainder of the coastal regions prevented the use of a similar methodology for this audit. A modified approach was therefore needed for the coastal areas and an increased emphasis on stochastic modelling of stream water quality and hazard mapping was required.

In the previous audits the time period of 1975 to 1995 was chosen as the base climatic period covered by the analysis. Wherever possible salt load time series have also been generated over the 1975 to 1995 period for this audit. However, because the data are incomplete for North and Sydney South Coast catchments, modelling had to be carried out regardless of temporal data constraints.

The methodology adopted for this study falls into three separate categories:

- Surface water quality analysis
- Salinity hazard mapping
- Groundwater salinity analysis.

3.1 SURFACE WATER QUALITY ANALYSIS

Varying amounts of stream salinity data are available both spatially and temporally for the river basins of the NSW coast. Stream salinity data consist only of discrete EC samples. While continuous EC flow monitors have recently (within the last three years) been installed at some sites on the North and South Coast, for consistency no continuous flow and EC measurements were used in this analysis.

Only streams outside the previous Hunter Audit study area have been analysed in this audit. These include the Karuah, Manning and Lake Macquarie and Tuggerah Lake basins in the Hunter basin as well as all river basins in the Sydney South Coast and North Coast basins.

Relationships between flow and EC, and flow and salt load were established for data at each gauging station. The measurement time was used to extract an instantaneous flow from HYDSYS and used regardless of its quality code. Where no instantaneous flow could be attached to the discrete EC samples, a mean daily flow was used. Linear and log-linear relationships with or without a fast Fourier transformation seasonal component were tested according to the methodology used by Beale et al. (2000) in the Murray-Darling Basin Salinity Audit. The regression model that best represented the data was chosen to generate a stochastically modelled daily salt load or daily EC time series for all available observed daily flows.

For all gauging stations where sufficient flow data and a stochastic model were available salt loads were generated as a daily time series. This was achieved by applying regression relationships for discrete flow and EC data to the available daily time series. Stations varied in the amount and time period for which daily flow data were available. As modelled flows were not available from rainfall / runoff models such as the Sacramento Model to fill gaps in the observed record, it was not possible to produce a uniform generation period for comparison as was done in previous audits (Beale et al. 2000 and Beale et al. 2001).

The statistical structure of the generated salinity time series was presented as a means of direct comparison with the EC ranges reported in the two previous audits (Beale et al. 2001 and Beale et al. 2000). Comparison was also made with the statistical structure of the observed EC data to ensure that the modelled data remained similar to the observed. Departures between the modelled and observed are to be expected as exceedance probabilities of modelled salinities are bound to the observed flow regime.

3.2 SALINITY MAPPING

This audit developed a methodology for salinity hazard mapping for the coastal zone of NSW. However, due to data constraints these maps did not create an accurate picture of salinity hazard across the whole of the study area and the draft salinity hazard maps have not been published.

There has been limited salinity outbreak mapping in the coastal catchment. For example, there was anecdotal evidence that salinity scalds have been identified in the Walcha area for many years but these have not been mapped. Salinity was noted in conjunction with active gully erosion in sodic landscapes during soil landscape mapping of the Braidwood sheet (B. Jenkins pers. comm. 2002). However, the areas formed a very small percentage of the soil landscapes and no soil profile data was collected or saline sites mapped. Some saline discharge sites occur naturally; however, salinity outbreaks are also the result of poor or inappropriate land management practices. Strong linkages may exist between land and stream salinisation effects and these can interact with each another.

The intent of the salinity hazard mapping methodology was to extrapolate from known salinity outbreaks to potential areas where salinity ‘may’ exist or become a problem in the future. The aim was to aid further investigation of salinity rather than to define specifically where salinity ‘will’ occur. For example, proximity to a high hazard should be a criterion for further investigation.

A two-fold methodology was adopted:

- First, the Fuzzy Landscapes Analysis GIS (FLAG) model (Roberts et al. 1997 and Dowling 2000) was used to analyse the salinity and waterlogging hazard due solely to topography. The FLAG wetness index was used as an independent indicator of waterlogging in this work. This index is a composite of the Upness or pressure accumulation index and the Lowness index (low points in the landscape where discharge may occur if there is sufficient pressure accumulation). However, the wetness index on its own does not distinguish between areas that may be prone to waterlogging and those that are also prone to salinisation. Other factors such as geology and soil type affect whether groundwater discharge to the land surface is saline or fresh. Summerell et al. (2003) provides further detail on the interpretation of FLAG modelling results.

- Second, a weights-of-evidence salinity hazard map was constructed from various data layers as described below. These products were merged to produce the draft hazard map.

3.2.1. The weights-of-evidence approach

The method requires an evidence map (i.e. known salinity sites) be compared to a number of predictive layer maps. The predictive layer maps chosen for this exercise are presented in Table 1. A probability was calculated for each combination of attributes from all predictive layers based on the number of mapped salinity hits for each combination. Several layers of varying scale were used as input to this hazard mapping exercise. The option to include land use as a predictive hazard layer was explored but later rejected.

Table 1. Data types and sources used in the weights-of-evidence salinity hazard map

Predictive layer	Type	Scale / resolution	Source
Atlas geology	Vector	1:9 M	AUDIT
Land-use	Raster	100 m	ALCC
Elevation	Raster	25 m	DEM
Rainfall	Raster	5 km	ESOCLIM
Landform	Raster	25 m	FLAG model
Ground water flow systems	Vector	1:5 M	BRS
'Best' soils map	Vector	1:250 000	DSNR NRIS
Sodic soil landscapes	Vector	1:250 000	DSNR NRIS
Soil salinity profiles	Point	point data	SALIS

Vector layers were rasterised to 100 m grid cell size. Raster layers that were sourced at a resolution lower than 100 m were re-sampled to 100 m using a bilinear interpolation method for continuous data (i.e. rainfall, elevation and derivatives of elevation) and nearest neighbour for categorised data (i.e. landform and geology). A more detailed description of the method can be found in Bonham-Carter (1994).

Predictive layers.

Atlas Geology: Geology classes in this layer were used without any modifications.

Land-use: This layer was reclassified into the following 3 classes:

- woody (consisting of *native woody*, *plantation*, *orchard* and *unknown*)
- non-woody vegetation (consisting of crop and pasture)
- other (consisting of urban, bare, water) 100 m.

Elevation: The 25 m DEM was re-sampled to 100 m and reclassified to classes of 100 m width (values ranged 0–2223 m).

Rainfall: Monthly ESOCLIM surfaces generated from the 9 second DEM (ranged from 47$^{1–}$ 2848 mm). This 9-second data was bilinearly re-sampled to 100 m and then reclassified into 100 mm band widths.

Rainfall seasonality: The seasonality was calculated as the proportion of annual rainfall falling during the winter months of June, July and August, from the monthly ESOCLIM surfaces, and was then broken up into classes of 10% width.

Landform: Four landform classes were calculated by dividing the cumulative distribution function of the FLAG Upness Index at the points of inflection. Pixel sets from the DEM at 25 m were re-sampled to the nearest 100 m.

Sodic soil landscapes: A best soils map for the coast was constructed by the DIPNR Natural Resource Information Systems group by combining all published, and also late draft, soil landscape maps at 1:100 000 scale with CRA maps at 1: 250 000 scale. Sodic soil landscapes were identified by reference to the published data and by interrogation of the SALIS database for sodic soil profiles. As soil landscapes encompass a catena of soil types within a landscape the FLAG derived landform boundaries were used to further define areas of sodic soils to the colluvial and depositional landforms.

Evidence layer

Salinity: Salt outbreak mapping from the National Land and Water Audit (NLWRA) in the vector form (i.e. polygons) was converted to raster form by applying a 100 m grid over the layer. Where any part of a salinity polygon existed in a cell, the cell value was coded as saline. This was combined with SALIS point data for any soil site recorded with salinity greater than 2 $dS.cm^{-1}$. SALIS data was grided in the same way (where a point existed in a cell location the cell was given a saline code).

Combination

These layers and their associated information were combined into a single layer. An identifier for combinations of layers was then generated and the proportion of salinised cells in each zone was computed. This was then applied back to the grid to provide a salinity hazard reading for the zone between 0–1 (i.e. 1 means that all cells within a zone were saline and 0 is non-saline).

The final draft hazard map merged the weights of evidence map with the FLAG wetness index to show on a scale of 0 to 1 the probability that areas predicted as prone to waterlogging (FLAG component) were also saline.

3.3 GROUNDWATER SALINITY ANALYSIS

The aim of the groundwater analysis was simply to identify the availability of data and give an indication of the spatial location of groundwaters of varying salinity. All bore salinity data obtained from the TRITON water quality database were cross-referenced with bore location details obtained from the DIPNR groundwater database. The polygons of the 1:250 000 geology coverage were used to assign bores to a definable area upon which they could be grouped. Where an individual bore had multiple readings a single average value of EC was obtained. Where there was more than one bore in a geology polygon the average EC for all bores within the polygon was calculated. Polygons were grouped into discrete salinity bands representing the range of average EC and mapped for each basin.

4. Results

The results are summarised as stream salinity (modelled using stochastic relationships between flow and salt load) and stream salt loads (generated as a daily time series by applying regression relationships for discrete flow and EC data). A review of the salinity hazard mapping (using a GIS approach) results is also presented.

4.1 SURFACE WATER SALINITY

Stream salinity was modelled using stochastic relationships between flow and salt load to produce a daily time series of salt concentration for all gauging stations where sufficient daily flow and a regression relationship was available. Average, median and 80th percentile non-exceedance values for daily EC ($\mu S.cm^{-1}$) were calculated only for those days on which flow was recorded. Days for which zero flows were recorded and days for which there was missing flow data were excluded from the analysis. Stations vary in the amount and time period for which daily flow data were available. The period for which EC values have been generated and the number of data points available are shown in Appendices 1 to 20. Modelled salinity data were used rather than observed data to extend the analysis over the maximum possible flow record and obtain a better understanding of the variability within streams. Care was taken to preserve the range of modelled EC within reasonable bounds consistent with the observed data.

The stochastic relationships between flow and EC derived in this work were assumed to be stationary and independent of climatic or land-use change, or increased water abstraction. Considering the short period of data availability and the paucity of information this was a reasonable, though expedient, assumption.

Threshold salinity values of 800 $\mu S.cm^{-1}$ and 1600 $\mu S.cm^{-1}$ were used in previous audits as benchmarks for water quality assessment. They represent the maximum desirable water standard set by the World Health Organisation for human consumption (800 $\mu S.cm^{-1}$) and a threshold at which adverse environmental changes can be expected (1600 $\mu S.cm^{-1}$). Predictions of possible changes to the current salinity regime were not feasible and therefore the environmental effects of such a stress could not be assessed. In general, though, the 800 $\mu S.cm^{-1}$ threshold was exceeded in very few tributaries on the coast and the higher threshold was approached by South Creek and exceeded only in the Capertee River in the Hawkesbury Basin during base flows.

Overall, stream salinity does not present a water quality problem on the coast outside the Hunter. All of the tributaries and mainstream reaches analysed in the Hunter audit (Beale et al. 2001) had median salinities greater than 400 $\mu S.cm^{-1}$. By comparison, for the 193 streams that could be analysed for the rest of the coast, only 15 had median ECs greater than 400 $\mu S.cm^{-1}$ and only 4 were greater than 800 $\mu S.cm^{-1}$ (namely the Capertee River and South Creek, Toongabbie Creek and Shannon Brook). It should be noted that for a significant number of coastal catchments there were no data (Figures 2 to 7).

This audit does not differentiate between the types of salt that may be in the stream. Electrical conductivity measurements, which form the basis of this analysis, do not discern between salt types. The form of the salt can determine the nature of water quality problems. For example, Bungonia Creek (215014) in the Shoalhaven basin appears to have relatively high salinity. However, the dominant salts were mainly calcium carbonate or bicarbonates and these have less agricultural significance than sodium chloride. Management of saline sites should be tailored to the composition of the salts present. For example, sulphate salts (common in the western Sydney area) are particularly corrosive to concrete. Differences between salt types can only be addressed through more detailed sampling.

Figure 2. Median salinity range (EC) for stochastically modelled catchments in North Coast river basins

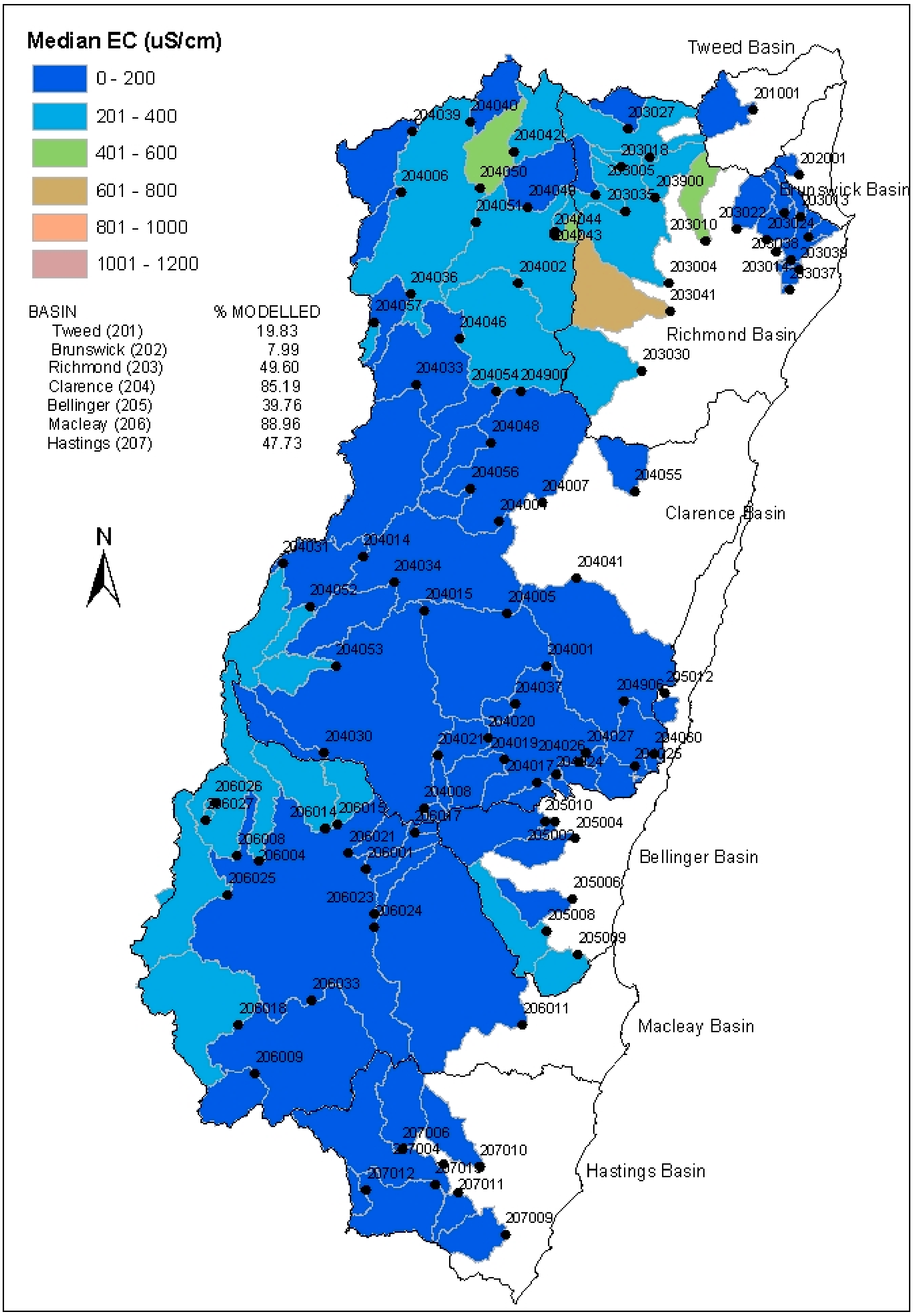


Figure 3. 80th percentile (non-exceedance) salinity range (EC) for stochastically modelled catchments in North Coast river basins

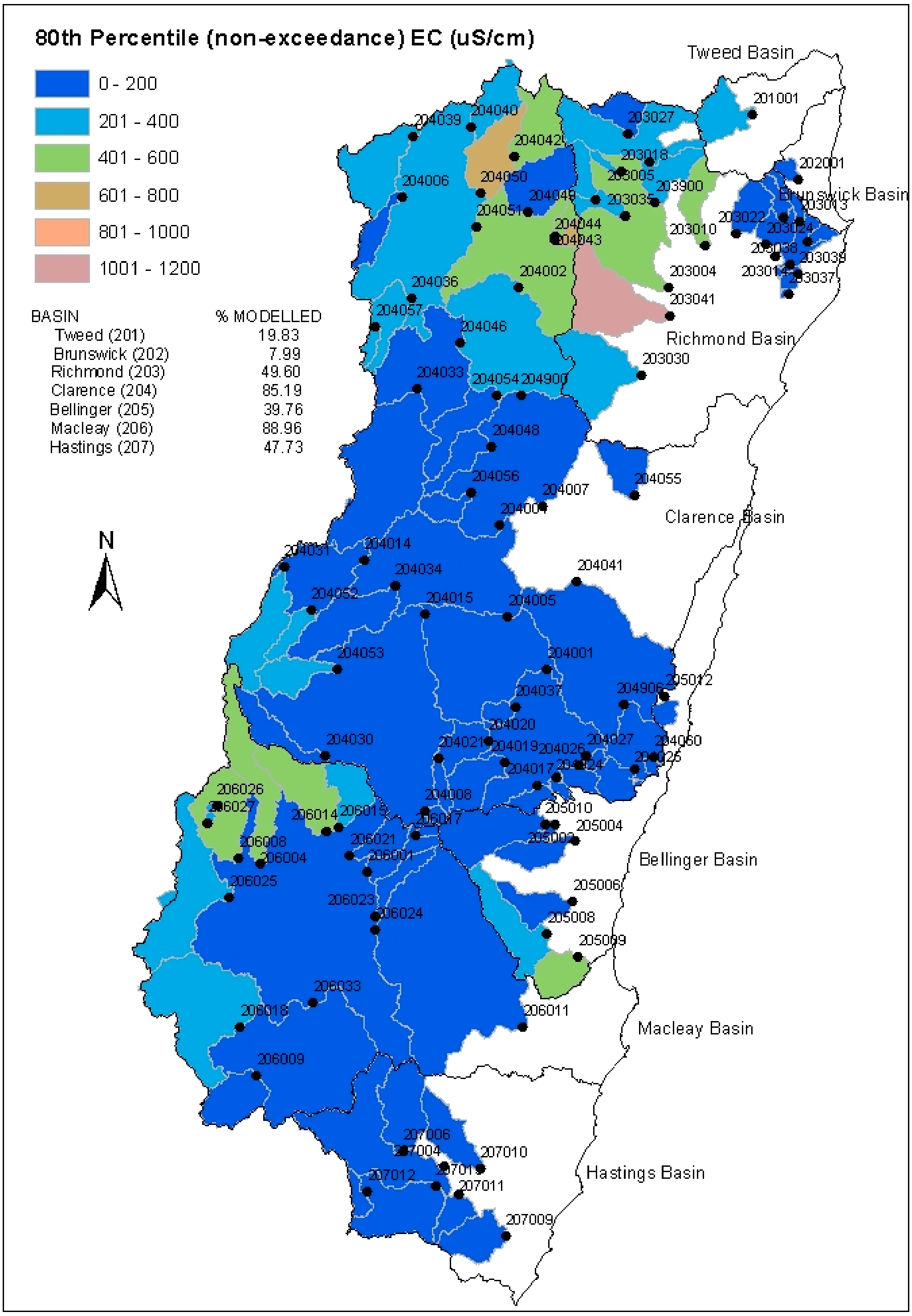


Figure 4. Median salinity range (EC) for stochastically modelled catchments in additional Hunter River basins

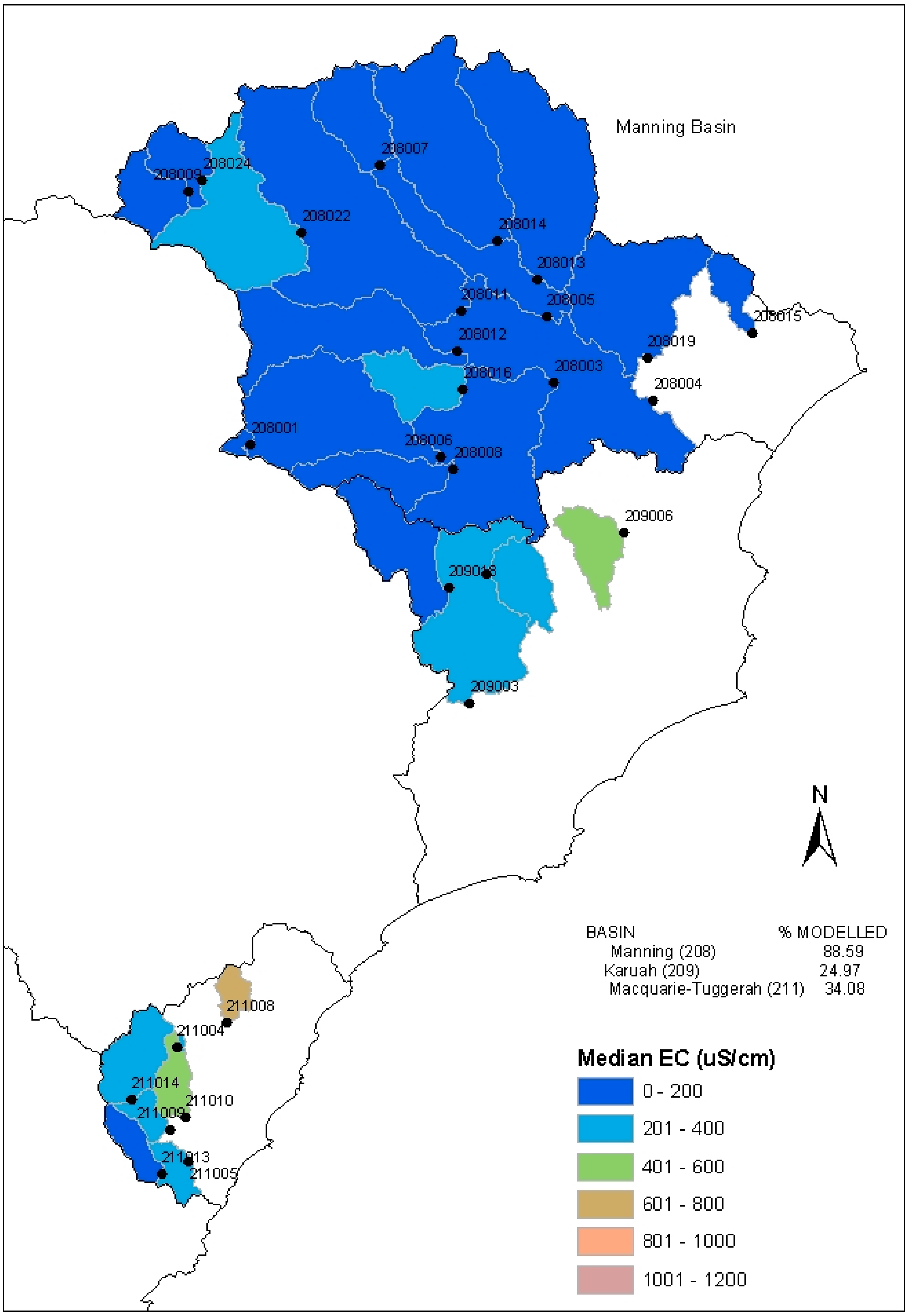


Figure 5. 80th percentile (non-exceedance) salinity range (EC) for stochastically modelled catchments in additional Hunter River basins

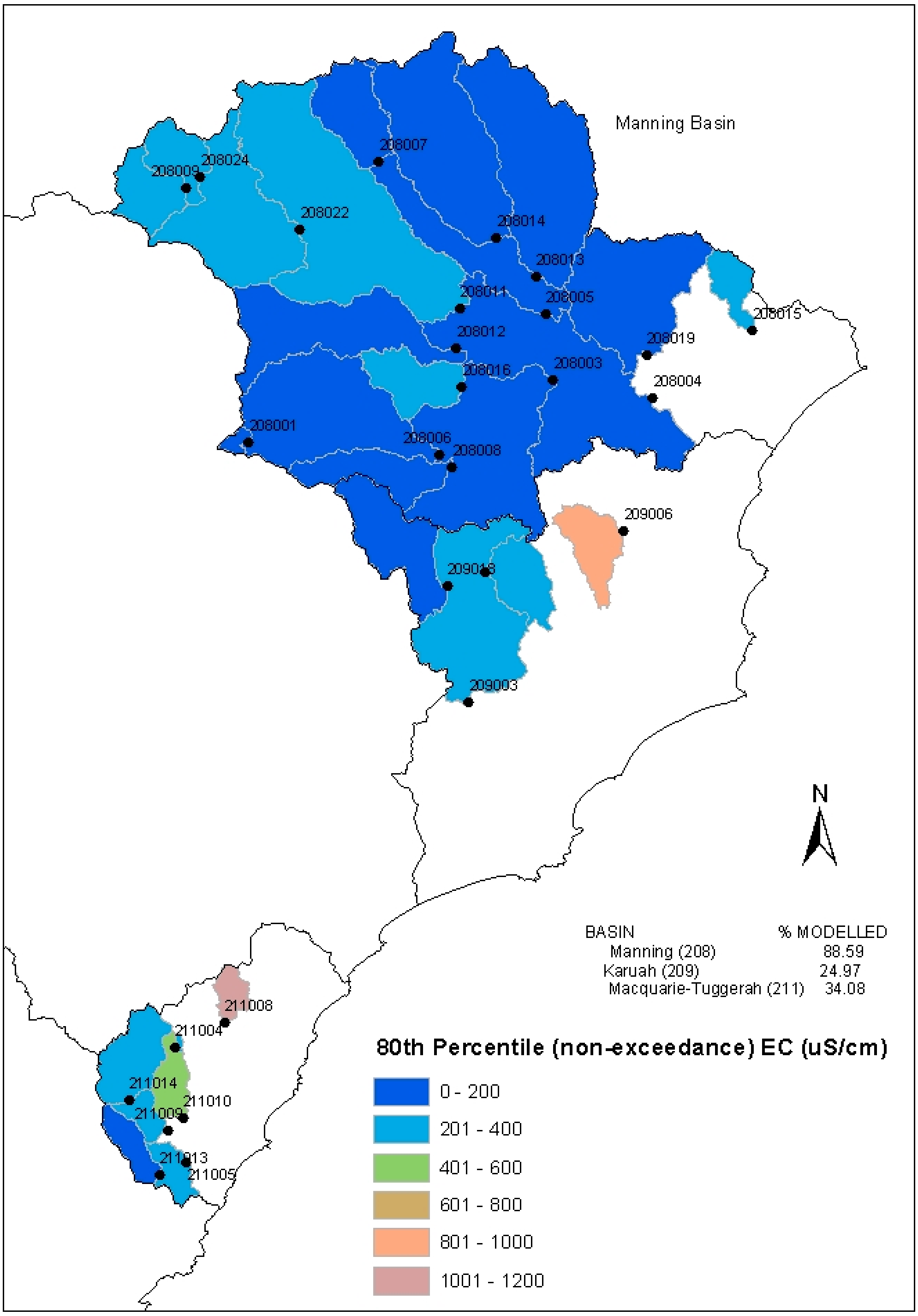


Figure 6. Median salinity range (EC) for stochastically modelled catchments in Sydney South Coast river basins

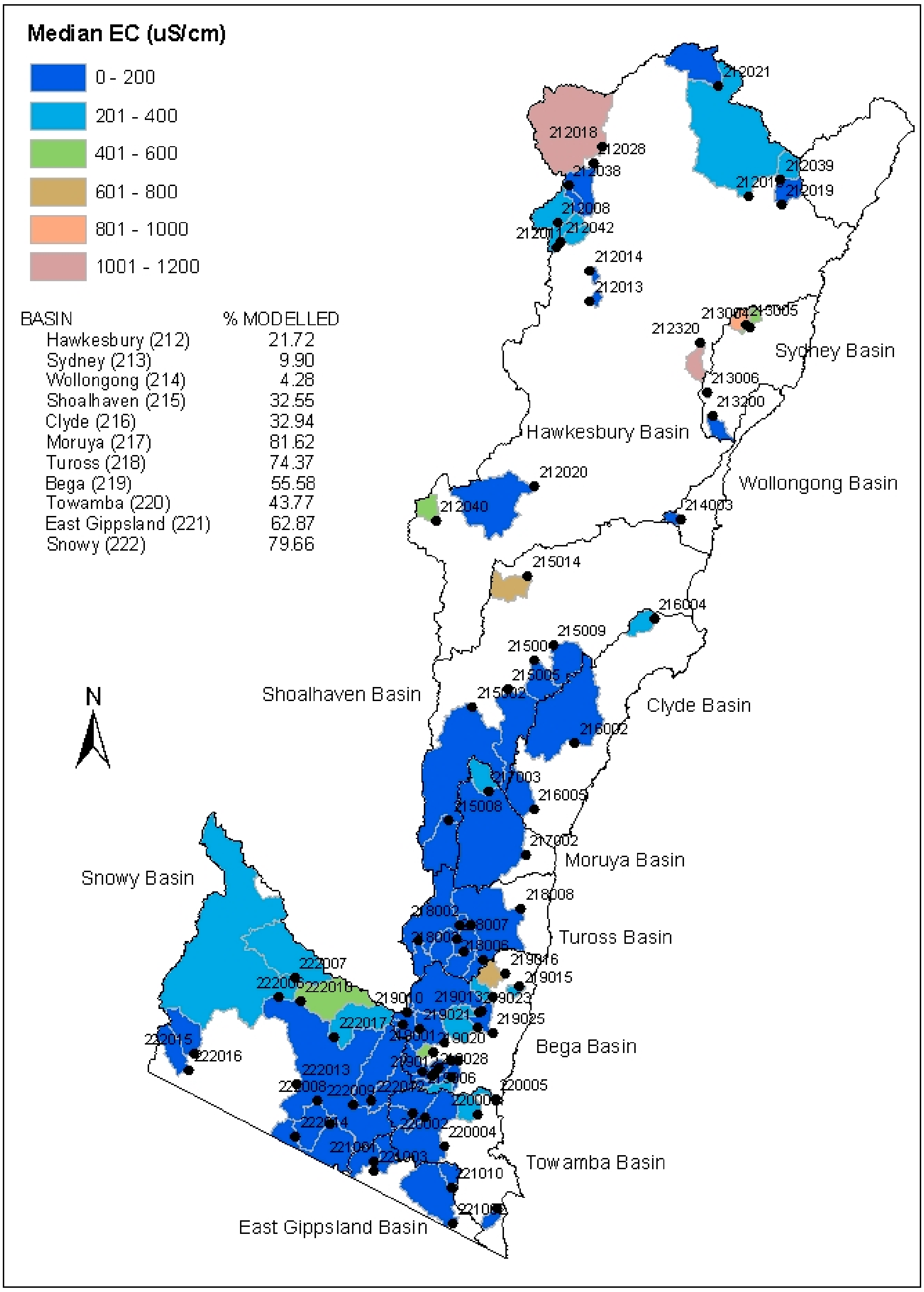
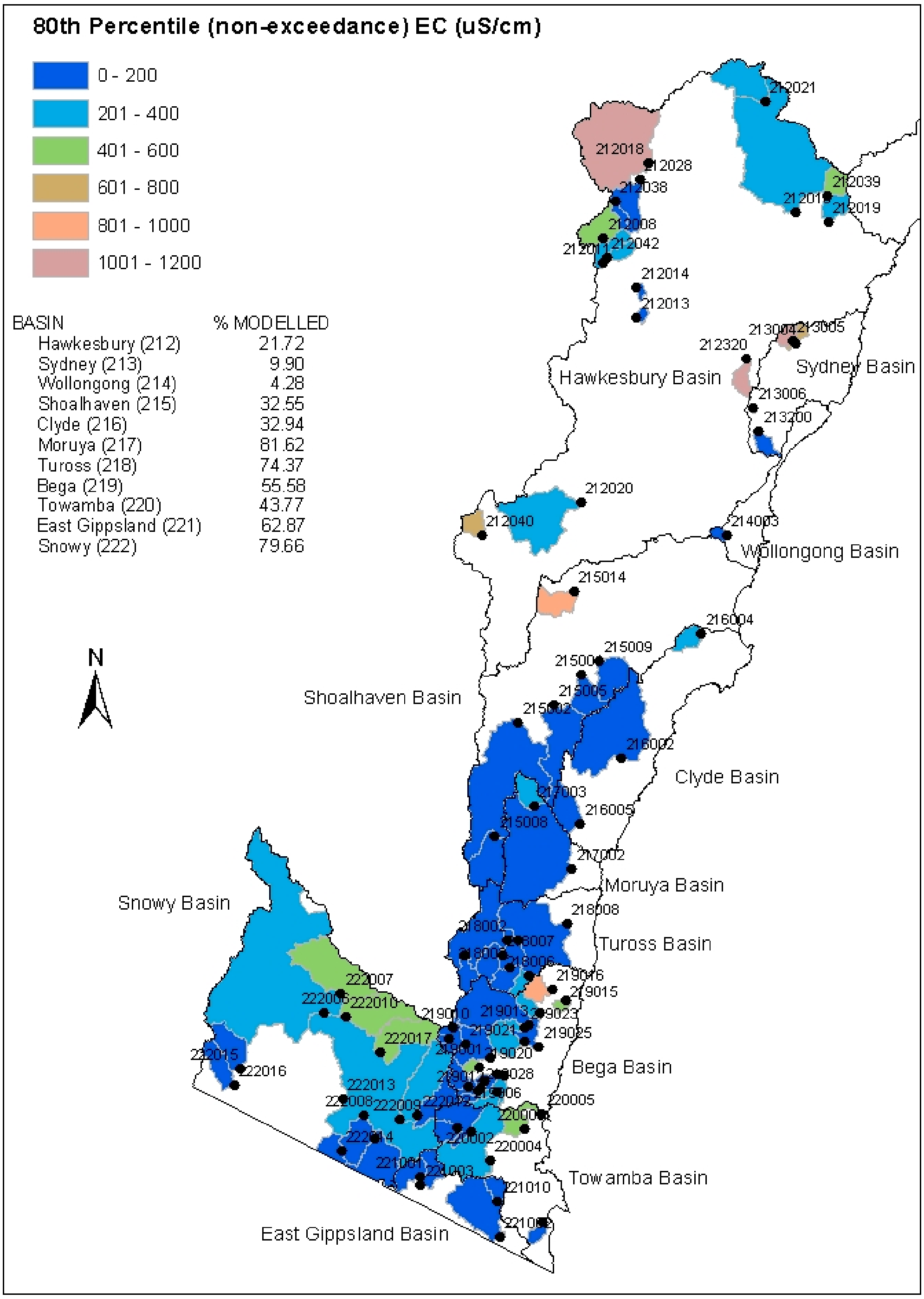


Figure 7. 80th percentile (non-exceedance) salinity range (EC) for stochastically modelled catchments in Sydney South Coast river basins



4.2 INSTREAM SALT LOAD

Appendices 1 to 20 report average annual salt load ($t.yr^{-1}$) for stations in each basin (e.g. Table 8, Appendix 2) and average annual salt load per unit source area ($t.\ km^2.y^{-1}$) for stations in each basin (e.g. Figure 22, Appendix 2). These give an indication of the relative contribution of the drained areas as a salt source. However, for each basin, years with missing days were excluded from the analysis and stations vary in the time period for which data was available. Therefore, the averages reported will not be directly comparable if they represent the outcomes of different climatic periods. The number of full years for which annual statistics were compiled and the period of record are given in Appendices 1 to 20 (e.g. Table 8, Appendix 2).

Appendices 1 to 20 include tables showing the proportion of each land-use category (woody, crop/pasture or other) for each of the tributary catchments modelled for salinity and salt load by basin. The land-use of the area not included in the stream analysis is also shown as the last entry in the table (e.g. Table 9, Appendix 2). There was no consistent relationship between land-use and salt load from the catchments modelled indicating that other factors such as geology, topography and climate are much more significant determinants of relative salt export and stream salinity.

4.3 SUMMARY OF REGIONAL GROUNDWATER SALINITY INFORMATION

The location of groundwater bores in the North Coast, Hunter and Sydney South Coast basins respectively are shown in Figures 8 to 10 and highlight the large areas for which there was no data. Groundwater salinity EC ($\mu S.cm^{-1}$) from the TRITON bore data was apportioned to geology and maps for the North Coast, Hunter and Sydney South Coast catchments respectively, and is presented in Figures 11 to 13.

4.3.1. North Coast basins

Tweed basin

High salt load (60 $t.km^{-2}.y^{-1}$) drains an area with at least one geology of apparently moderate groundwater salinity (800–3000 $\mu S.cm^{-1}$).

Brunswick basin

High stream salt load (50 $t.km^{-2}.y^{-1}$) drains an area with apparently fresh groundwater (48–350 $\mu S.cm^{-1}$).

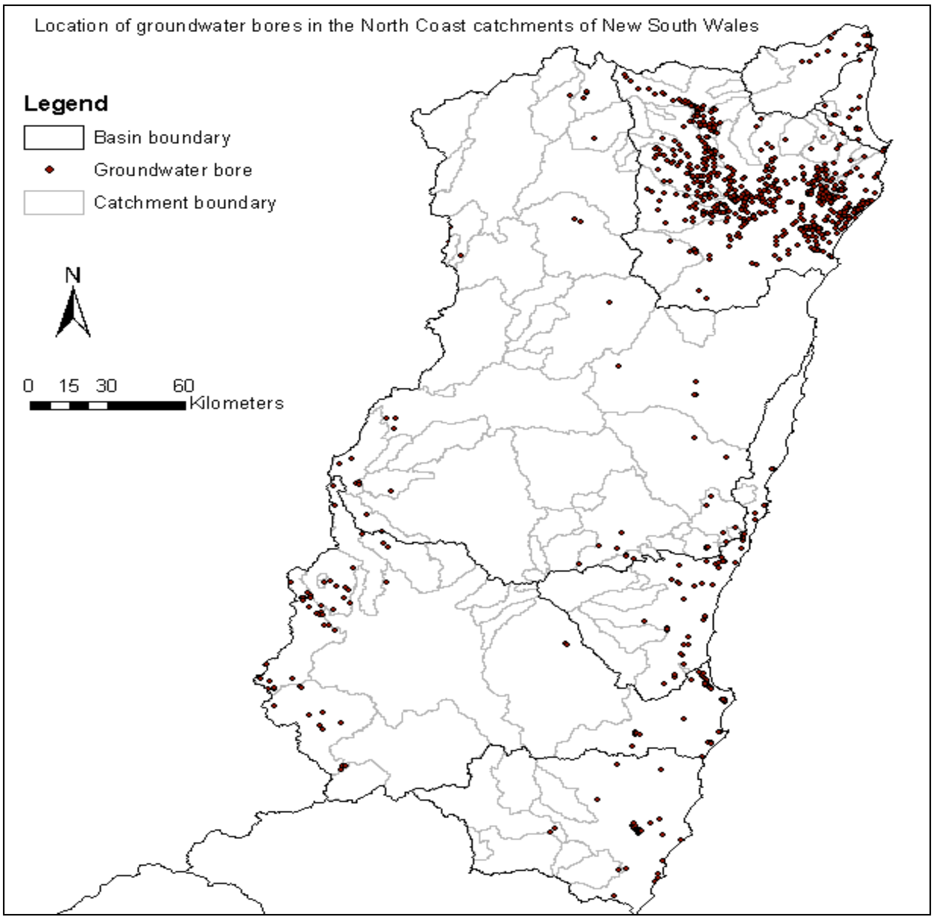
Richmond basin

Many streams in this basin show high salt loads (> 20 $t.km^{-2}.y^{-1}$) corresponding to geologies with moderate to high groundwater salinities (Figure 24). Shannon Brook above Yorklea produces 69 $t.km^{-2}.y^{-1}$ and was one of the few streams classed as having a water quality problem from this analysis. It drains an area dominated by geology with an apparent groundwater salinity of 3000–5500 $\mu S.cm^{-1}$. The Richmond River above Casino produces 24 $t.km^{-2}.y^{-1}$ draining geologies in the 800–3000 $\mu S.cm^{-1}$ and 3000–5500 $\mu S.cm^{-1}$ ranges. The Richmond River above Wiangaree delivers 54 $t.km^{-2}.y^{-1}$ from an area dominated by geology with groundwater salinity of 3000–5500 $\mu S.cm^{-1}$. However, the Wilson River above Eltham drains an area dominated by geology with apparently fresh groundwater (48–350 $\mu S.cm^{-1}$) but traverses minor areas of moderate salinity (800–3,000 $\mu S.cm^{-1}$). It produces 51 $t.km^{-2}.y^{-1}$ in salt load indicating that minor geological components can dominate stream salt load. A similar case was found for Terania Creek above Keerong and the Leycester River above Rock Valley.

Clarence basin

For most of the Clarence basin there was no groundwater salinity / geology information (Figure 28). High salt loads in the Tooloom Creek (204050), Washpool Creek (204054), Peacock Creek (204043) and Gorge Creek (204044) correspond with geologies of moderate to high groundwater salinities. However, other catchments exporting high levels of salt such as the Orara River have no corresponding groundwater salinity data. Hazard areas identified in the hazard mapping process mainly correspond to areas where there was no data except for the area immediately around Grafton where very high (5500–7100 $\mu S.cm^{-1}$) and extreme (7,100–26,000 $\mu S.cm^{-1}$) groundwater salinities are assigned to the geology.

Figure 8. Location of groundwater bores for North Coast catchments



In this case hazard was more likely to be associated with acid sulfate soils landscapes than the features normally described as dryland salinity. Although the two forms do exist side by side, dryland salinity as such is of little consequence by comparison with the magnitude of the acid sulfate soil / flood plain system problem in this area.

Bellinger basin

Groundwater salinities for the Bellinger basin (Figure 32) appear for the most part to be fresh (48–350 $\mu S.cm^{-1}$) to slightly saline (350–800 $\mu S.cm^{-1}$) although all streams analysed export 20 $t.km^{-2}.y^{-1}$ or more salt load. Very high loads coming from the Nambucca River above Bowraville (91 $t.km^{-2}.y^{-1}$) are associated with apparently fresh groundwater while Warrell Creek also has high salt loads (44 $t.km^{-2}.y^{-1}$) draining an area including a geology of moderate groundwater salinity (800–3000 $\mu S.cm^{-1}$). The resolution of the groundwater salinity data must therefore be in question.

Macleay basin

For most of the Macleay basin there was no groundwater/geology data (Figure 36). Of the streams analysed in this basin, only Serpentine Creek carried a salt load greater than 20 $t.km^{-2}.y^{-1}$. This was from an area with no groundwater salinity data. The area in the headwaters of the catchment near Armidale show slightly elevated levels of stream salinity as compared to the remainder of the catchment, but carry only relatively low to moderate salt loads from a geological area shown as having moderate groundwater salinities.

Hastings basin

There was no extrapolated groundwater salinity data for most of this basin (Figure 40).

4.3.2. Hunter basins

Manning basin

Most of the Manning basin has no groundwater salinity data (Figure 44). Stream salinities overall are low but the majority of the tributaries carry relatively high salt loads.

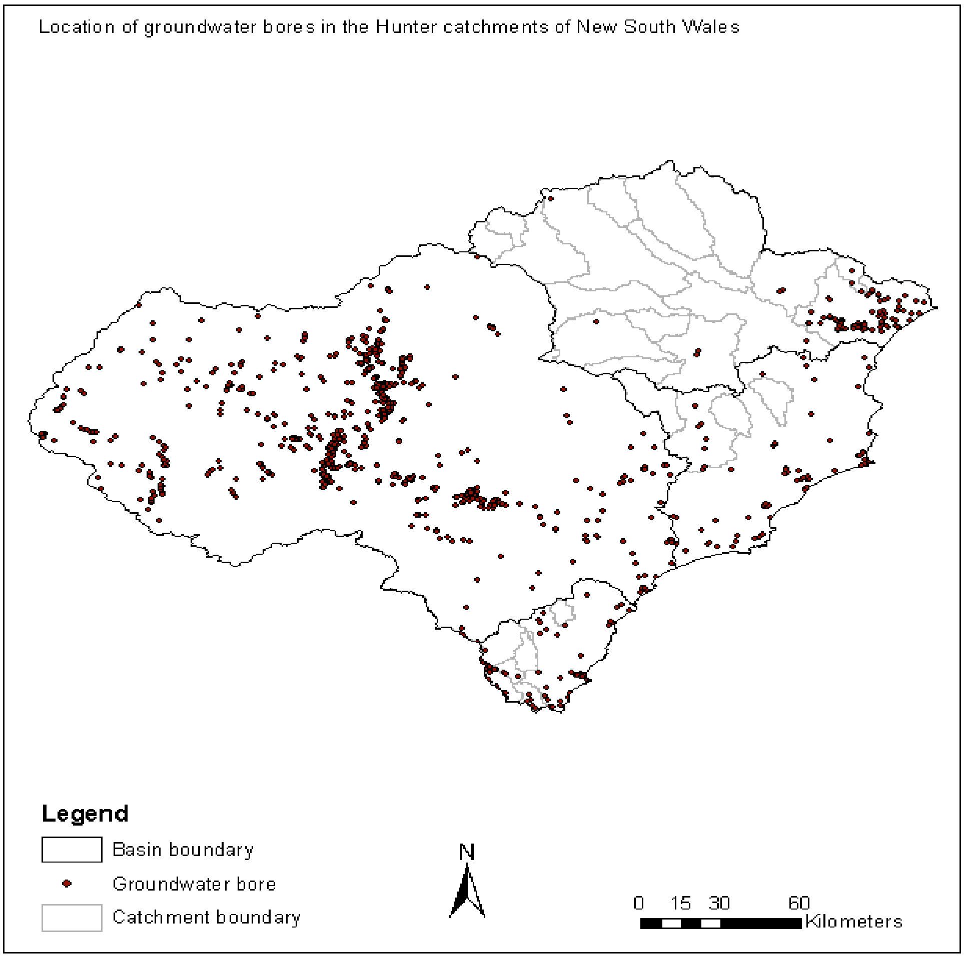
Karuah basin

The availability of groundwater salinity data was patchy in this basin and absent for most of its area (Figure 48). All streams analysed had relatively high salt loads (20–31 $t.km^{-2}.y^{-1}$). The Wang Wauk River above Willina drains an area with no groundwater salinity data but was one of the few streams with a water quality issue (80th percentile salinity > 800 $\mu S.cm^{-1}$) and exports 31 $t.km^{-2}.y^{-1}$. Hazard areas identified in this basin, particularly between Nabiac and Taree, are more representative of acid sulfate soil landscapes than dryland salinity per se, and are underlain by groundwaters of moderate to high salinity.

Lake Macquarie and Tuggerah Lake basin

Most of this catchment is underlain by geology of apparently moderate groundwater salinity (Figure 52). All streams analysed drain this area. Cox's Creek above Bathurst Rd exceeds 1000 $\mu S.cm^{-1}$ for 20% of the time and carries 59 $t.km^{-2}.y^{-1}$. The remaining streams, although generally fresh, also carry high to very high salt loads (18–57 $t.km^{-2}.y^{-1}$). No hazard was identified, however, for this basin.

Figure 9. Location of groundwater bores for Hunter catchments



4.3.3. Sydney South Coast basins

Hawkesbury basin

Only approximately 22% of this basin was modelled in the stream analysis. For most of the basin, extrapolated groundwater salinity/geology information is available (Figure 56). Higher salinity (3000–5500 µS.cm^{-1}) groundwater underlies areas in western Sydney, the Capertee valley and near Goulburn and these areas were highlighted by the hazard methodology. These geologies also correspond with high median stream salinities and relatively high salt loads in the Capertee River (1300 EC and 23 t.km^{-2}.y^{-1}) and South Creek (1200 µS.cm^{-1} and 28 t.km^{-2}.y^{-1}). The remaining streams modelled mostly drain areas with low groundwater salinities (800–3000 µS.cm^{-1}) but generally have low to moderate salt loads (3–19 t.km^{-2}.y^{-1}) and are generally fresh.

Sydney basin

Figure 60 shows the central and western parts of the Sydney basin are underlain by geology of high groundwater salinity (3000–5500 µS.cm^{-1}) corresponding to areas of high hazard. Very high to extreme salt loads are associated with Fishers Ghost Creek, Toongabbie Creek and the estuarine Parramatta River draining this geology (72, 181 and 129 t.km^{-2}.y^{-1} respectively). Toongabbie Creek also has a median salinity greater than 800 µS.cm^{-1}. Moderate groundwater salinities are located in the southern portion of the basin where O'Hare Creek produces 20 $t.km^{-2}.y^{-1}$ but no hazard was highlighted by the hazard methodology.

Wollongong basin

Groundwater salinity data was only extrapolated for approximately half of this basin (Figure 64). The hazard methodology did not predict any salinity hazard in this basin. However, moderately saline (800–3000 $\mu S.cm^{-1}$) and highly saline (3000–5500 $\mu S.cm^{-1}$) groundwater dominates. Only one stream (Macquarie Rivulet) occupying approximately 4% of the basin was covered by the stream analysis. This stream produces 32 $t.km^{-2}.y^{-1}$ salt load from a part of the catchment apparently underlain at least in part by geology with moderate groundwater salinity.

Shoalhaven basin

The availability of groundwater salinity data was patchy in this basin and absent for the majority of its area (Figure 68). Areas of high salinity groundwater are noted in the headwaters east of Lake Bathurst and south of Nowra. Stream analysis in the Shoalhaven was limited to headwater streams where for the most part no groundwater salinity data was extrapolated. Bungonia Creek has 80th percentile (non-exceedance) stream salinity greater than 800 $\mu S.cm^{-1}$ but exports only 11 $t.km^{-2}.y^{-1}$ in salt load from an area with apparently moderate groundwater salinity (800–3000 $\mu S.cm^{-1}$). The fresh Mongarlowe River carries 26 $t.km^{-2}.y^{-1}$ salt load from an area with no extrapolated groundwater salinity. Dryland salinity in this catchment was only minimally predicted by the hazard mapping process but known salinity outbreaks have been mapped for this area. By contrast, the Shoalhaven catchment above Kado produces 13 $t.km^{-2}.y^{-1}$ salt load. Large areas of high hazard were identified for this area where only small outbreaks are currently known.

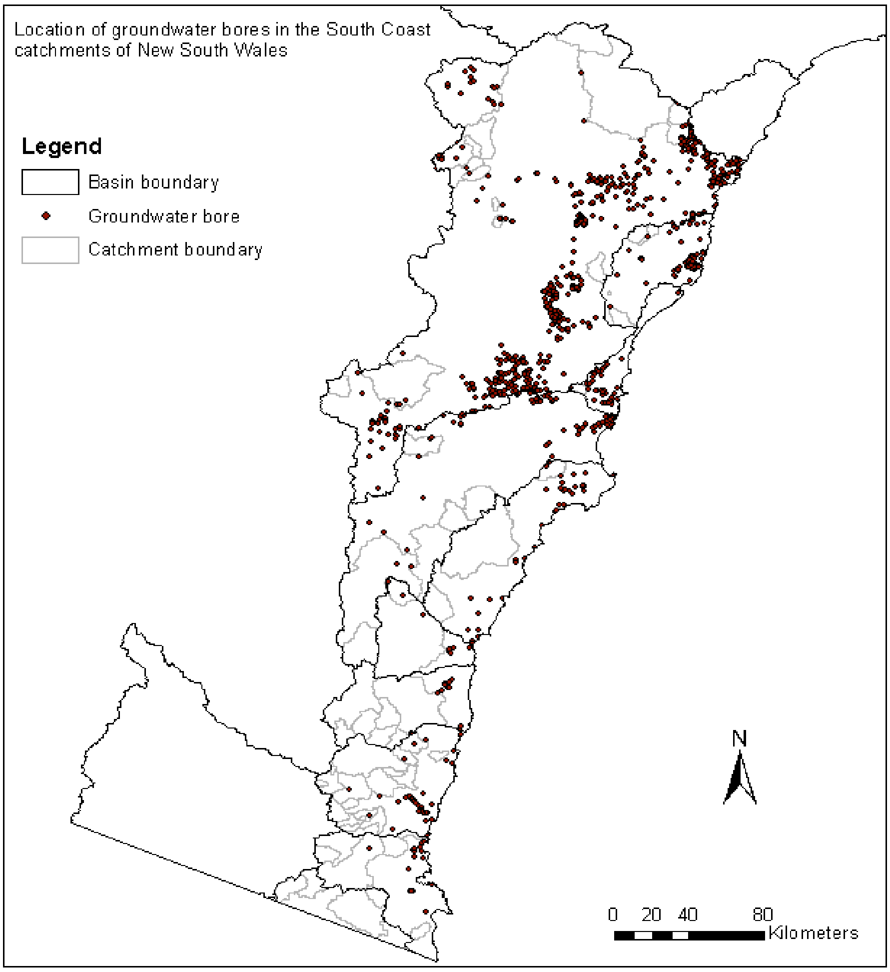
Clyde basin

Streams analysed in the Clyde basin occupy only 33% of the basin. However, they mainly drain areas with moderate extrapolated groundwater salinity of 800–3000 $\mu S.cm^{-1}$ (Figure 72) and produce salt loads of 22–37 $t.km^{-2}.y^{-1}$. Small areas of high hazard were identified for these streams but there was no current evidence of salt outbreaks.

Moruya basin

Approximately 82% of the basin has been analysed for salt load in two streams, both carrying 22 $t.km^{-2}.y^{-1}$. Figure 76 shows that only a very small part of this area has extrapolated groundwater salinity data with high values (3000–5500 $\mu S.cm^{-1}$). A small area of very high extrapolated groundwater salinity (5500–7100 $\mu S.cm^{-1}$) was located in the lower catchment outside the stream analysis area but this is not apparently associated with any identified hazard or any known outbreaks. Hazard was identified in the mid-basin but was discounted by expert opinion due to soil type (M. Talau pers. comm. 2002). The salt load analysis, however, suggests that the Deva River has significant salt stores.

Figure 10. Location of groundwater bores for the Sydney South Coast catchments



Tuross basin

Approximately 74% of the basin has been analysed for stream salt load. TheYowri River and Wandella Creek carry 19 and 17 $t.km^{-2}.y^{-1}$ respectively while the remaining tributaries carry 9–11 $t.km^{-2}.y^{-1}$. This area partially coincides with extrapolated groundwater salinities (Figure 80). The majority of hazard identified for this basin also coincides with this area of apparent high salinity groundwater. However, this high hazard zone was discounted (M. Talau pers. comm. 2002) due to soil type and lack of physical evidence of outbreaks.

Bega basin

Ten of the tributaries analysed for salt load in this basin export from 20–30 $t.km^{-2}.y^{-1}$. Extrapolated groundwater salinity data is available for only about 60% of the basin (Figure 84). Of the area covered by the stream analysis, only approximately half has corresponding groundwater information. The groundwater salinities were predominantly of moderate salinity but these also drain areas underlain by apparently low salinity groundwater where the Tantawangalo River salt loads are 20 $t.km^{-2}.y^{-1}$. In the northern part of the basin, geology with high salinity groundwater (3000–5500 $\mu S.cm^{-1}$) is drained by Nutleys Creek, which produces 16 $t.km^{-2}.y^{-1}$. The nearby Narira River drains an area underlain by geology of only moderate groundwater salinity but produces 30 $t.km^{-2}.y^{-1}$ salt load. The Narira River was also one of the few streams where salinity exceeds 800 $\mu S.cm^{-1}$ during low flows.

Towamba basin

Several streams analysed in this basin have high to very high salt loads. Merimbula Creek at Merimbula produces 75 $t.km^{-2}.y^{-1}$ salt load from an area apparently underlain by groundwater with low salinity. Merrica Creek at Nadgee produces 33 $t.km^{-2}.y^{-1}$ salt load from an area with no groundwater data. An increase in salt load in the Towamba River between New Building Bridge and Towamba corresponds with high groundwater salinity (3000–5500 $\mu S.cm^{-1}$) in the Myrtle Creek catchment. Quite extensive areas of hazard were identified for the Pambula River which produces 19 $t.km^{-2}.y^{-1}$ salt load, but draining an area of apparently low groundwater salinity. Hazard was also identified in the Merimbula Creek and Merrica River.

East Gippsland basin

There was no extrapolated groundwater salinity data for this basin. Streams analysed in the basin produce from 9–13 $t.km^{-2}.y^{-1}$ salt load. Only small patches of high hazard were identified, mainly in the Genoa River catchment, which produces 9 $t.km^{-2}.y^{-1}$ salt load.

Snowy basin

There was no extrapolated groundwater salinity data for the majority of this basin. Very little hazard at all was identified for the basin. Salt loads in the Snowy basin streams range from very low (3 $t.km^{-2}.y^{-1}$) to moderate (15 $t.km^{-2}.y^{-1}$).

Figure 11. North Coast catchments EC from TRITON bore data apportioned to geology

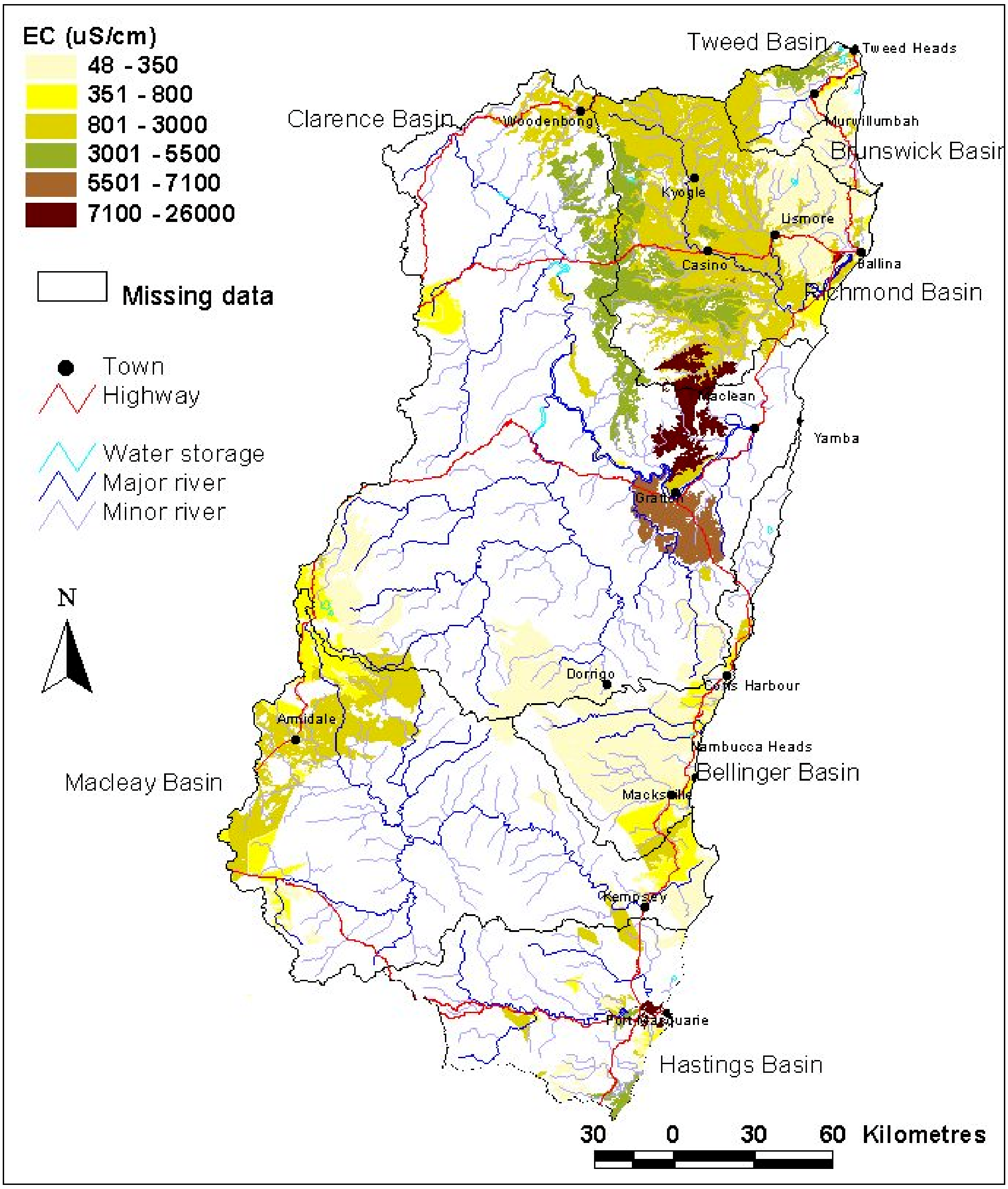


Figure 12. Hunter catchments EC from TRITON bore data apportioned to geology

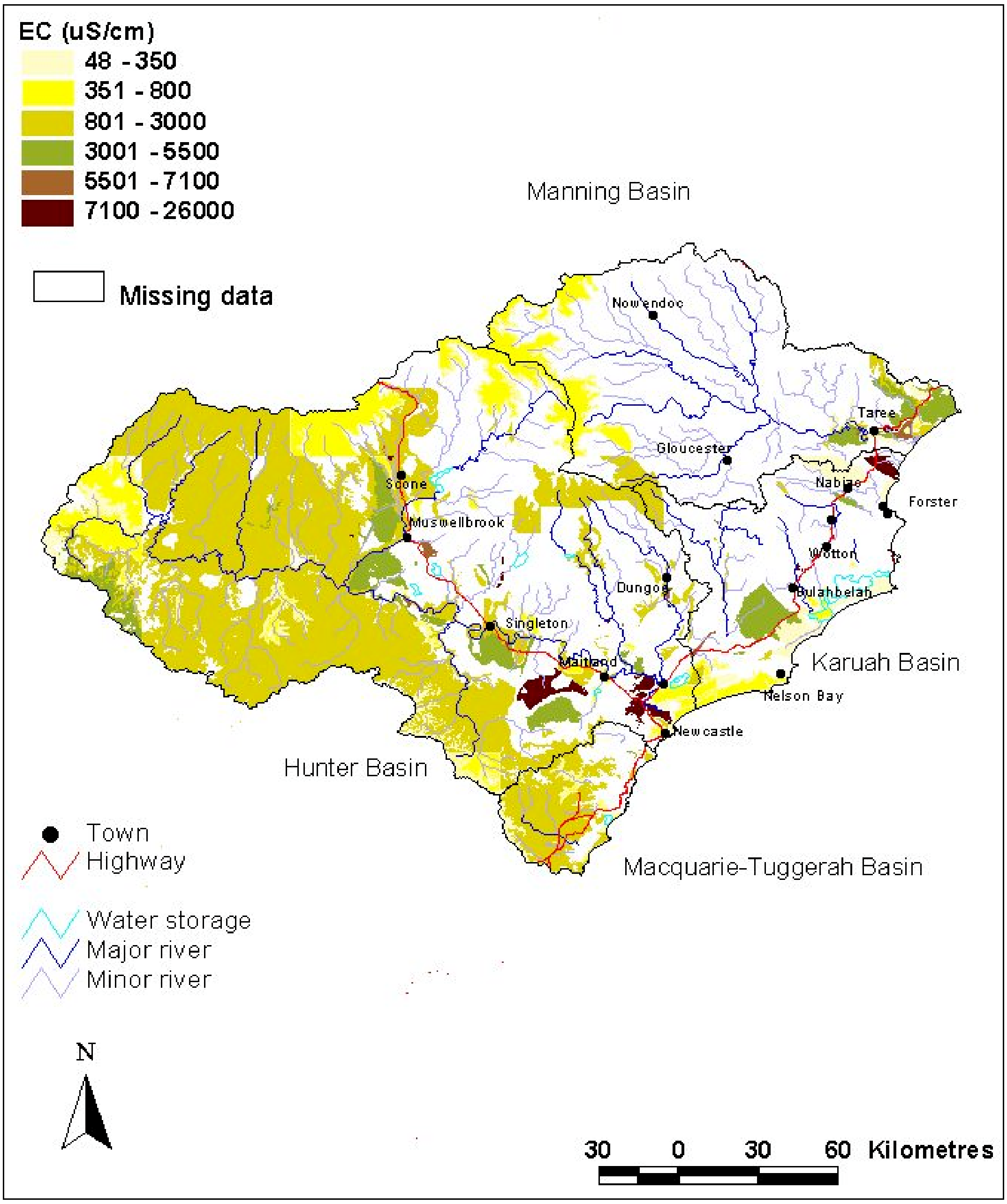
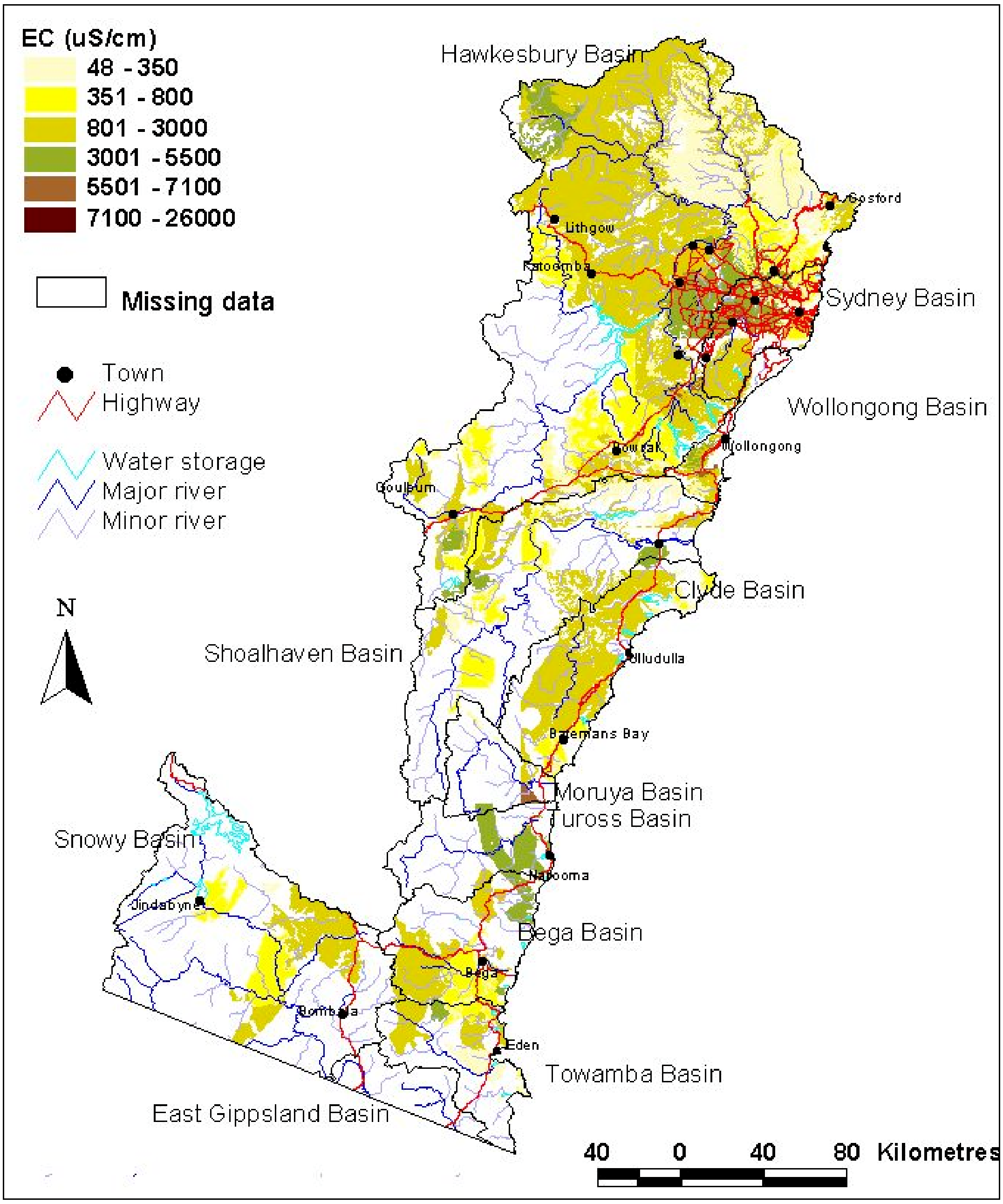


Figure 13. Sydney South Coast catchments EC from TRITON bore data apportioned to geology



5. Discussion of coastal salinity

Differences in structural features of coastal catchments compared to inland catchments of the Murray-Darling Basin result in different salinity processes in terms of both physical processes and interaction with human development.

Drainage patterns are generally different, often with large hydraulic gradients and short flow paths due to topography and proximity to the sea, although considerable variation was apparent between basins (Appendix 21).

- Land-use is generally dominated by vegetation in rural hinterland areas while urbanisation and industrial development are more prominent and concentrated on the coastal strip. Industrial and urban development may increase the salt load generated from the tributary catchments examined in this audit more so than rural land-uses. However, overall there was no consistent relationship between land-use and salinity demonstrated in this audit. This indicates that other factors such as geology, topography and climate are currently much more significant determinants of relative salt export and stream salinity. These factors, plus proximity to the coast, influence source-sink relationships in the deposition, wash off and storage of cyclic salt in the landscape.
- Significant areas of the coast are formed over geologies of marine and estuarine origin, which contain high levels of connate salt.
- Cumulative salt loads in stream networks are often less significant than the stream salinity within a particular reach, particularly in an estuarine environment. The scale of the effects on downstream users is not comparable with those experienced in the Murray-Darling Basin.
- On the coastal zone, infrastructure associated with urbanisation rather than agricultural production was generally more economically important. This has a significant impact on any economic analysis of salinity in coastal regions.
- Acid sulfate soils, which represent a particular form of salinisation, occur more widely on the coast than on inland areas.
- Parna (wind blown clay soil deposits derived from Australia's salty interior) are a major source of salt in the Murray-Darling Basin but are rare on the coast, although there may be some intermixing around the main Snowy Range (Chapman pers. comm. 2002). On the other hand, distance from the coastline and its impact on rates of cyclic salt deposition, was a consideration for coastal catchments. Sodium deposition rates of more than 45 $kg.ha^{-1}.yr^{-1}$ have been noted on the far Sydney south coast, 20–25 $kg.ha^{-1}.yr^{-1}$ 20 km inland, and less than 15 $kg.ha^{-1}.yr^{-1}$ 50 km inland (Turner, 1996).

5.1 SALT LOADS

As previously noted, care was taken to ensure that the range of modelled EC was consistent with the observed range.

High salt load values do not necessarily constitute an environmental or social problem for the coast except where salt may accumulate and result in damage to the environment and infrastructure. For example the Goulburn River above Sandy Hollow (6817 km^2) in the Hunter catchment was considered to be a catchment with a salinity problem. This catchment contains coal mines and contributes nearly one third of all the salt in the Hunter River. However, the salt load from the Goulburn River is less than that produced by the nearby Manning River at Killawarra (6618 km^2) which is considered a non-saline catchment. Salt loads in the Goulburn and Manning Rivers were 50600 $t.yr^{-1}$ vs 59400 $t.yr^{-1}$ or 7.4 $t.km^{-2}.y^{-1}$ vs 9 $t.km^{-2}.y^{-1}$ respectively.

Salt load accumulation in stormwater detention structures, constructed wetlands and urban flood control structures, in western Sydney has the potential to be serious. The salt load generated per unit area is greater than 180 $t.km^{-2}.y^{-1}$, approximately six times the generation rate calculated for the worst catchments in the Murray-Darling Basin.

5.2 STREAM SALINITY IMPACTS

In other audits, threshold salinity values of 800 and 1600 $\mu S.cm^{-1}$ have been used as benchmarks for water quality and environmental impacts of salinity. A value of 1600 $\mu S.cm^{-1}$ was used in other audits where it was treated as a threshold for aquatic ecosystem damage. However, there is increasing evidence that small changes in stream salinity can have different effects on aquatic ecosystem health depending on the species. Nielsen and Brock (2002) examined salinity thresholds for ecosystem health and found that although toxic effects on aquatic plant recruitment are marked at 1600 $\mu S.cm^{-1}$, some species will be affected at salinities lower than this.

Of the 193 streams analysed in this audit only three have historic median salinities above 800 $\mu S.cm^{-1}$. These are Capertee River, South Creek and Toongabbie Creek. Eight streams have 80th percentile salinities above this threshold and two, the Capertee River and South Creek in the Hawkesbury basin have 80th percentile salinities of 1650 $\mu S.cm^{-1}$ and 1584 $\mu S.cm^{-1}$ respectively.

5.3 GROUNDWATER SALINITY

The analysis of groundwater salinity was carried out to assess availability of data and to evaluate the outcomes of the hazard mapping process. Average bore salinities were assigned to geology polygons of the 1:250 000 map sheets by location only. Bore stratigraphy could not be assessed for a more accurate examination of the data. The outcome of this analysis is shown in Figures 8 to 10. Individual maps for each basin are included in Appendices 1 to 20. This was an extrapolation exercise using scant data and should be interpreted with care when drawing conclusions from these results.

The first observation of note was that a large proportion of the area has no data. There are also edge-matching problems with the geology polygons themselves. However, where areas are shown with relatively high groundwater salinity, they do often correspond well with salt load and salinity data from the stream analysis (e.g. 203041 Shannon Brook in the Richmond).

Some areas such as the highly saline groundwater areas around Grafton may be artificially high due to association with acid sulfate soil landscapes. Bore data from highly saline acid sulfate soil landscapes may be lumped into a broader geology at this resolution. However, salinity outbreaks are known to occur here in close proximity to acid sulfate soils.

On the South Coast moderate to high groundwater salinities (3000–5500 $\mu S.cm^{-1}$) correspond well with areas of known salinity outbreaks and areas highlighted on the draft hazard map for the upper Shoalhaven, western Sydney, and the Capertee catchment in the Upper Hawkesbury basin. Similar groundwater salinities in the Tuross, Moruya and Bega basins correspond with areas predicted by the hazard mapping. However, expert opinion based on soil landscape mapping seems to discount these areas due to lack of evidence of soil salting (M. Talau pers. comm. 2002).

5.4 LAND USE ON THE COASTAL ZONE

The woody classification on the coast is primarily native forest and the classification of crops and pastures can be considered as pasture in most cases as there is very little cropping. Consultation with agronomists on the coast confirms that coastal pastures are basically summer growing deep-rooted perennial species that can be either native or exotic. Only relatively insignificant areas are sown to ryegrass style pastures for winter forage by dairy farmers. Although many of the summer growing pastures are inherently poor for agricultural production, they are hydrologically efficient users of water and represent a low potential for groundwater recharge. The small amount of cropping on the North Coast is mainly sugar farming located in areas of low salinity risk and represents a low risk land-use from a salinity point of view.

5.5 SULFIDE SLUDGES

The production of sulfide sludges associated with landscape salinisation and the benthic break down of organic matter can produce dramatic impacts in streams and rivers by de-oxygenation of the water during high flow events. Although stream salinity is lowest during these high flows, run-off from saline seeps and drains involving sulfides can strip oxygen from the water. This process has caused massive fish kills in coastal rivers, particularly where linked with the drainage of acid sulfate soils. Most acid sulfate soil landscapes mapped on the coast are confined to low lying Holocene sedimentary deposits. Older Pleistocene deposits, which may also potentially contribute sulfate salts, occur at higher elevations in some of these coastal catchments (R. Bush pers. comm. 2002). These processes are particularly important where drainage treatments are considered as a part of urban or agricultural development or flood mitigation schemes. The conventional approach to reclaiming dryland salinity sites involves reducing recharge to dry them out; however, sites where acid sulfate processes are involved should be maintained wet.

Many dryland salinity sites are essentially degraded wetlands with a naturally occurring high watertable. Very little is known regarding salt transport processes from these degraded sites into the stream or the ecological effects of different salt wash off products, such as sulphide sludges.

5.6 INFRASTRUCTURE DEVELOPMENT IN HAZARD ZONES ON THE COAST

Land and stream salinisation in coastal areas is primarily caused by infrastructure development in high salinity hazard zones. The placement of inappropriate or poorly designed infrastructure in these zones disturbs the water cycle and salt balance mobilising salt stores. The Manning – Hunter region and western Sydney are extreme examples on the NSW coast. Large-scale power generation and coal mining infrastructure in the Hunter and the industrial and urban infrastructure development of western Sydney interact with an inherently saline landscape. Urbanisation of the western Sydney area and mining in the Hunter will continue due to demographic pressure, therefore the economic effects of salt impact on infrastructure are likely to be substantial.

6. Conclusions and recommendations

The literature review for the coastal zone highlighted that stream salinity is not currently a major problem in coastal NSW. The high level of forested area on the coast compared with the predominantly cleared regions studied in the Murray-Darling Basin and Hunter audits would largely account for this. The higher rainfall levels in coastal environments also reduce the likelihood of salinisation in the coastal zone. The literature review collated a number of disparate studies and provides a more comprehensive summary of the salinity issue in the coastal zone. The review highlighted the need for systematic long term monitoring on the coast to enable a robust assessment of salinity. One of the crucial differences between this audit and previous audits of the Murray-Darling Basin and Hunter Valley is the lack of baseline groundwater and stream data in the coastal regions.

Draft salinity hazard maps were developed to highlight areas that are predisposed to salinisation because of their physical characteristics and to provide a basis for prioritising and locating salinity actions within and between basins. However, there were a number of problems with input data, including resolution incompatibilities in some data layers. The salt outbreak maps used as the primary evidence layer were also incomplete. Other significant data sets, such as groundwater vulnerability mapping, were not uniformly available for all of the coastal area and could therefore not be used. This audit highlighted significant problems with primary datasets (see Appendix 22). Evaluation of the draft salinity hazard maps by regional staff found they did not satisfactorily identify salinity hazard. For this reason the draft maps are not included in this report. The topographic FLAG wetness maps are included in the appendices as these provide an objective measure of one contributing factor—topography. These maps give a clear indication of the likely locations of the wetness associated with salinity. However, a high FLAG Wetness index may also indicate a waterlogging hazard independent of salinity.

The important findings of this audit are that:

- median salinity values for most coastal rivers and tributaries are low
- stream salt loads are not currently a major threat in coastal regions
- agricultural practices currently present a low risk for stream salinisation across the coastal basins
- major salinity problems on the coast are associated with infrastructure in salinity hazard areas

Median salinity values for most coastal rivers and tributaries are low

Threshold salinity values of 800 µS.cm^{-1} and 1,600 µS.cm^{-1} were used in previous audits as benchmarks for water quality assessment. They represent the maximum desirable drinking water standard set by the World Health Organisation for human consumption (800 µS.cm^{-1}) and a threshold at which adverse environmental changes can be expected (1,600 µS.cm^{-1}). Predictions of possible changes to the current salinity regime were not feasible and therefore the environmental effects of such a stress could not be assessed. In general, though, the 800 µS.cm^{-1} threshold was exceeded in a very few tributaries on the coast and the higher threshold was approached by South Creek and exceeded only in the Capertee River in the Hawkesbury basin during low flow (80th percentile salinity).

For the 193 streams analysed in this audit only 15, had median ECs greater than 400 µS.cm^{-1} and only 4 were greater than 800 µS.cm^{-1}. The World Health Organisation (WHO) standard for desirable water quality for human consumption is 800 µS.cm^{-1}. By comparison, all of the tributaries and mainstream reaches analysed in the Hunter audit (Beale et al. 2001) had median salinities greater than 400 µS.cm^{-1}. It should be noted that for a significant number of coastal catchments there were no data.

Irrigation of some sensitive (mainly horticultural) crops may cause leaf burn using sprinkler systems and water from streams that exceed 400 µS.cm^{-1} for significant periods of flow. However, the method of application (e.g. sprinkler or drip systems) is an important determinant of the risk.

Maps showing the location of all the tributary catchments colour coded for median and 80th percentile ranges are shown in figures 2 to 7 (chapter four). In the majority of cases analysed (92% of tributaries), water quality is good to excellent from a salinity point of view. In general, water quality is only considered poor where EC approaches or exceeds 800 µS.cm^{-1} for significant periods of time (median and 80th percentile).

Stream salt loads are not currently a major threat in coastal regions

Salt load is the mass of salt held in the water moving past a point in a stream. There is generally an inverse relationship between stream salinity and salt load. That is, the highest salt loads are associated with the lowest salt concentrations (salinity) during high flow events while the lowest salt loads are associated with the highest salinity during periods of low flow.

Many catchments on the coast show salt loads per unit of source area far in excess of similar sized catchments analysed in the Murray-Darling Basin and Hunter Valley audits (Beale et al. 2000 and Beale et al. 2001). However, salt loads in streams are generally considered a problem only where there is some downstream impact on infrastructure or where there is an accumulation in an important sink such as a wetland or irrigation district. For these reasons, salt load is not considered an environmental or social threat in coastal regions. High salt loads are, however, significant in highlighting the source of salt throughout the catchment indicating a risk that could otherwise be masked by high rainfall and flow or current land-use.

This indicates a potential risk in particular tributary catchments that may be mobilised if the land-use was significantly changed.

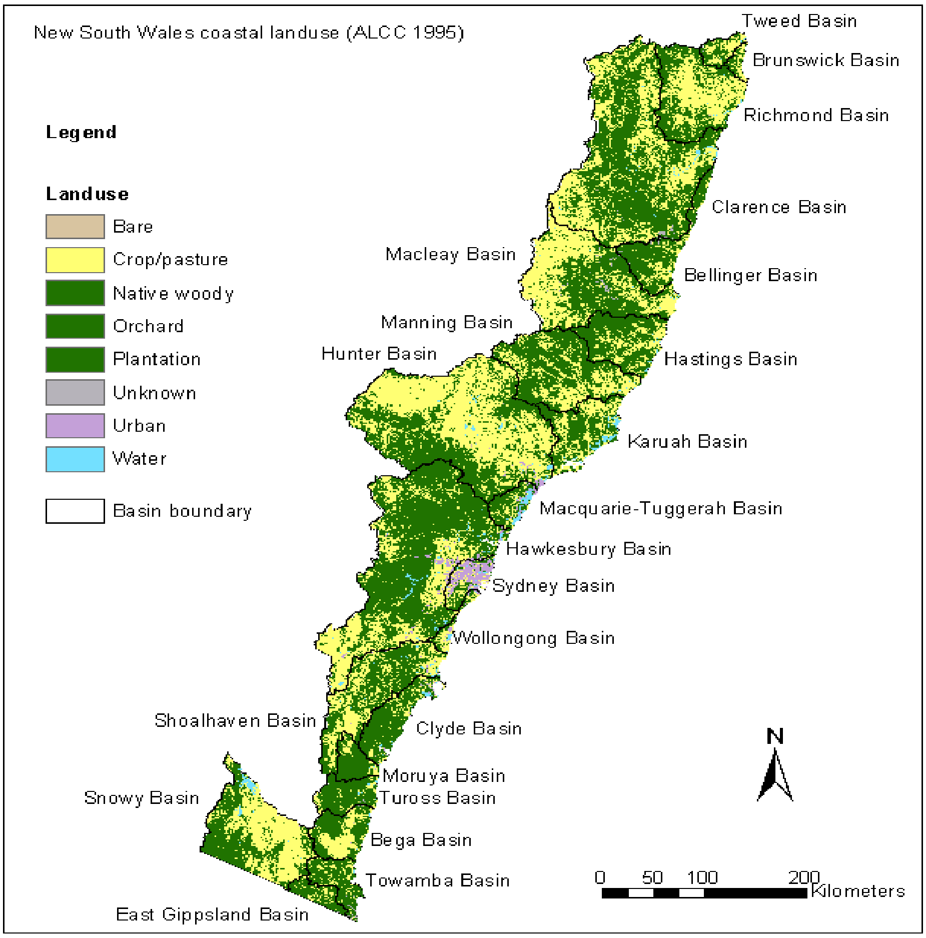
Agricultural practices currently present a low risk for stream salinisation across the coastal basins

The vegetation of the coastal catchments is dominated by evergreen forest (Figure 14). On the coast the primary use for cleared land is grazing. Either native or exotic deep-rooted perennial grasses dominate these pastures and the majority have significant proportions of summer active species. These summer active species tend to operate as the key functional group within a suite of species controlling the water balance. Given that the hydraulic characteristics of a catchment are set by its basic geomorphology, the three main factors influencing deep drainage below the root zone of the vegetation are:

- the timing and amount of rainfall
- the size and shape of the root system and how it develops over time
- how long the vegetation stays green in relation to evaporative demand, which is highest in summer.

Although many pastures are of low forage value and considered agriculturally poor, such as crab grass and whisky grass, they are functionally significant water users and therefore generally present a very low risk for salinity. Control of deep drainage mitigates against the development of secondary salting. Johnston (2003) using field experiments and modelling using the Meat Research Corporations Sustainable Grazing Systems Model (Johnson et al.2003) has shown that the loss of the summer active functional group of plants from a pasture has a far more significant detrimental effect on deep drainage than management factors such as fertility and grazing management. Management, however, is a factor in the sustainability of this functional group.

Figure 14. Over 50% of the NSW coastal region is forest



As a general statement, agriculture within the coastal region of NSW is not significantly affected by salinity. However, in some localised cases, particularly in the tablelands around Braidwood and Goulburn, salinity does occur in association with sheet, rill and gully erosion. In these cases it is management and degraded pastures that currently activate the salinity risk, land clearing having occurred many years previously. In these areas, salt and water dynamics could be reviewed and land-use and management improved.

The relative proportion of land-use by area, between the tributary catchments producing similar salt loads examined in this audit (even within individual basins) varies considerably. Therefore, other factors such as geology, topography and climate are currently much more significant determinants of relative salt export and stream salinity than land-use. The risk of salinisation by change in land-use is dependent upon the hazard set by these other determinants. In this study, no consistent relationship was found between land-use and salt load generated, between the tributary catchments.

Major salinity problems on the coast are associated with infrastructure in salinity hazard areas

In areas located over natural salt hazards, salinity problems may be of little consequence under current rural land-uses. However, as infrastructure is developed for urban or industrial activities (such as flood mitigation structures, buildings, roads and utility structures, constructed wetlands, sporting facilities, and recreational areas) there may be significant salinity impacts. Salinity is recognised as a problem in western Sydney with the potential to affect large areas of new development in the near future.

Urban salinity risks are also present in major rural townships such as Grafton and Goulburn. Expansion of coal mining in the Hunter also presents a significant challenge for stream salinity in some areas.

There is a need for appropriate conceptual models of:

- the natural processes of salt movement in the landscape
- the impact of risk factors (for example land-use change such as development of infrastructure) on the natural processes
- the impact of the modified landscape process on the infrastructure and environment.

These conceptual models are needed as a basis for planning, prevention, remedial treatment and actions for salinity management. Quantifying the scale of these impacts and the appropriate action is site and task specific. An urban runoff and drainage model capable of handling semi-rural and urban development scenarios for salt mobilisation and wash off could be incorporated into current departmental modelling frameworks.

Key recommendations

1. Base line spatial data sets such as the 1:25 000 scale geology and salt outbreak maps should be progressively upgraded.
2. Groundwater monitoring networks should be upgraded to provide coverage of significant groundwater flow systems and detailed conceptual models of the groundwater flow systems should be developed as a basis for infrastructure planning.

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Appendix 1. Tweed and Brunswick river basins

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Tweed and Brunswick river basins.

Stream salinity

Table 2. Stream salinity in the Tweed River basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
201001	03/04/1957	15/08/2001	15865	195	256	206

Table 3. Stream salinity in the Brunswick River basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
202001	19/10/1971	31/07/2001	10644	131	148	133

Salt Load

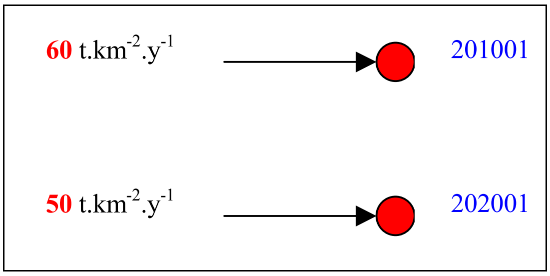
Table 4. Saltloads for the Tweed and Brunswick River basins

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Basin	Station	Station name	Area (km^2)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
Tweed	201001	Oxley R @ Eungella	215	03/04/1957	15/08/2001	12902	10943	34
Brunswick	202001	Brunswick R @ Durrumbul	41	19/10/1971	31/07/2001	2055	1807	27

Figure 15. Generated salt load per unit source area for stations in the Tweed and Brunswick basins

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 16. Land-use in the Tweed River basin

Tributaries and residual area.

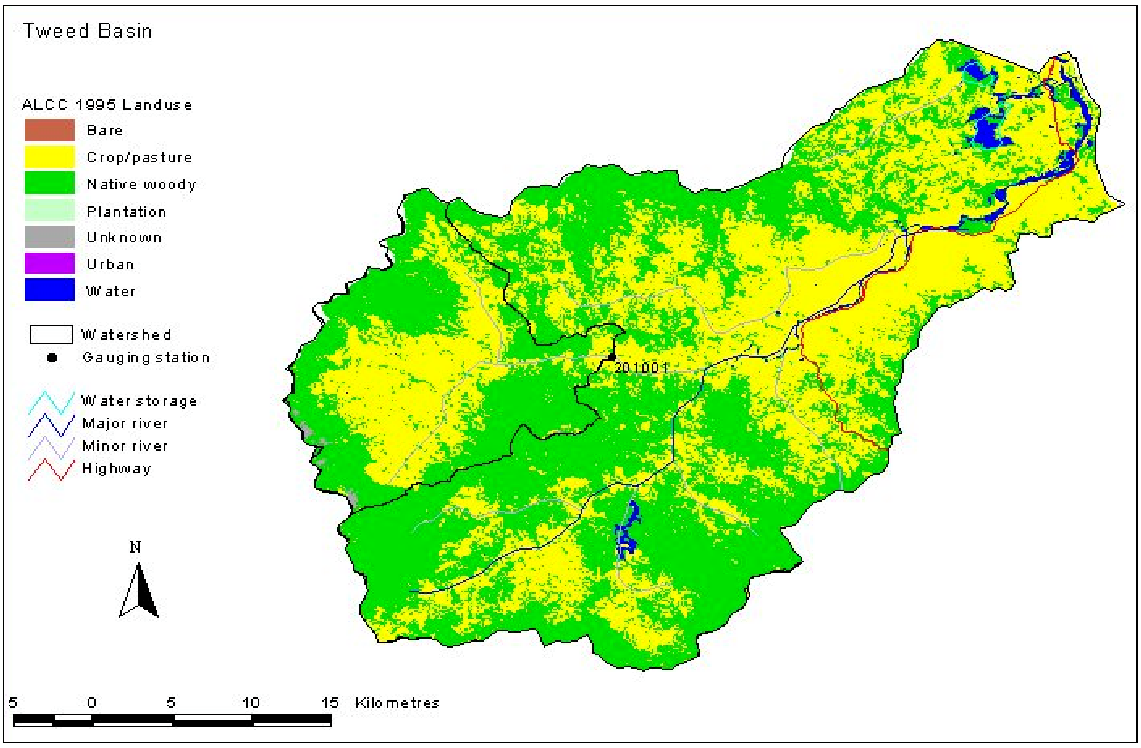


Table 5. Land-use statistics for catchments in the Tweed River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
201001	Oxley R @ Eungella	57	43	0
201###	Tweed remaining	51	47	2

Figure 17. Land-use in the Brunswick River basin
Tributaries and residual area.

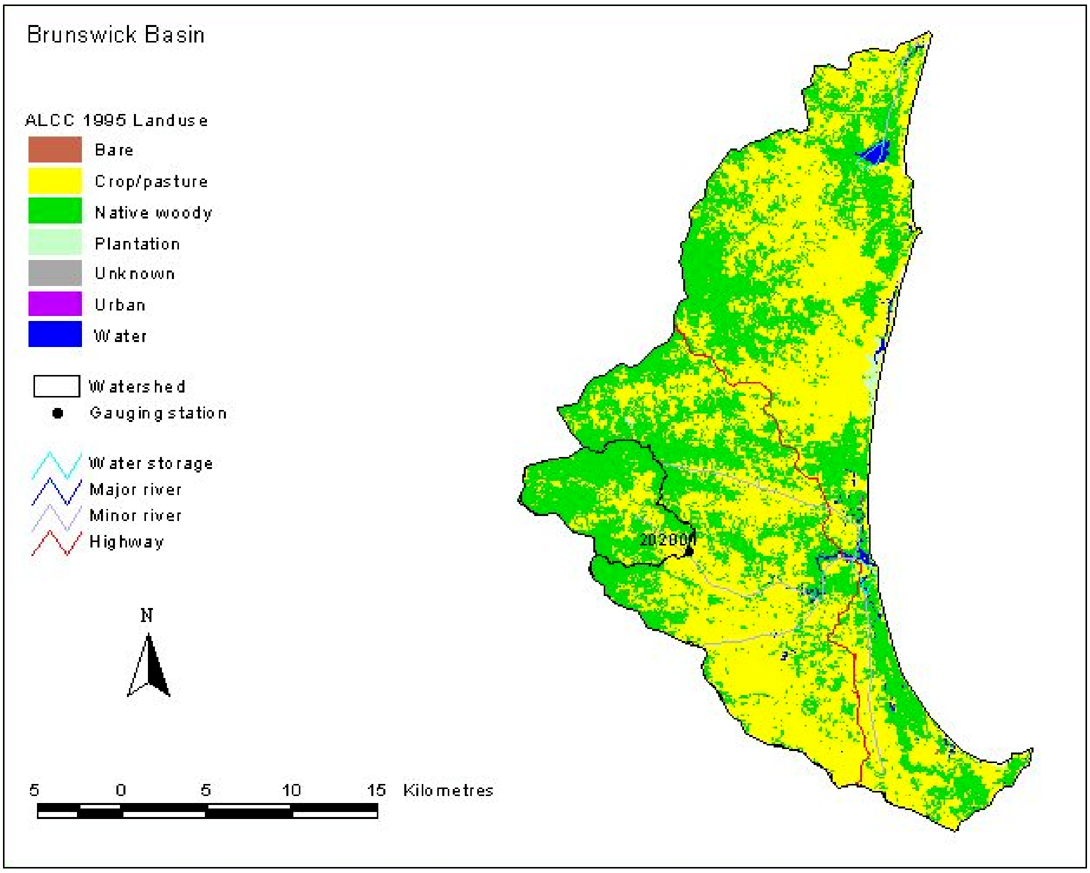


Table 6. Land-use statistics for catchments in the Brunswick River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
202001	Brunswick R @ Durrumbul	74	26	0
202###	Brunswick remaining	40	59	1

Groundwater Salinity

Figure 18. Projected groundwater salinity in the Tweed River basin

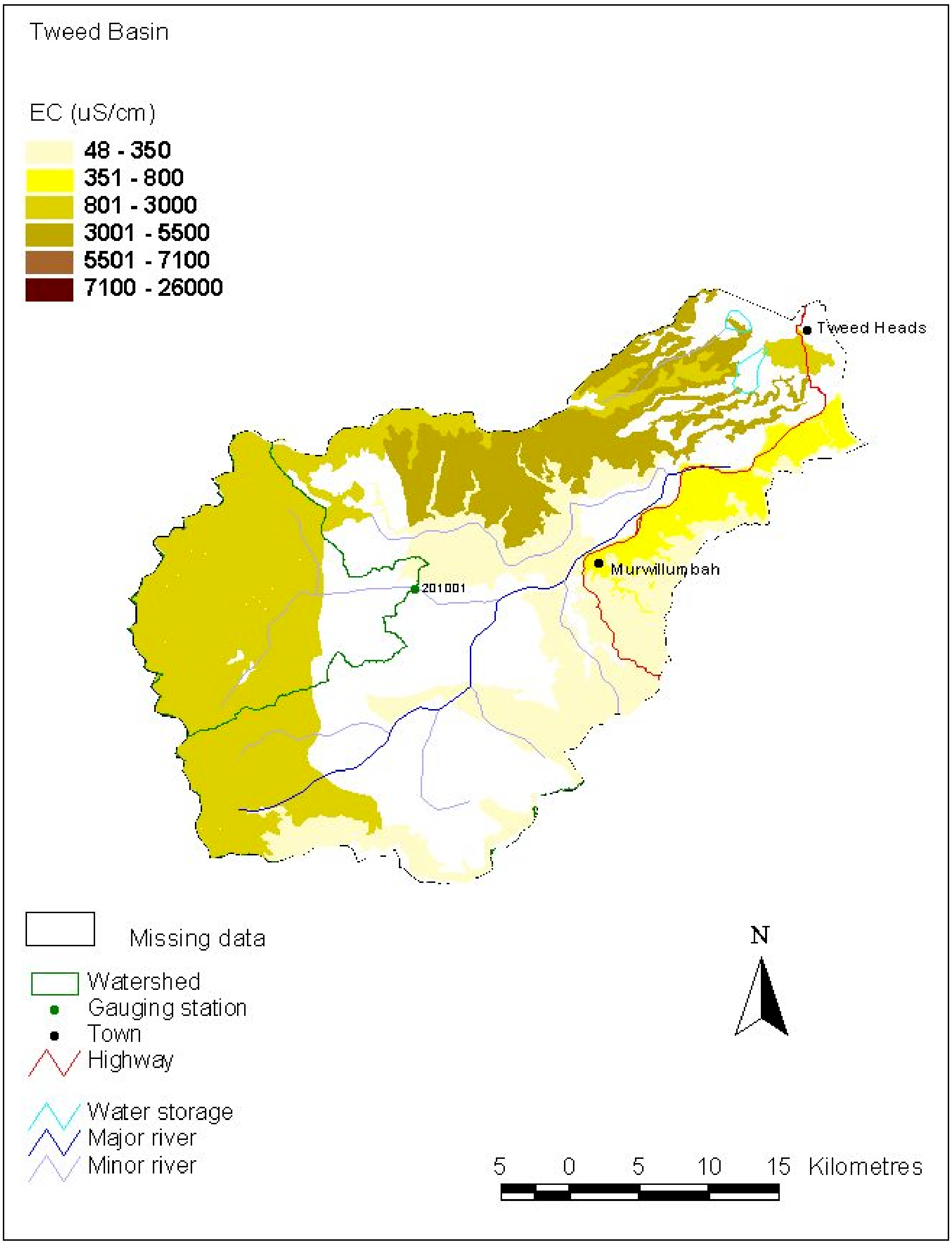
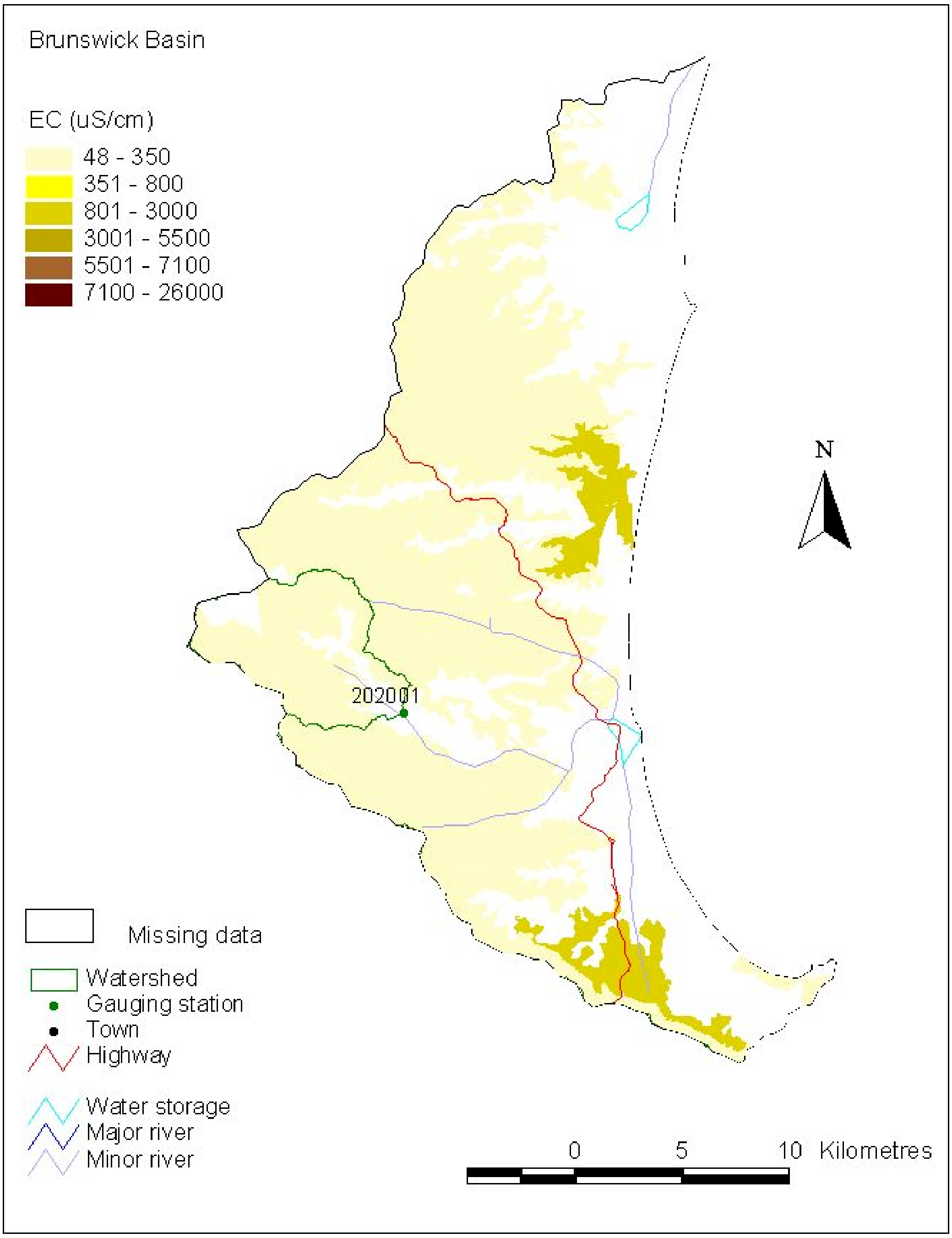


Figure 19. Projected groundwater salinity in the Brunswick River basin



FLAG Wetness map

Figure 20. FLAG wetness map for the Tweed River basin

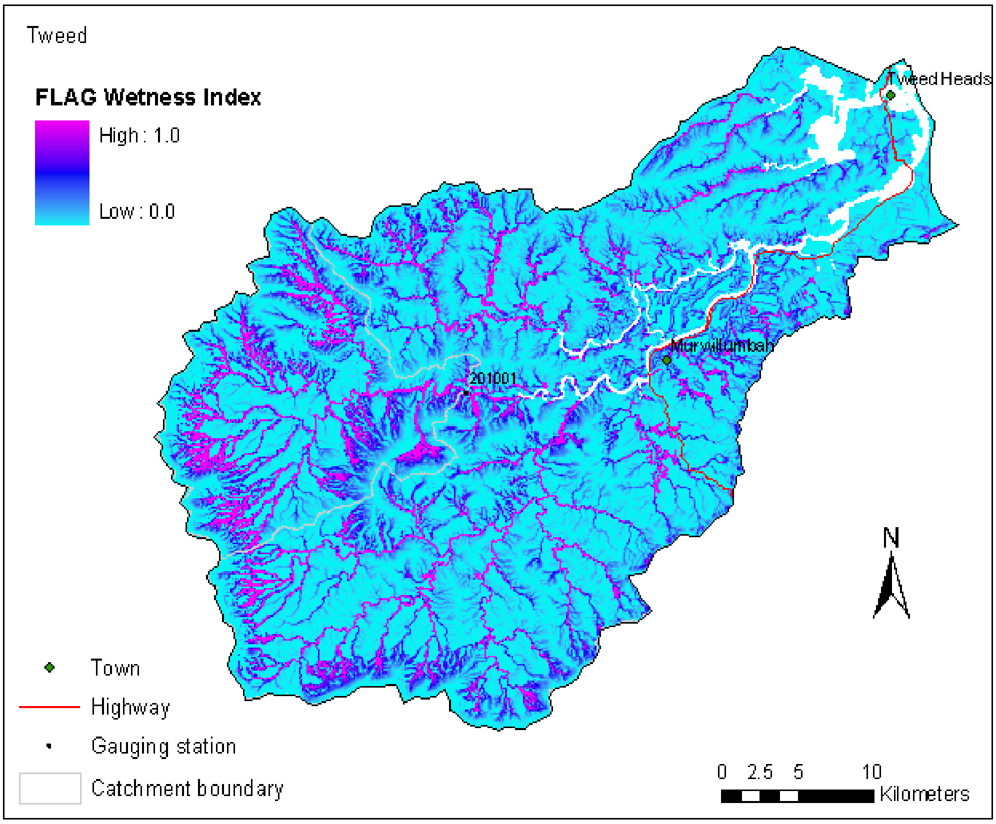
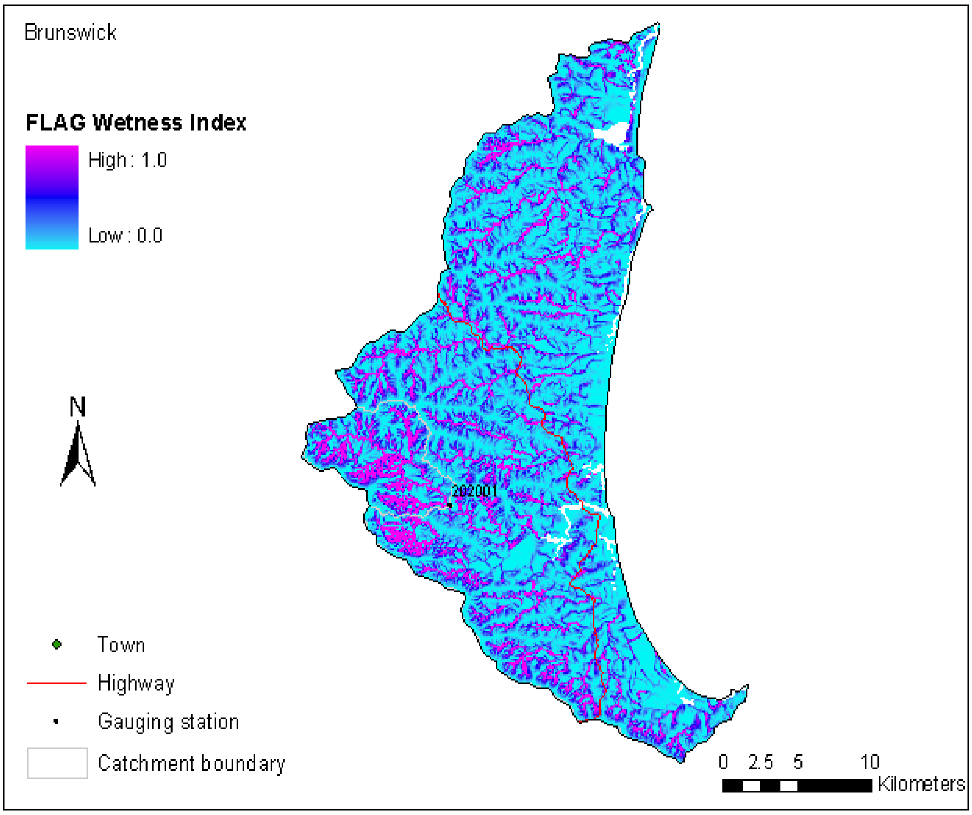


Figure 21. FLAG wetness map for Brunswick River basin



Appendix 2. Richmond River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Richmond River basin.

Stream salinity

Table 7. Stream salinity in the Richmond River basin

Station	Start date	End date	n (days)	Median daily EC (µS.cm^{-1})	80th Percentile daily EC (non-exceedance) (µS.cm^{-1})	Mean daily EC (µS.cm^{-1})
203002	11/05/1976	08/01/2001	9035	75	86	77
203004	22/03/1970	08/02/2001	11354	333	419	345
203005	07/01/1971	30/07/2001	10877	241	291	247
203010	18/06/1967	29/08/2001	12179	420	495	430
203012	10/01/1977	08/01/2001	8609	102	127	113
203013	03/10/1974	26/10/1988	1225	92	109	94
203014	23/08/1957	30/08/2001	15878	102	122	103
203018	08/05/1981	06/03/1985	842	208	248	213
203022	20/06/1967	13/04/1983	5563	113	125	119
203023	10/10/1975	29/07/2001	9396	180	241	189
203024	28/06/1982	01/10/1999	2911	94	113	97
203030	28/09/1979	30/08/2001	5690	280	378	298
203035	11/10/1976	02/05/1985	2917	281	356	292
203037	27/09/1979	23/08/1988	2566	80	86	67
203038	03/08/1979	23/09/1987	3071	100	111	100
203039	11/02/1973	20/06/1993	6953	98	114	106
203041	03/08/1979	16/01/1989	3261	797	1005	825
203900	06/01/1985	30/07/2001	3162	269	313	289

Only Shannon Brook (203041) represents a water quality issue for this basin.

Salt load

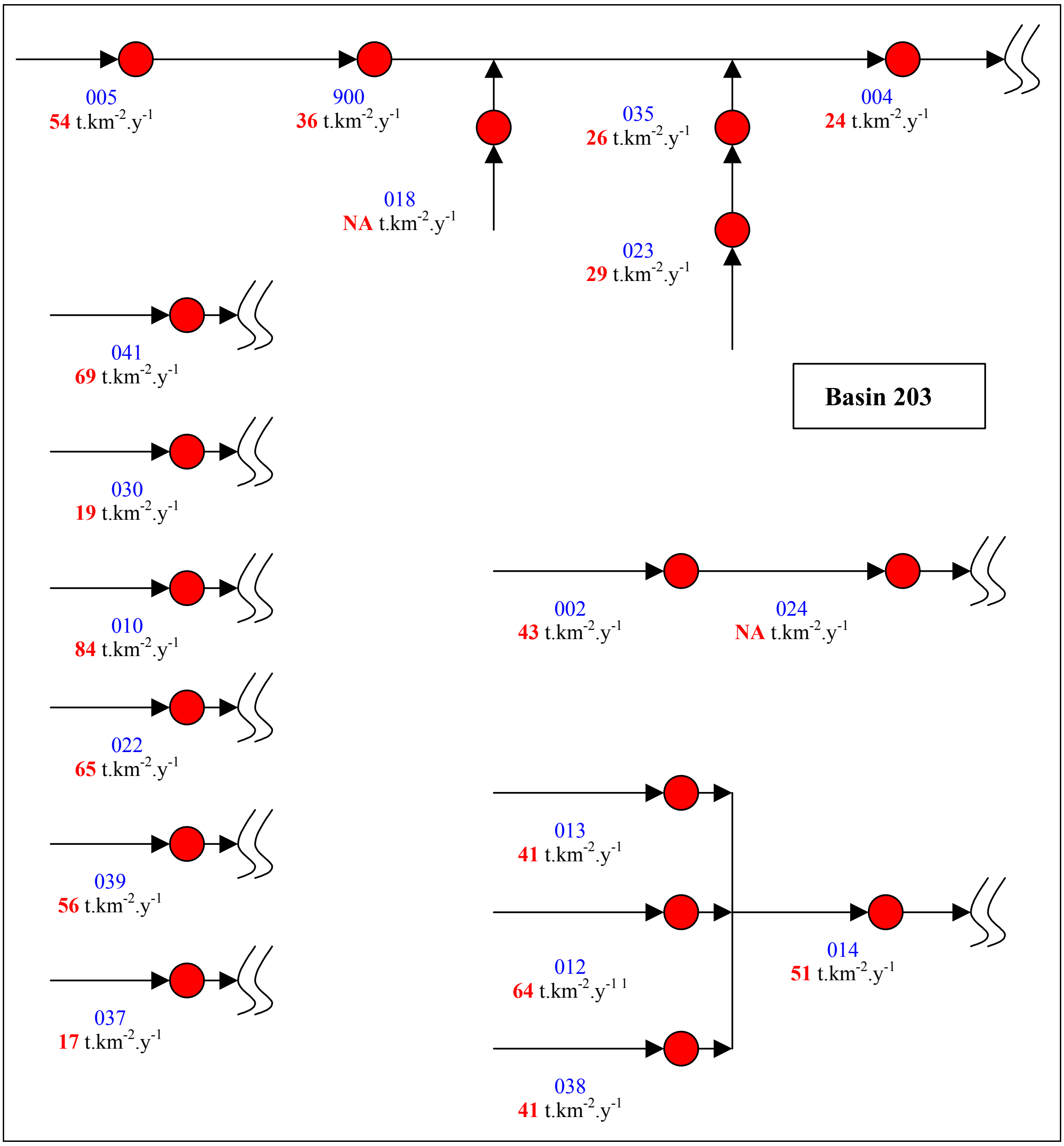
Table 8. Saltloads for the Richmond River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
203002	Coopers Ck @ Repentance	62	11/05/1976	08/01/2001	2650	2210	24
203004	Richmond R @ Casino	1781	22/03/1970	08/02/2001	41899	39740	14
203005	Richmond R @ Wiangaree	651	07/01/1971	30/07/2001	35380	29147	26
203010	Leycester R @ Rock Valley	177	18/06/1967	29/08/2001	14987	11400	29
203012	Byron Ck @ Binna Burra	37	10/01/1977	08/01/2001	2379	2228	21
203013	Wilsons R @ Federal	54	03/10/1974	26/10/1988	2212	2212	2
203014	Wilsons R @ Eltham	222	23/08/1957	30/08/2001	11328	10471	39
203018	Eden Ck @ Upper Eden Ck	31	08/05/1981	06/03/1985	NA	NA	NA
203022	Terania Ck @ Keerong	159	20/06/1967	13/04/1983	10336	7726	11
203023	Iron Pot Ck @ Toonumbar	99	10/10/1975	29/07/2001	2864	2036	24
203024	Coopers Ck @ Ewing Bridge	172	28/06/1982	01/10/1999	NA	NA	NA
203030	Myrtle Ck @ Rappville	447	28/09/1979	30/08/2001	8699	7062	20
203035	Iron Pot Ck @ Ettrick	189	11/10/1976	02/05/1985	4899	4673	5
203037	Duck Ck @ Alstonville	6	27/09/1979	23/08/1988	101	101	2
203038	Pearces Ck @ Booyong	13	03/08/1979	23/09/1987	536	611	6
203039	Maguires Ck @ Teven	34	11/02/1973	20/06/1993	1890	1718	16
203041	Shannon Brk @ Yorklea	500	03/08/1979	16/01/1989	34304	27702	6
203900	Richmond R @ Kyogle	840	06/01/1985	30/07/2001	29909	19064	5

NA Annual statistics are not available because of missing daily values in all years.

Figure 22. Generated salt load per unit source area for stations in the Richmond River basin
Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 23. Land-use in the Richmond River basin

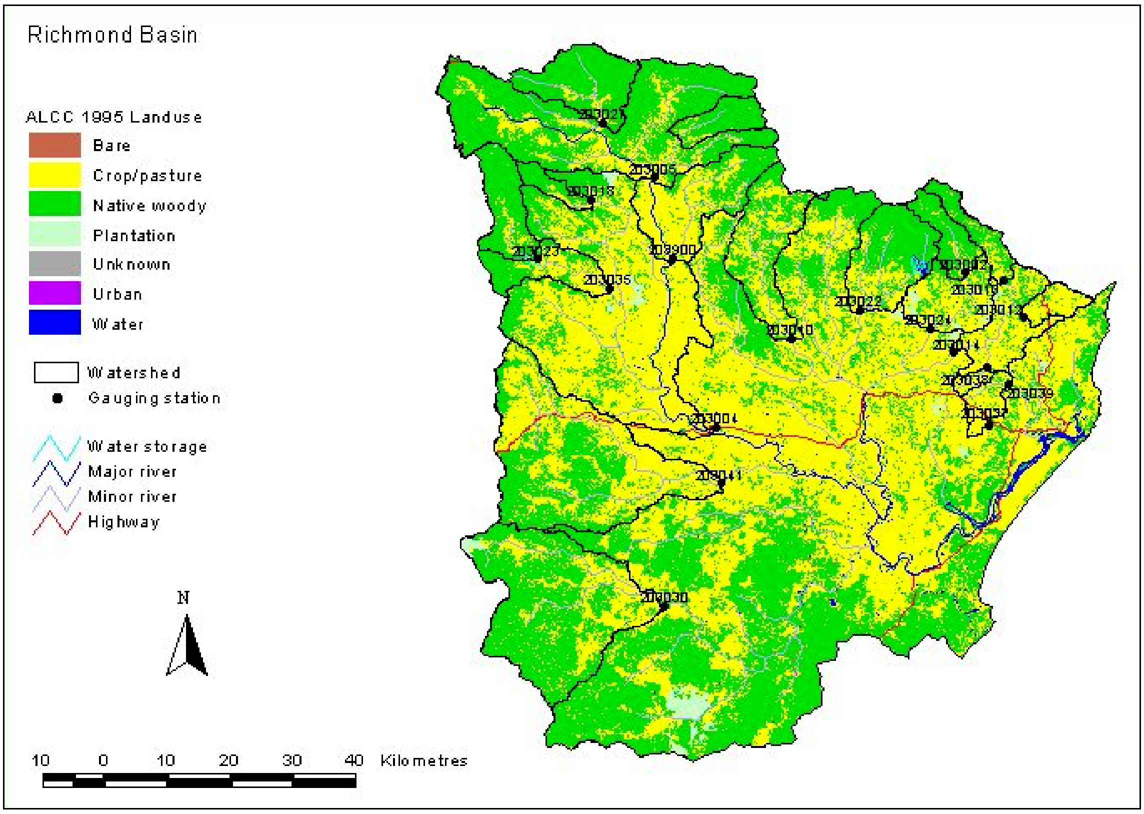


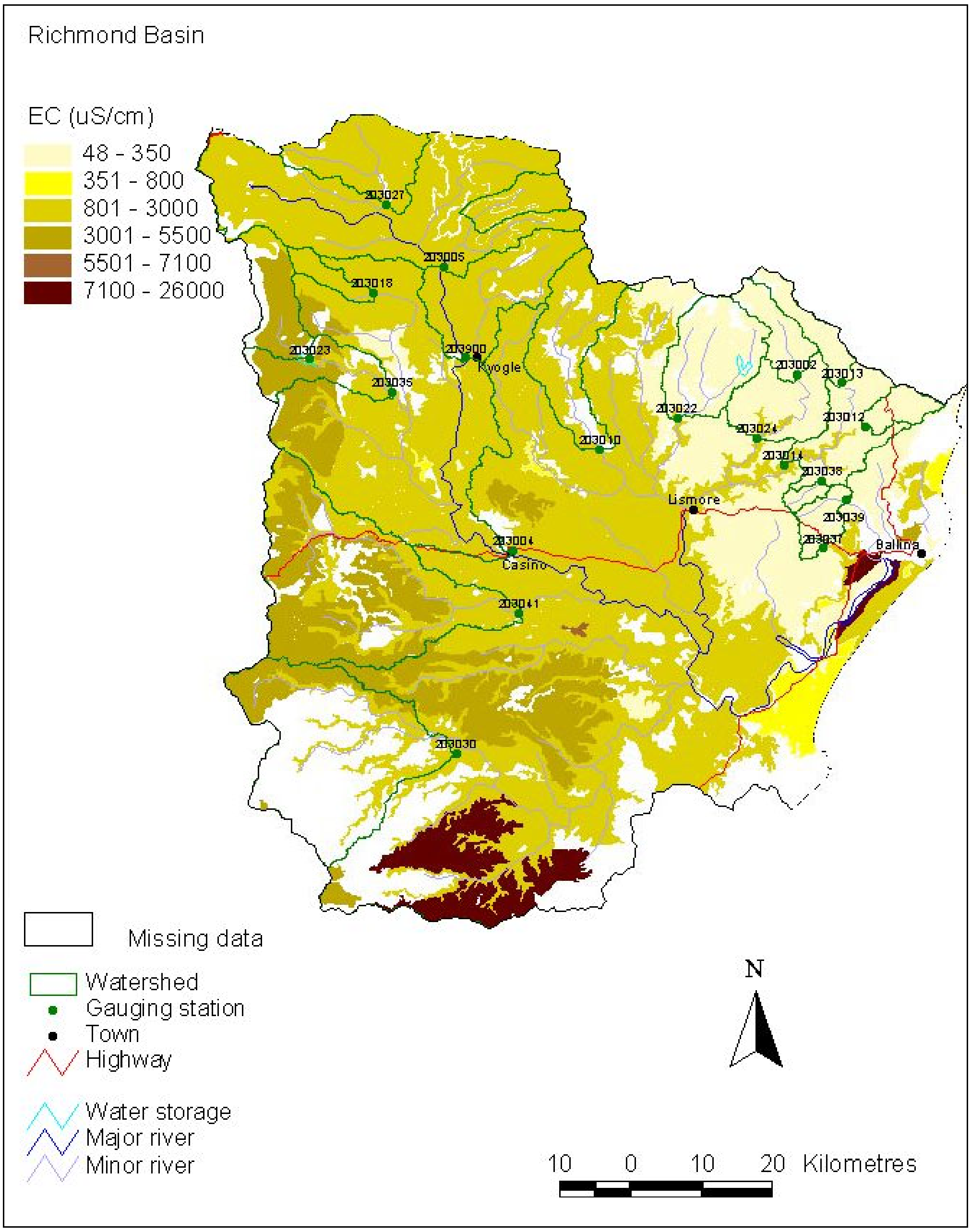
Table 9. Land-use statistics for catchments in the Richmond River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
203002	Coopers Ck @ Repentance	87	13	0
203004	Richmond R @ Casino	26	74	0
203005	Richmond R @ Wiangaree	75	25	0
203010	Leycester R @ Rock Valley	53	47	0
203012	Byron Ck @ Binna Burra	14	86	0
203013	Wilsons R @ Federal	73	27	0
203014	Wilsons R @ Eltham	22	78	0
203018	Eden Ck @ Upper Eden Ck	82	18	0
203022	Terania Ck @ Keerong	68	31	1
203023	Iron Pot Ck @ Toonumbar	89	11	0
203024	Coopers Ck @ Ewing Bridge	37	63	0
203027	Findon Ck @ Terrace Ck	92	8	0
203030	Myrtle Ck @ Rappville	70	30	0
203035	Iron Pot Ck @ Ettrick	54	46	0
203037	Duck Ck @ Alstonville	7	93	0

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
203038	Pearces Ck @ Booyong	15	85	0
203039	Maguires Ck @ Teven	19	81	0
203041	Shannon Brk @ Yorklea	45	55	0
203900	Richmond R @ Kyogle	37	63	0
203###	Richmond remaining	43	56	1

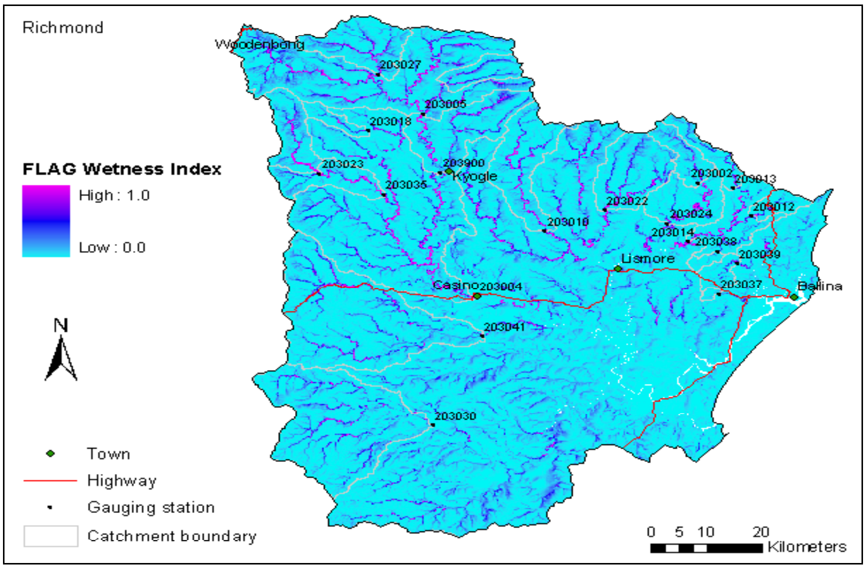
Groundwater salinity

Figure 24. Projected groundwater salinity in the Richmond River basin



FLAG wetness map

Figure 25. FLAG wetness map for Richmond River basin



Appendix 3. Clarence River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Clarence River basin.

Stream salinity

Table 10. Stream salinity in the Clarence River basin

Station	Start date	End date	n (days)	Median daily EC (µS.cm^{-1})	80th percentile daily EC (non-exceedance) (µS.cm^{-1})	Mean daily EC (µS.cm^{-1})
204001	16/06/1956	21/11/2001	14788	53	63	55
204002	07/08/1965	28/08/2001	12539	330	425	345
204004	11/01/1963	23/10/2001	13316	95	100	95
204005	10/12/1973	14/05/1986	4456	84	100	86
204006	28/02/1983	20/11/1985	566	64	75	66
204007	14/08/1971	19/11/2001	10732	148	200	158
204008	10/10/1973	18/11/2001	9377	39	55	42
204014	05/11/1972	21/10/2001	10465	133	166	138
204015	27/05/1970	22/10/2001	11157	86	103	88
204017	19/08/1971	24/06/2001	10852	41	55	44
204019	02/11/1972	06/10/1985	4656	44	52	44
204021	04/02/1978	13/06/1985	2594	50	67	53
204025	11/01/1969	12/02/2001	10834	77	88	78
204026	12/04/1953	06/11/1985	10735	52	61	53
204027	07/06/1973	15/11/1992	6726	67	69	67
204030	30/08/1977	25/10/2001	8129	136	173	142
204031	19/04/1984	21/10/2001	6253	225	289	234
204033	03/08/1978	09/03/2001	8481	88	95	89
204034	17/08/1971	22/10/2001	10727	83	103	84
204036	15/03/1952	27/08/2001	17315	161	347	284
204037	17/02/1971	05/06/2001	10427	75	86	81
204039	03/09/1979	09/03/2001	5545	192	219	195
204041	30/06/1960	26/04/1966	1886	103	113	106
204042	07/09/1981	05/12/1986	1675	381	539	417
204043	26/03/1960	29/07/2001	11572	341	456	361
204044	24/04/1969	06/05/1985	4833	530	683	550
204046	07/08/1969	27/08/2001	11590	95	119	98
204048	02/09/1977	19/11/1985	3164	78	92	78
204050	03/01/1982	05/12/1986	1345	464	627	489
204051	27/03/1976	09/04/2001	8827	231	302	244
204054	21/03/1980	06/05/1985	1492	92	119	95
204055	29/02/1972	05/07/2001	5387	158	191	161

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
204056	24/05/1975	23/10/2001	9576	33	45	39
204057	09/08/1982	23/09/1985	880	277	350	283
204060	23/05/1975	18/04/1990	4636	158	177	155
204900	15/07/1971	20/11/2001	8607	217	289	230
204906	16/11/1972	06/12/2001	10280	139	153	139

Water quality is not an issue in this basin.

Salt load

Table 11. Saltloads for the Clarence River basin

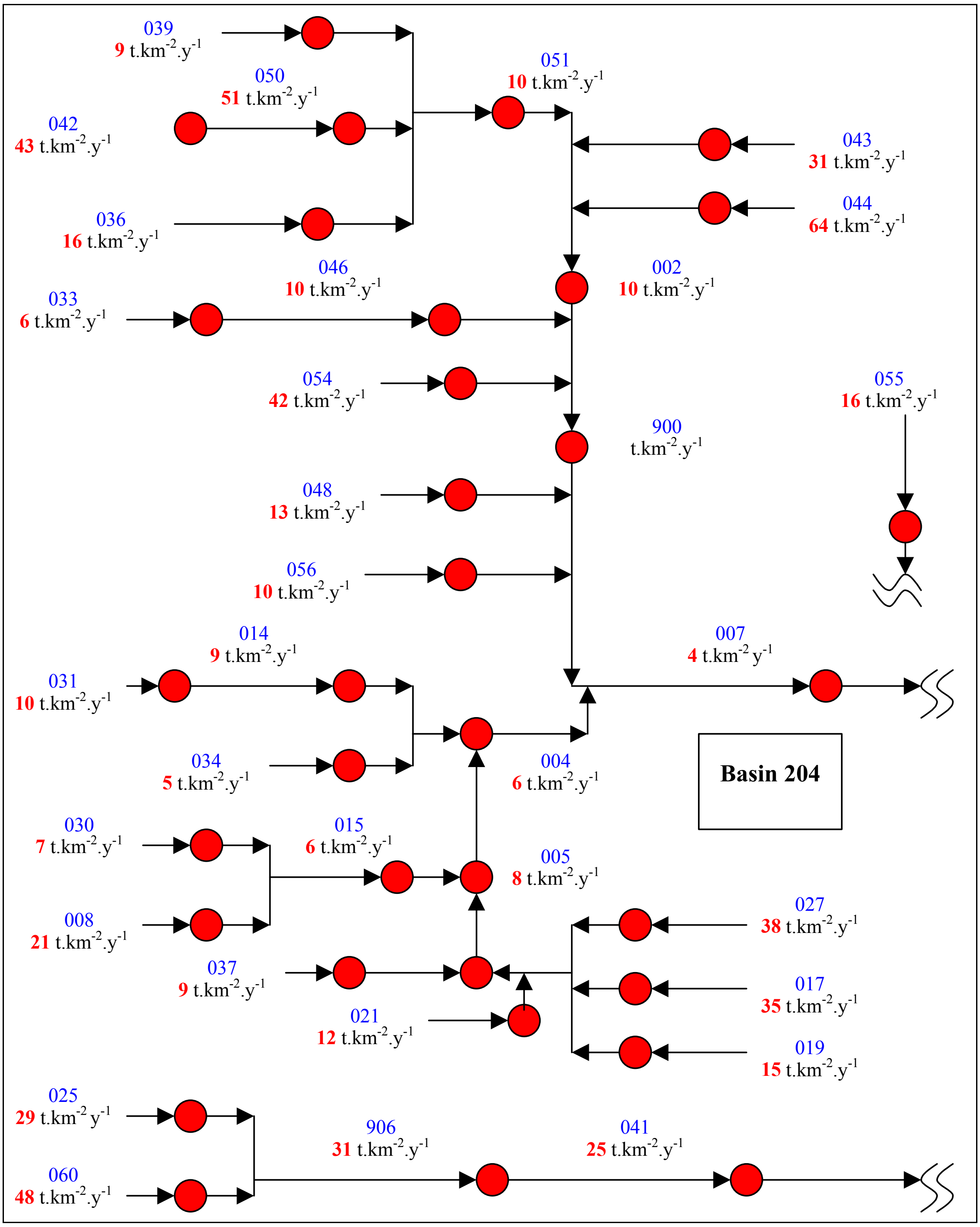
Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average Annual Saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
204001	Nymboida R @ Nymboida	1574	16/06/1956	21/11/2001	22587	18824	26
204002	Clarence R @ Tabulam	4516	07/08/1965	28/08/2001	45784	49401	18
204004	Mann R @ Jackadgery	7825	11/01/1963	23/10/2001	47581	47261	18
204005	Nymboida R @ Buccarumbi	5298	10/12/1973	14/05/1986	43465	37483	6
204007	Clarence R @ Lilydale	16865	14/08/1971	19/11/2001	59244	59500	4
204008	Guy Fawkes R @ Ebor	33	10/10/1973	18/11/2001	689	608	20
204014	Mann R @ Mitchell	882	05/11/1972	21/10/2001	7781	6554	20
204015	Boyd R @ Broadmeadows	2640	27/05/1970	22/10/2001	16057	13281	22
204017	Bielsdown Ck @ Dorrigo	75	19/08/1971	24/06/2001	2662	2663	27
204019	Nymboida R @ Bostobrick	217	02/11/1972	06/10/1985	3260	2827	10
204021	Blicks R @ Hernani	67	04/02/1978	13/06/1985	816	522	3
204025	Orara R @ Karangi	135	11/01/1969	12/02/2001	3880	3649	26
204026	Bobo R @ Bobo Nursery	79	12/04/1953	06/11/1985	2673	2249	22
204027	Little Nymboida R @ Timmsvale	33	07/06/1973	15/11/1992	1251	1052	9
204030	Aberfoyle R @ Aberfoyle	209	30/08/1977	25/10/2001	1505	947	20
204031	Mann R @ Shannon Vale	349	19/04/1984	21/10/2001	3436	2745	14
204033	Timbarra R @ Billyrimba	993	03/08/1978	09/03/2001	6251	4426	18
204034	Henry R @ Newton Boyd	401	17/08/1971	22/10/2001	2013	1374	26
204036	Cataract R @ Sandy Hill	195	15/03/1952	27/08/2001	3126	2263	40
204037	Clouds Ck @ Clouds Ck	63	17/02/1971	05/06/2001	572	402	26
204039	Maryland R D/S Wylie Ck	387	03/09/1979	09/03/2001	3660	1226	12
204041	Orara R @ Bawden Bdg	1811	30/06/1960	26/04/1966	45593	45593	2
204042	Tooloom Ck @ Tooloom Falls	314	07/09/1981	05/12/1986	13654	15261	4
204043	Peacock Ck @ Bonalbo	48	26/03/1960	29/07/2001	1479	1078	31
204044	Gorge Ck @ Bonalbo	46	24/04/1969	06/05/1985	2937	3035	13

Station	Station name	Area (km^2)	Start date	End date	Average Annual Saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
204046	Timbarra R @ Drake	1724	07/08/1969	27/08/2001	16664	12849	26
204048	Coombadjha Ck @ Coombadjha	163	02/09/1977	19/11/1985	2171	1469	6
204050	Tooloom Ck @ Upper Tooloom	618	03/01/1982	05/12/1986	31240	31240	2
204051	Clarence R @ Paddys Flat	3085	27/03/1976	09/04/2001	29780	23824	19
204054	Washpool Ck @ Lionsville	267	21/03/1980	06/05/1985	11296	11296	1
204055	Sportsman Ck @ Gurranang	201	29/02/1972	05/07/2001	3195	3292	17
204056	Dandahra Ck @ Gibraltar Range	113	24/05/1975	23/10/2001	1147	1040	23
204057	Barney Downs Ck near Casino Rd	44	09/08/1982	23/09/1985	964	964	1
204060	Bucca Ck @ Central Bucca	21	23/05/1975	18/04/1990	998	963	7
204900	Clarence R @ Baryulgil	7514	15/07/1971	20/11/2001	65031	69819	6
204906	Orara R @ Glenreagh	432	16/11/1972	06/12/2001	13233	11991	24

Figure 26. Generated salt load per unit source area for stations in the Clarence River basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 27. Land-use in the Clarence River basin

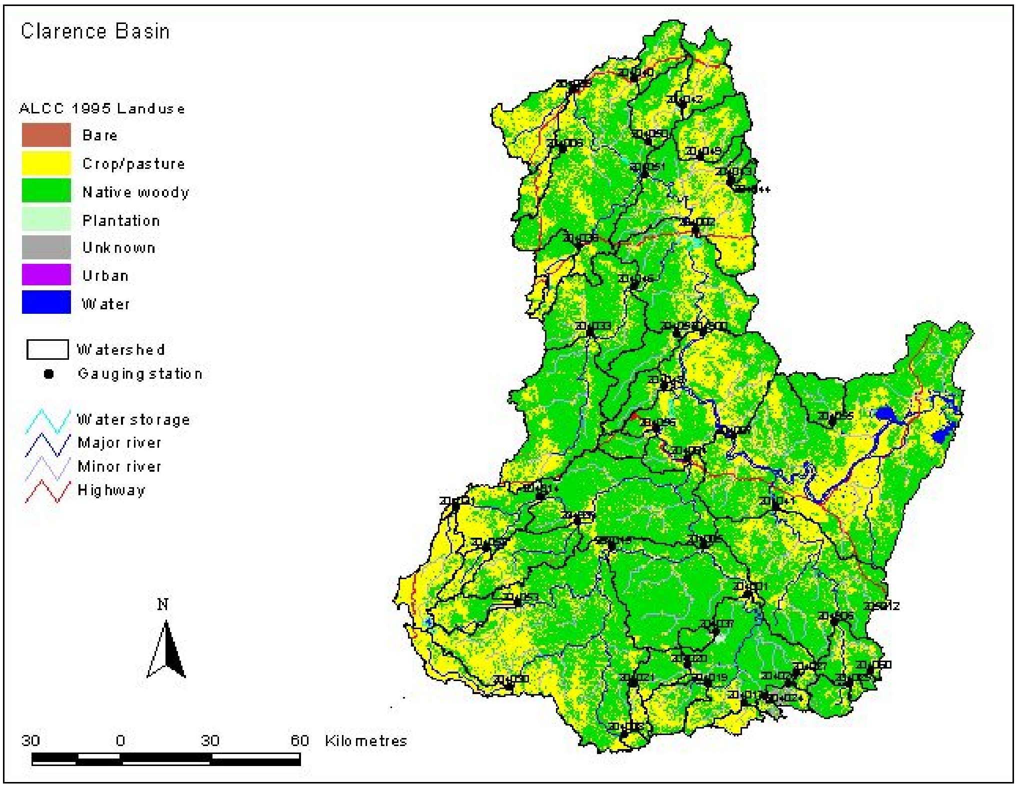


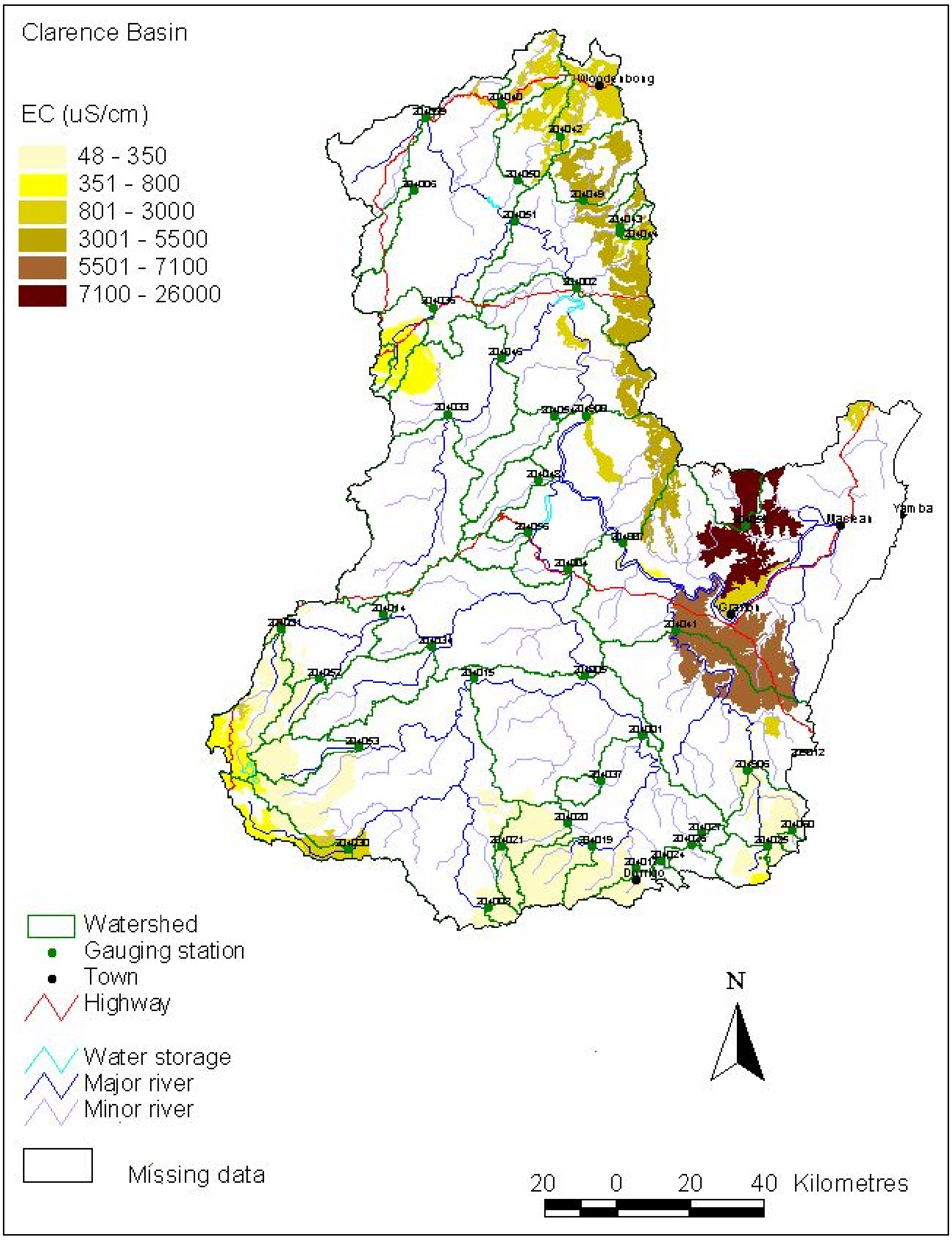
Table 12. Land-use statistics for catchments in the Clarence River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
204001	Nymboida R @ Nymboida	79	21	0
204002	Clarence R @ Tabulam	49	51	0
204004	Mann R @ Jackadgery	82	18	0
204005	Nymboida R @ Buccarumbi	88	12	0
204006	Bookookoorara R @ Undercliffe	46	54	0
204007	Clarence R @ Lilydale	52	47	1
204008	Guy Fawkes R @ Ebor	40	60	0
204014	Mann R @ Mitchell	43	57	0
204015	Boyd R @ Broadmeadows	56	44	0
204017	Bielsdown Ck @ Dorrigo No.2 & No.3	17	83	0
204019	Nymboida R @ Bostobrick	49	51	0
204020	Blicks R @ Dundurrabin	76	23	0
204021	Blicks R @ Hernani	29	71	0
204024	Wild Cattle Ck @ Megan 2	68	32	0
204025	Orara R @ Karangi	82	17	0

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
204026	Bobo R @ Bobo Nursery	76	24	0
204027	Little Nymboida R @ Timmsvale	60	40	0
204030	Aberfoyle R @ Aberfoyle	11	89	0
204031	Mann R @ Shannon Vale	12	87	1
204033	Timbarra R @ Billyrimba	74	26	0
204034	Henry R @ Newton Boyd	65	35	0
204036	Cataract R @ Sandy Hill	42	58	0
204037	Clouds Ck @ Clouds Ck	91	9	0
204039	Maryland R D/S Wylie Ck	28	72	0
204040	Koreelah Ck @ Hewetsons Mill	63	37	0
204041	Orara R @ Bawden Bdg	68	32	0
204042	Tooloom Ck @ Tooloom Falls	53	47	0
204043	Peacock Ck @ Bonalbo	79	21	0
204044	Gorge Ck @ Bonalbo	79	21	0
204046	Timbarra R @ Drake	74	25	0
204048	Coombadjha Ck @ Coombadjha	79	21	0
204049	Duck Ck @ Capeen	56	44	0
204050	Tooloom Ck @ Upper Tooloom	58	42	0
204051	Clarence R @ Paddys Flat	65	35	0
204052	Yarrow Ck @ Yarrow Ck	24	76	0
204053	Sara R @ kookabookra	49	50	0
204054	Washpool Ck @ Lionsville	95	5	0
204055	Sportsman Ck @ Gurranang	91	9	0
204056	Dandahra Ck @ Gibraltar Range	86	14	0
204057	Barney Downs Ck near Casino Rd	13	87	0
204060	Bucca Ck @ Central Bucca	96	4	0
204900	Clarence R @ Baryulgil	61	38	0
204906	Orara R @ Glenreagh	68	32	0
204###	Clarence remaining	54	42	4

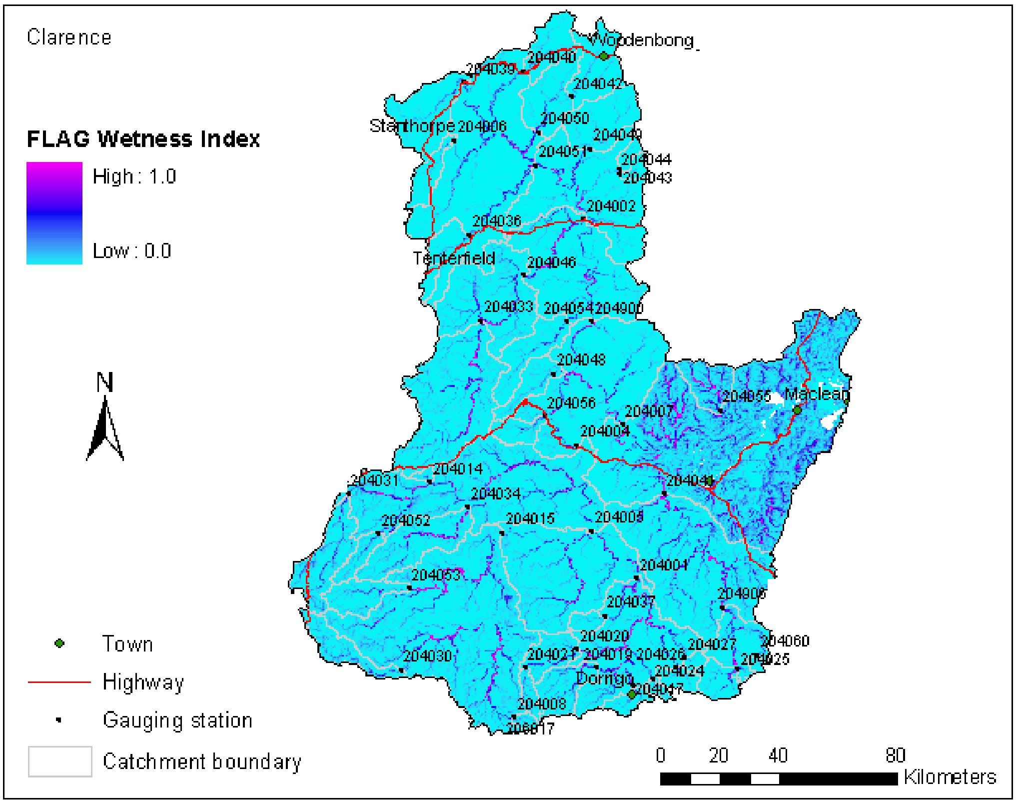
Groundwater

Figure 28. Projected groundwater in the Clarence River basin



FLAG wetness map

Figure 29. FLAG wetness map for the Clarence River basin



Appendix 4. Bellinger River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Bellinger River basin.

Stream salinity

Table 13. Stream salinity in the Bellinger River basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
205002	19/02/1982	24/06/2001	6834	73	86	75
205004	15/10/1971	19/03/1974	886	100	111	100
205006	26/08/1971	25/06/2001	10835	142	175	147
205008	25/03/1970	30/01/1989	6640	202	228	200
205009	15/05/1980	10/08/1985	1918	327	488	361
205010	15/10/1971	16/02/1982	3703	78	103	83
205012	21/05/1975	31/10/1985	3056	169	192	169

There are no water quality problems identified by this analysis in this basin.

Salt load

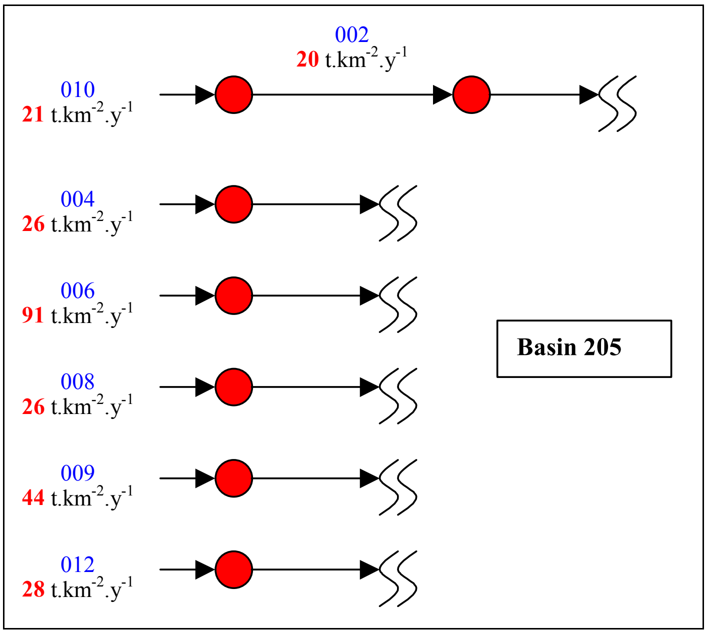
Table 14. Saltloads for the Bellinger River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
205002	Bellinger R @ Thora	443	19/02/1982	24/06/2001	8801	7982	14
205004	Kalang R @ Scotchman	166	15/10/1971	19/03/1974	4385	4385	2
205006	Nambucca R @ Bowraville	178	26/08/1971	25/06/2001	16158	9868	27
205008	Taylors Arm @ Grays XG	340	25/03/1970	30/01/1989	8850	6937	13
205009	Warrell Ck @ Warrell Ck	193	15/05/1980	10/08/1985	8425	8147	4
205010	Bellinger R @ Upper Thora	416	15/10/1971	16/02/1982	8734	7115	8
205012	Corinid R @ Upper Corindi	55	21/05/1975	31/10/1985	1531	1380	8

Figure 30. Generated salt load per unit source area for stations in the Bellinger River basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 31. Land-use in the Bellinger River basin

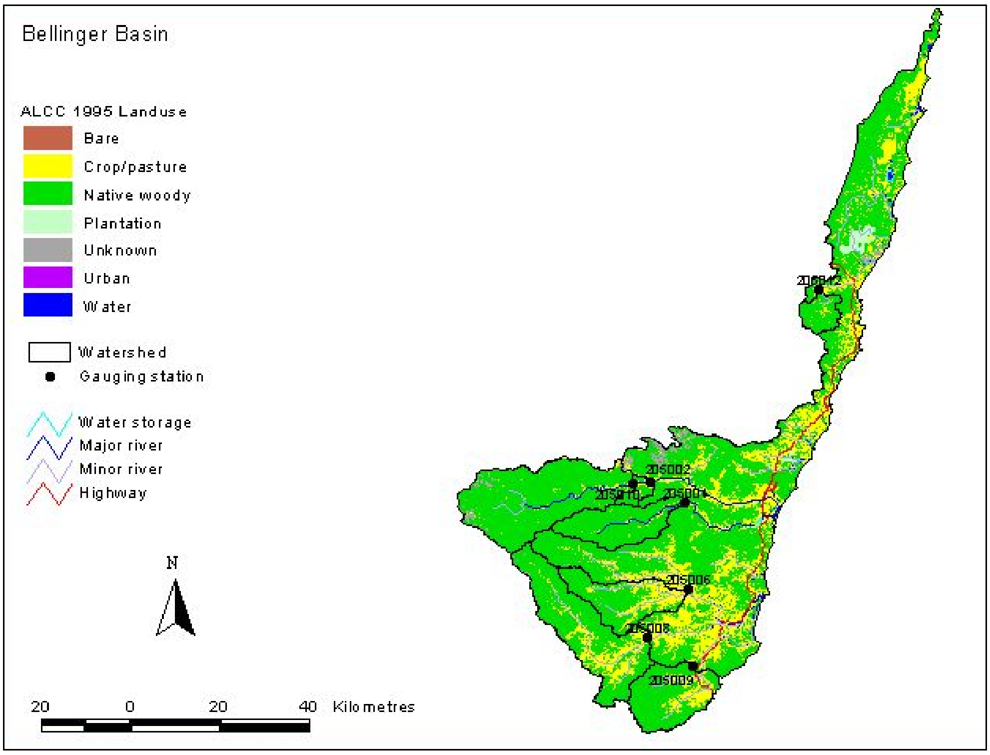
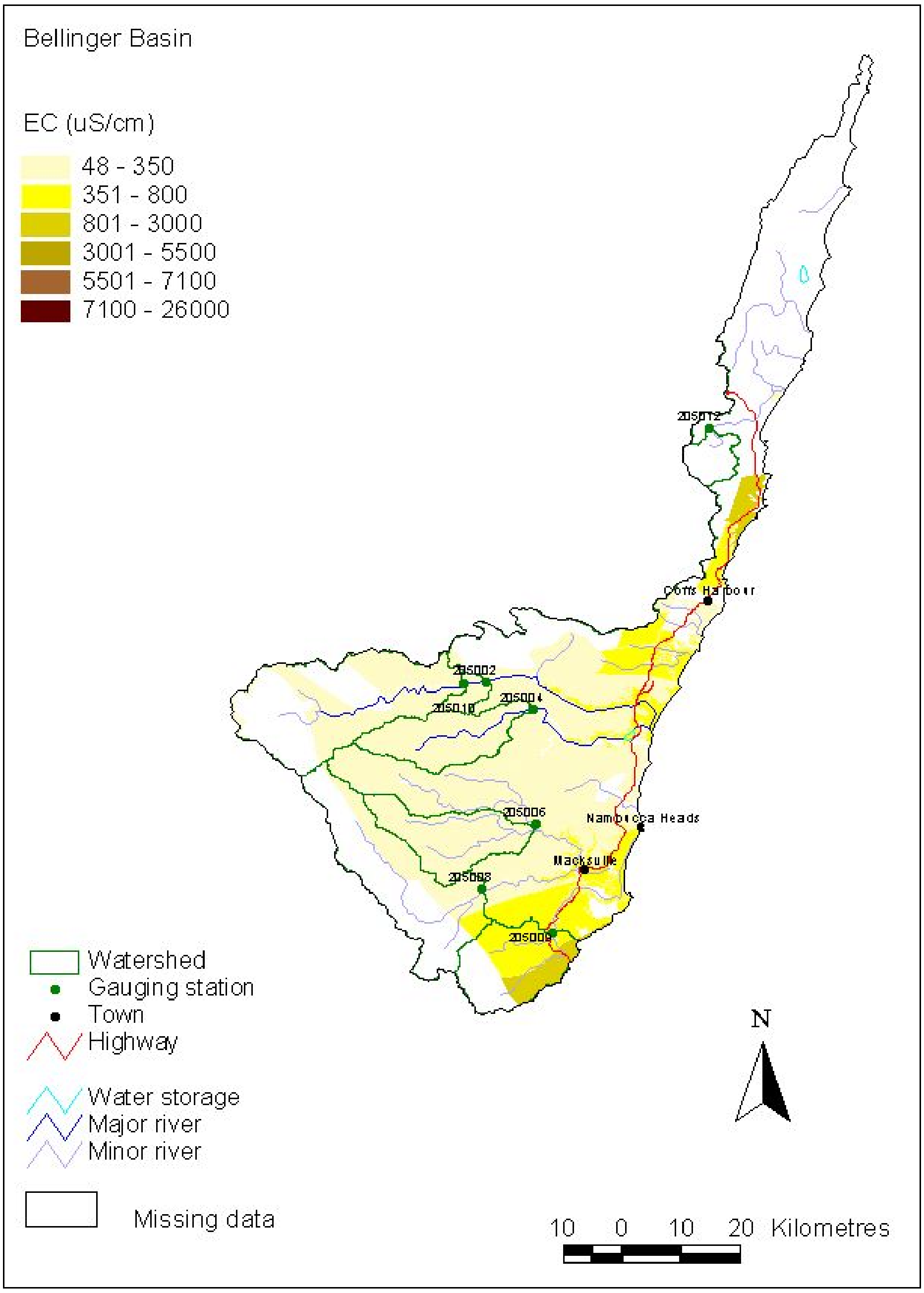


Table 15. Land-use statistics for catchments in the Bellinger River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
205002	Bellinger R @ Thora	84	16	0
205004	Kalang R @ Scotchman	96	4	0
205006	Nambucca R @ Bowraville	70	30	0
205008	Taylors Arm @ Grays XG	77	23	0
205009	Warrell Ck @ Warrell Ck	79	21	0
205010	Bellinger R @ Upper Thora	96	4	0
205012	Corinid R @ Upper Corindi	92	8	0
205###	Bellinger remaining	67	31	1

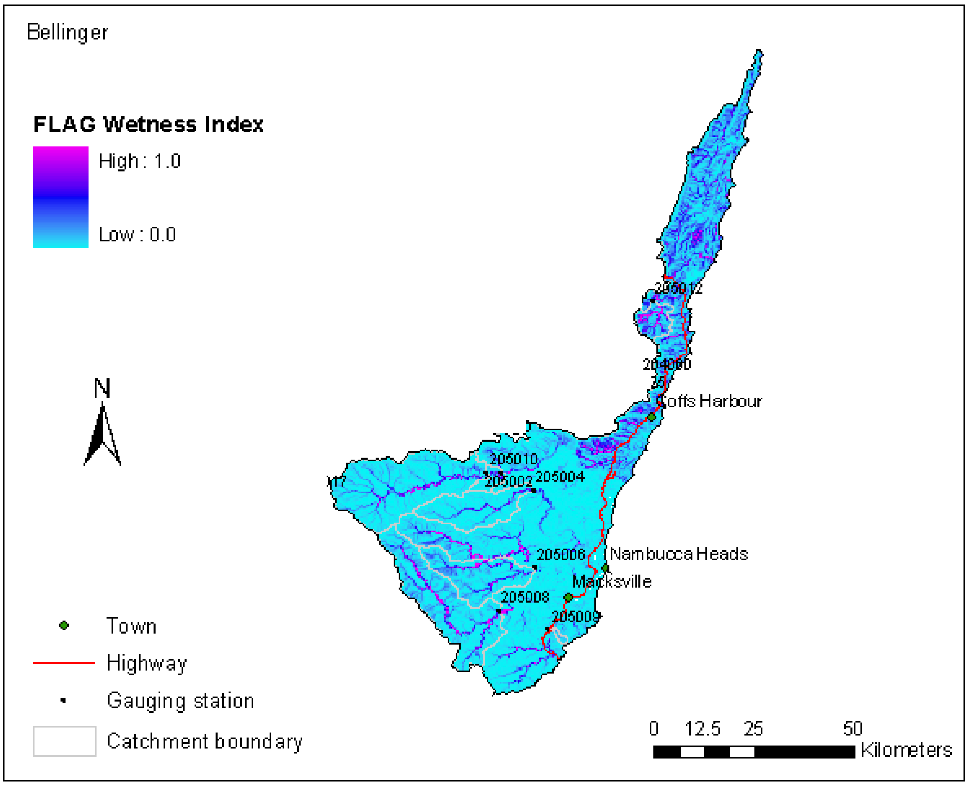
Groundwater salinity

Figure 32. Projected groundwater salinity in the Bellinger River basin



FLAG wetness map

Figure 33. FLAG wetness map for the Bellinger River basin



Appendix 5. Macleay River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Macleay River basin.

Stream salinity

Table 16. Stream salinity in the Macleay River basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
206001	06/03/1978	18/11/2001	8406	42	64	48
206004	23/12/1981	25/06/1985	1035	272	402	303
206008	20/06/1975	14/08/2001	5894	367	425	367
206009	22/01/1954	22/11/2001	17191	106	139	113
206011	16/01/1970	19/11/2001	11418	138	164	141
206014	24/06/1954	27/11/2001	15946	275	431	314
206015	07/02/1979	06/06/1985	1497	206	250	208
206017	28/07/1954	11/11/1985	11192	45	48	45
206018	12/11/1952	22/11/2001	14580	239	306	250
206021	05/06/1980	11/01/1983	1216	45	56	47
206023	26/03/1983	24/09/1985	771	61	84	66
206024	28/06/1969	18/11/2001	11603	136	188	147
206025	30/12/1972	19/12/2001	7055	352	391	348
206026	20/09/1974	16/10/2001	1934	275	275	202
206027	30/11/1974	26/09/2001	897	259	400	289
206033	18/12/1981	04/03/2001	6945	161	188	164

There were no water quality problems identified by the analysis in this basin.

Salt load

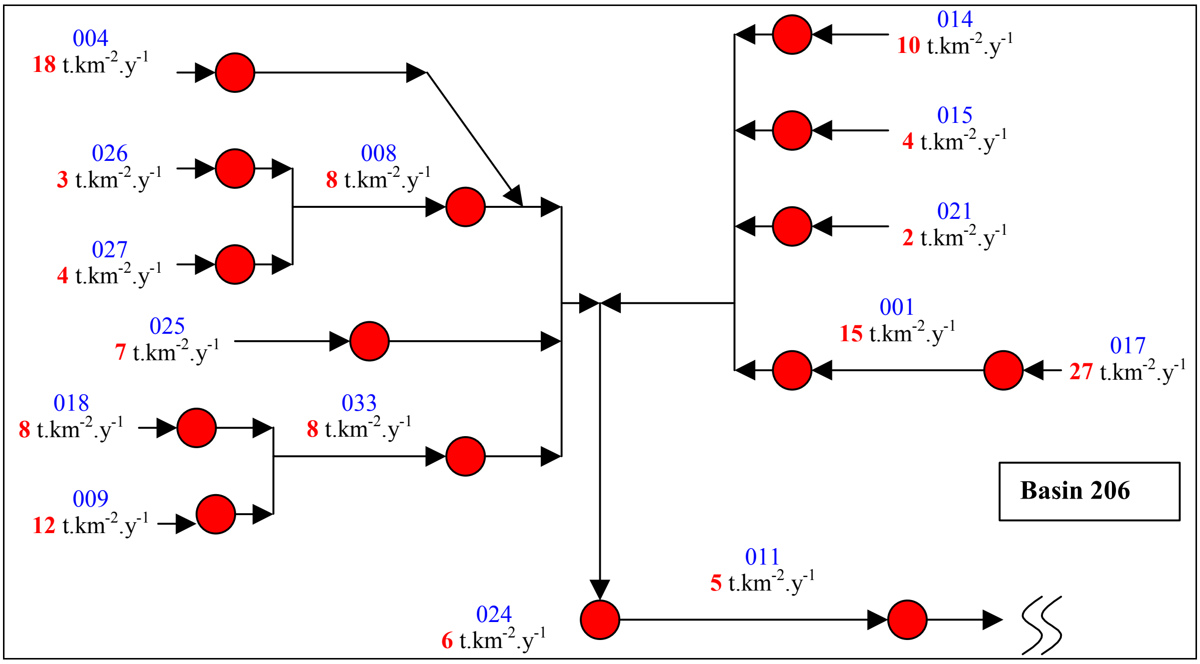
Table 17. Saltloads for the Macleay River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
206001	Styx R @ Jeogla	156	06/03/1978	18/11/2001	2322	1945	18
206004	Gara R @ Gara	417	23/12/1981	25/06/1985	7311	7311	1
206008	Commissioners Waters @ Tiverton	395	20/06/1975	14/08/2001	3023	1978	11
206009	Tia R @ Tia	263	22/01/1954	22/11/2001	3030	2590	43
206011	Macleay R @ Turners Flat	10127	16/01/1970	19/11/2001	51405	46085	13
206014	Wollomombi R @ Coninside	377	24/06/1954	27/11/2001	3755	2499	41

Station	Station name	Area (km²)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
206015	Chandler R @ Euringilly	208	07/02/1979	06/06/1985	876	587	3
206017	Serpentine Ck @ causeway	23	28/07/1954	11/11/1985	619	513	22
206018	Apsley R @ Apsley Falls	863	12/11/1952	22/11/2001	7101	4977	40
206021	Oaky R above Oaky Dam	140	05/06/1980	11/01/1983	315	315	2
206024	Macleay R D/S Georges R	8004	28/06/1969	18/11/2001	47433	41949	18
206025	Salisbury Waters near Dangars Falls	649	30/12/1972	19/12/2001	4667	2403	26
206026	Sandy Ck @ Newholme	9	20/09/1974	16/10/2001	30	16	20
206027	Pipeclay Ck @ Kirby Farm	9	30/11/1974	26/09/2001	36	13	19
206033	Apsley R @ Apsley Gorge	2463	18/12/1981	04/03/2001	20844	17109	16

Figure 34. Generated salt load per unit source area for stations in the Macleay River basin
Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 35. Land-use in the Macleay River basin

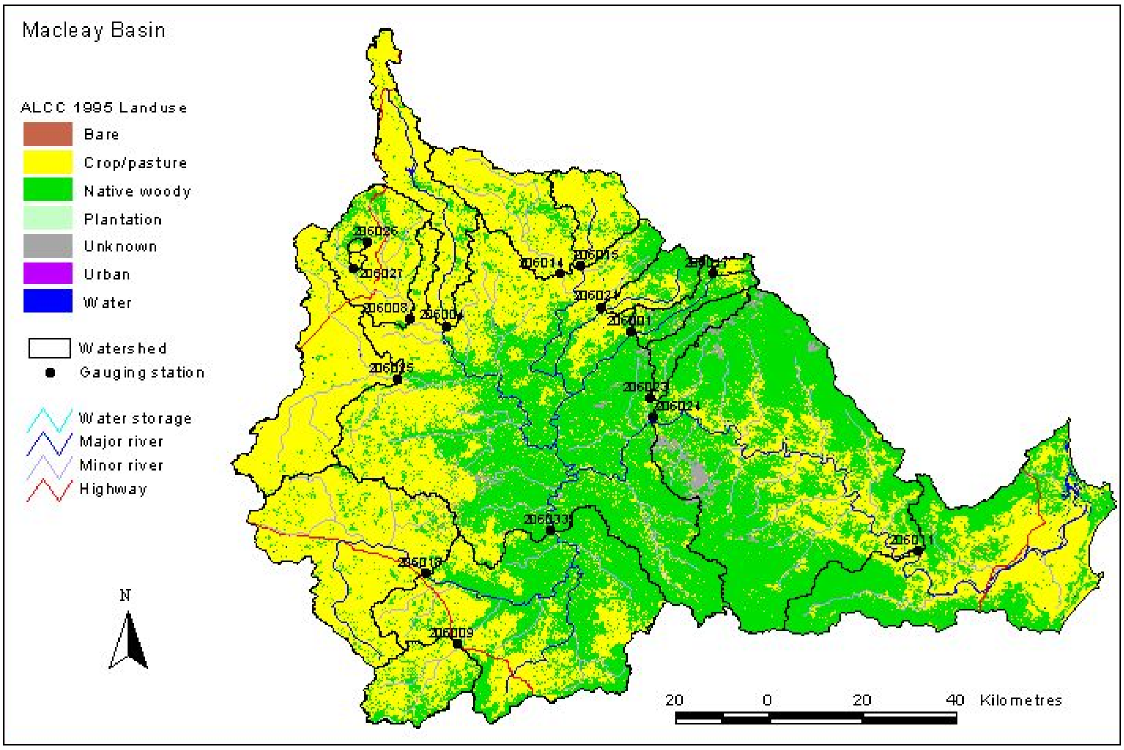
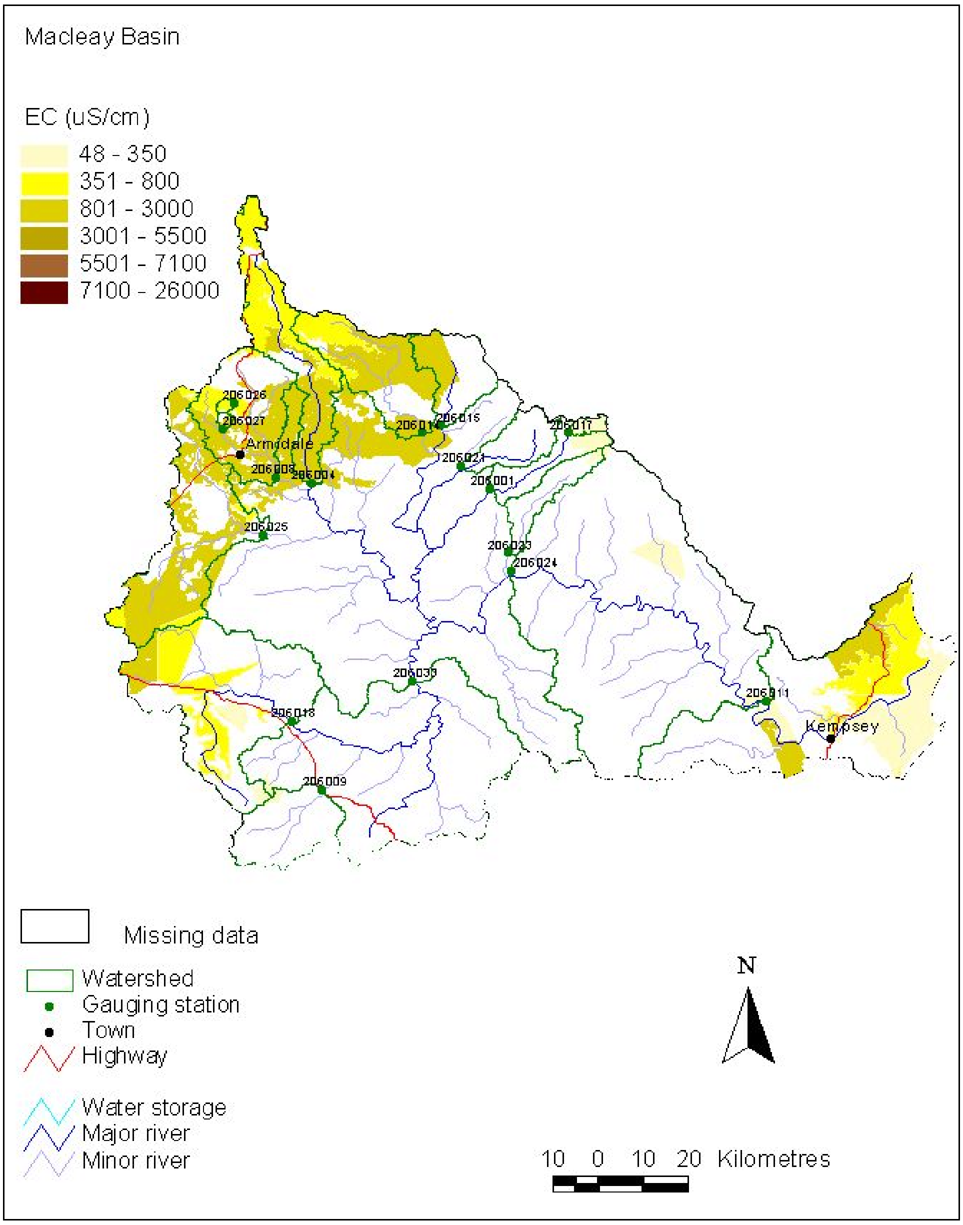


Table 18. Land-use statistics for catchments in the Macleay River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
206001	Styx R @ Jeogla	74	26	0
206004	Gara R @ Gara	10	90	0
206008	Commissioners Waters @ Tiverton	17	82	0
206009	Tia R @ Tia	33	67	0
206011	Macleay R @ Turners Flat	73	27	0
206014	Wollomombi R @ Coninside	13	87	0
206015	Chandler R @ Euringilly	15	85	0
206017	Serpentine Ck @ causeway	36	64	0
206018	Apsley R @ Apsley Falls	9	91	0
206021	Oaky R above Oaky Dam	55	45	0
206023	Georges R @ Big Hill	89	11	0
206024	Macleay R D/S Georges R	56	44	0
206025	Salisbury Waters near Dangars Falls	3	97	0
206026	Sandy Ck @ Newholme	36	64	0
206027	Pipeclay Ck @ Kirby Farm	5	94	0
206033	Apsley R @ Apsley Gorge	56	44	0
206###	Macleay remaining	51	47	2

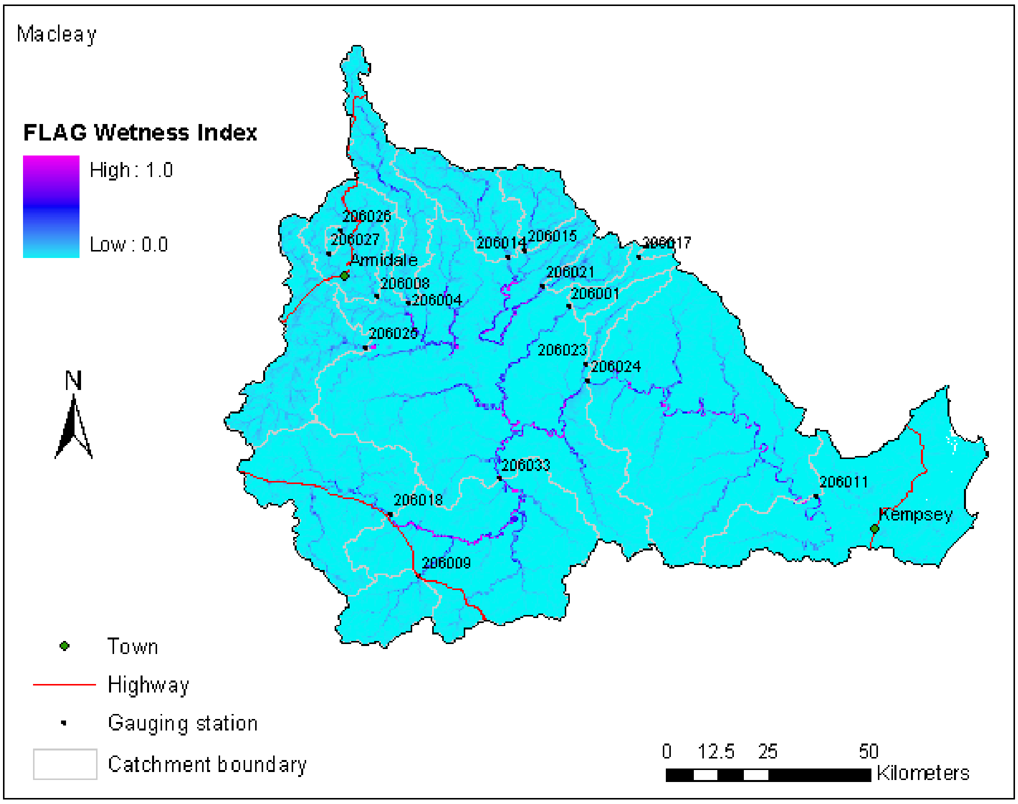
Groundwater salinity

Figure 36. Projected groundwater salinity in the Macleay River basin



FLAG wetness map

Figure 37. FLAG wetness map for the Macleay River basin



Appendix 6. Hastings River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Hastings River basin.

Stream salinity

Table 19. Stream salinity in the Hastings River basin

Station	Start date	End date	n (days)	Median daily EC (µS.cm^{-1})	80th percentile daily EC (non-exceedance) (µS.cm^{-1})	Mean daily EC (µS.cm^{-1})
207004	30/08/1972	31/07/2001	10336	127	153	130
207006	07/02/1973	08/01/2001	10000	77	94	80
207009	08/10/1979	16/03/1989	3094	105	111	105
207010	24/06/1985	31/07/2001	1624	116	134	116
207011	07/02/1980	17/06/1985	1729	114	147	119
207012	13/12/1972	02/02/1989	5895	128	147	130
207013	06/05/1975	20/11/2001	9442	153	178	155

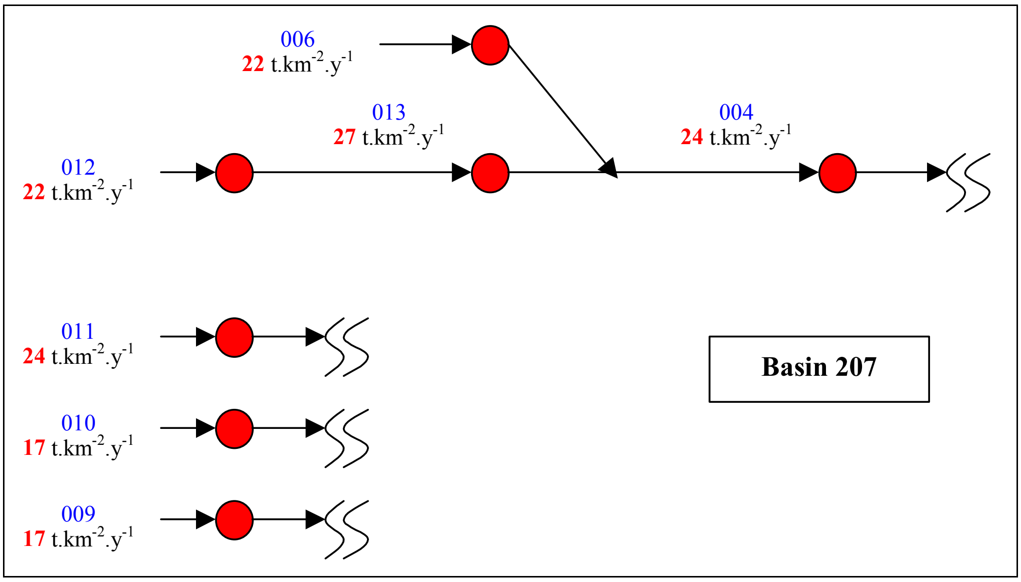
Salt load

Table 20. Saltloads for the Hastings River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
207004	Hastings R @ Ellenborough	1579	30/08/1972	31/07/2001	38269	29919	21
207006	Forbes R @ Birdwood	333	07/02/1973	08/01/2001	7203	6094	18
207009	Camden Haven R @ Kendall	226	08/10/1979	16/03/1989	3935	3659	5
207010	Pappinbarra Ck @ Beechwood	237	24/06/1985	31/07/2001	4036	2667	3
207011	Thone R @ Bagnoo	112	07/02/1980	17/06/1985	2702	2702	2
207012	Doyles R @ Doyles R Rd	64	13/12/1972	02/02/1989	1414	1082	16
207013	Ellenborough R D/S Bunnoo R Junction	497	06/05/1975	20/11/2001	13318	11677	22

Figure 38. Generated salt load per unit source area for stations in the Hastings River basin
Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 39. Land-use in the Hastings River basin

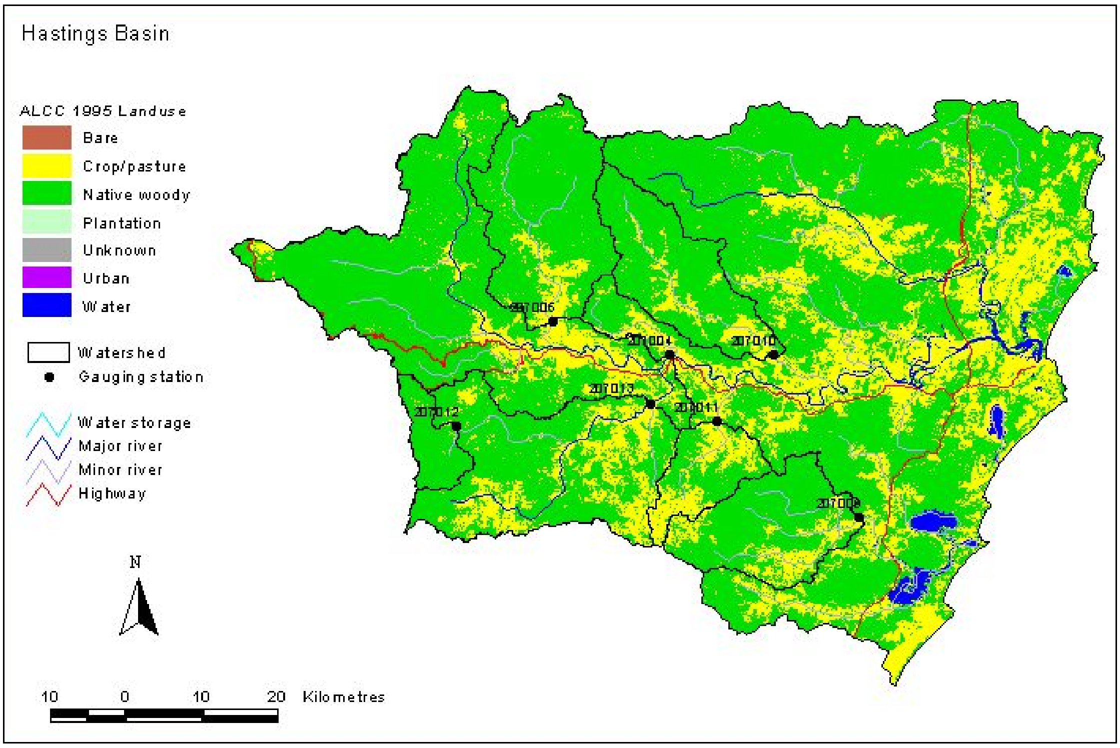
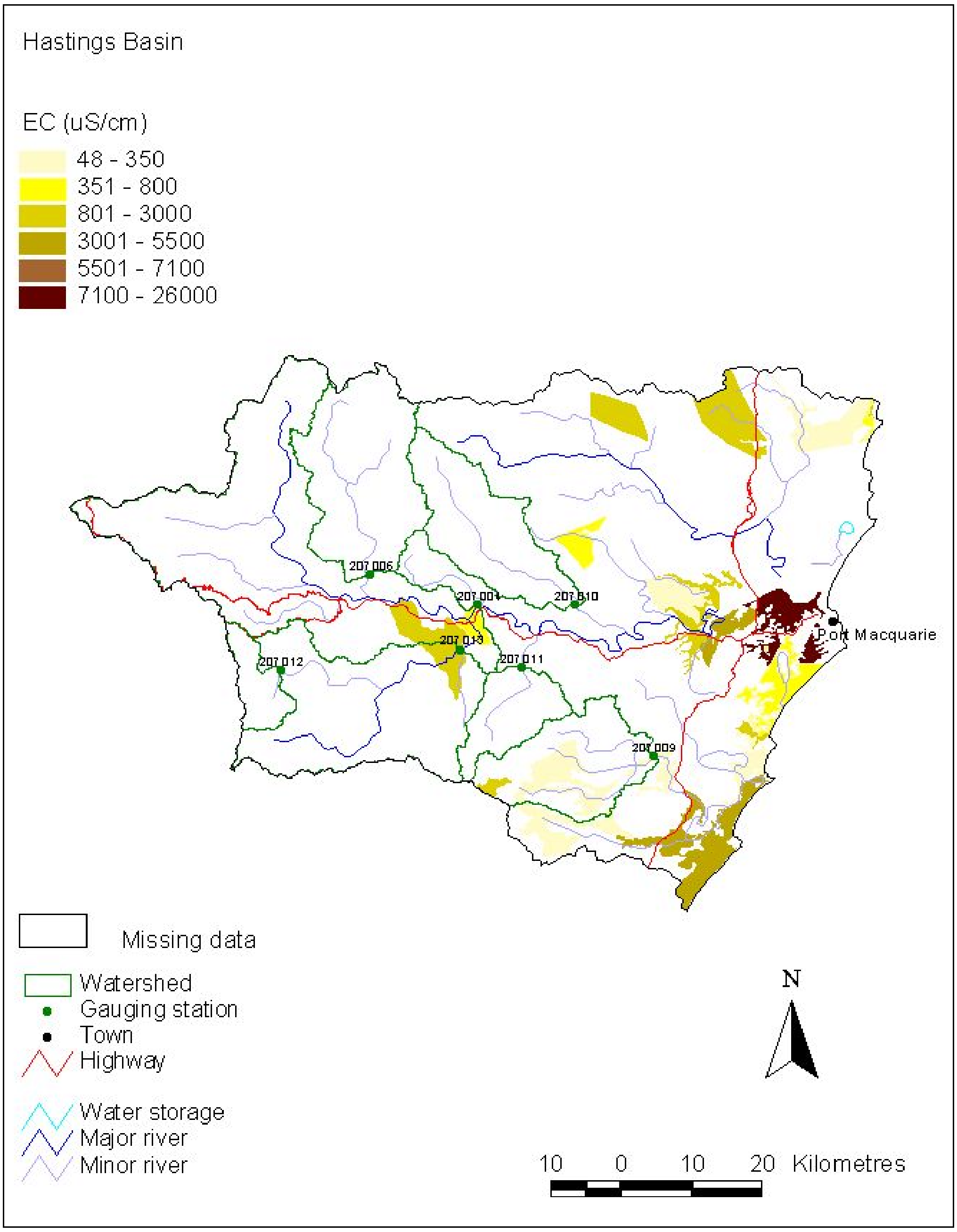


Table 21. Land-use statistics for catchments in the Hastings River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
207004	Hastings R @ Ellenborough	82	18	0
207006	Forbes R @ Birdwood	88	12	0
207009	Camden Haven R @ Kendall	78	22	0
207010	Pappinbarra Ck @ Beechwood	84	16	0
207011	Thone R @ Bagnoo	52	48	0
207012	Doyles R @ Doyles R Rd	99	1	0
207013	Ellenborough R D/S Bunnoo R Junction	70	30	0
207###	Hastings remaining	65	33	3

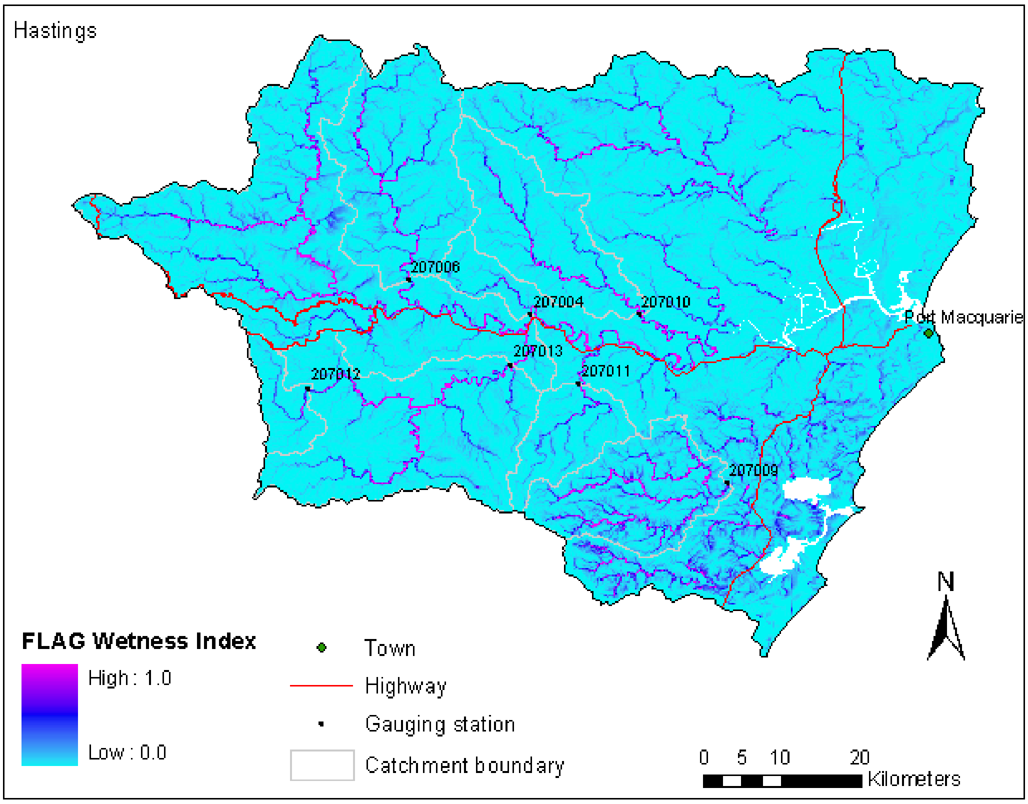
Groundwater salinity

Figure 40. Projected groundwater salinity in the Hastings River basin



FLAG wetness map

Figure 41. FLAG wetness map for the Hastings River basin



Appendix 7. Manning River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Manning River basin.

Stream salinity

Table 22. Stream salinity in the Manning River basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
208001	27/01/1954	19/07/2001	16246	20	28	22
208003	24/08/1972	20/01/2002	10481	134	169	139
208004	25/08/1972	12/12/2001	10437	161	189	164
208005	28/11/1972	20/01/2002	10504	145	167	147
208006	05/05/1972	22/11/2001	10544	81	103	84
208007	30/06/1973	12/10/2001	10187	94	108	94
208008	05/03/1972	18/06/1985	4645	84	102	88
208009	01/01/1986	25/11/2001	5758	192	241	198
208011	15/05/1973	12/10/2001	10026	177	216	183
208012	29/04/1971	19/06/1985	5153	164	200	169
208013	03/05/1980	29/10/1985	2064	153	170	152
208014	03/05/1980	29/10/1985	2064	155	186	158
208015	19/10/1978	12/11/2001	7014	198	264	209
208016	08/09/1979	28/10/1985	2037	286	367	297
208019	14/08/1971	29/10/1985	5088	148	180	152
208022	30/11/1979	19/01/1992	4281	256	291	261
208024	04/02/1982	23/10/2001	7144	180	219	184

Salt load

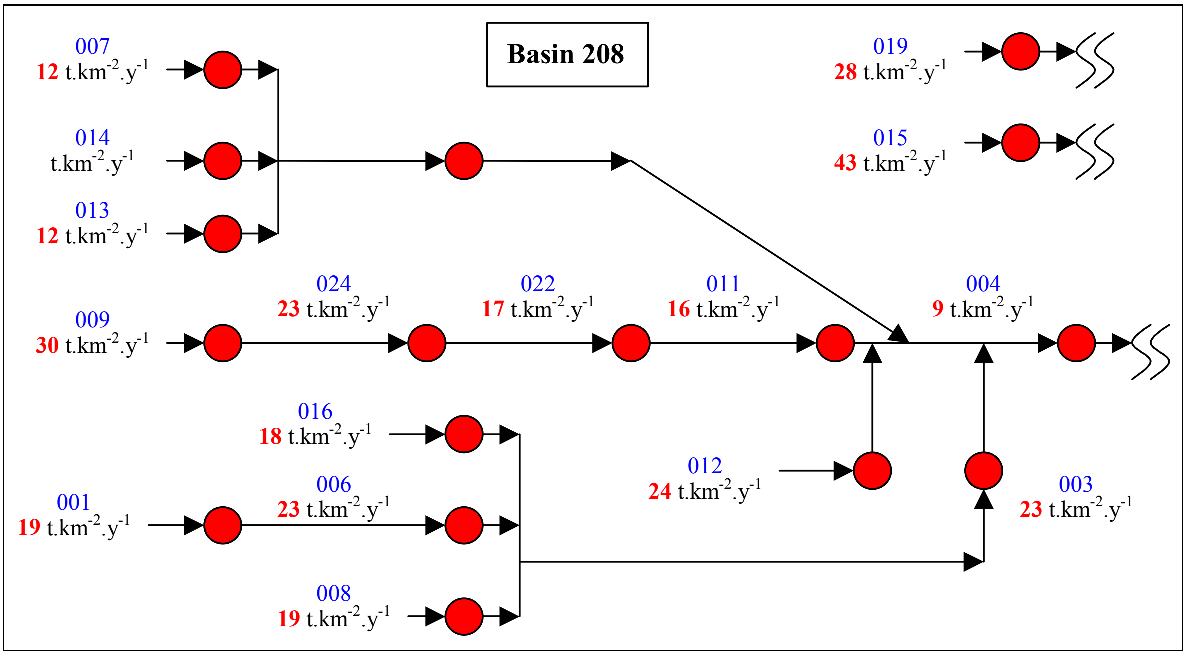
Table 23. Saltloads for the Manning River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
208001	Barrington R @ Bobs XG	21	27/01/1954	19/07/2001	392	387	29
208003	Gloucester R @ Doon Ayre	1629	24/08/1972	20/01/2002	36736	32686	21
208004	Manning R @ Killawarra	6618	25/08/1972	12/12/2001	59382	57902	10
208005	Nowendoc R @ Rocks XG	1883	28/11/1972	20/01/2002	28664	23967	25
208006	Barrington R @ Forbesdale	605	05/05/1972	22/11/2001	13859	12172	23
208007	Nowendoc R @ Nowendoc	221	30/06/1973	12/10/2001	2608	2262	22
208008	Gloucester R @ Forbesdale	195	05/03/1972	18/06/1985	3773	2842	7
208009	Barnard R @ Barry	152	01/01/1986	25/11/2001	4634	4858	13

Station	Station name	Area (km²)	Start date	End date	Average annual saltload (t.yr⁻¹)	Median annual saltload (t.yr⁻¹)	n
208011	Barnard R @ Mackay	1811	15/05/1973	12/10/2001	28637	20223	20
208012	Manning R @ Woko	462	29/04/1971	19/06/1985	10967	8733	12
208013	Rowleys R @ No.1	713	03/05/1980	29/10/1985	8743	7198	4
208014	Cooplacurripa R @ Glamis	649	03/05/1980	29/10/1985	8826	6979	4
208015	Lansdowne R @ Lansdowne	92	19/10/1978	12/11/2001	3968	3132	18
208016	Bowman R @ Wapra	179	08/09/1979	28/10/1985	3305	2416	4
208019	Dingo Ck @ Munyaree	516	14/08/1971	29/10/1985	14357	12709	10
208022	Barnard R @ the Pimple	766	30/11/1979	19/01/1992	12790	9084	10
208024	Barnard R D/S Back R Junction	281	04/02/1982	23/10/2001	6426	5847	18

Figure 42. Generated salt load per unit source area for stations in the Manning River basin
Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 43. Land-use in the Manning River basin

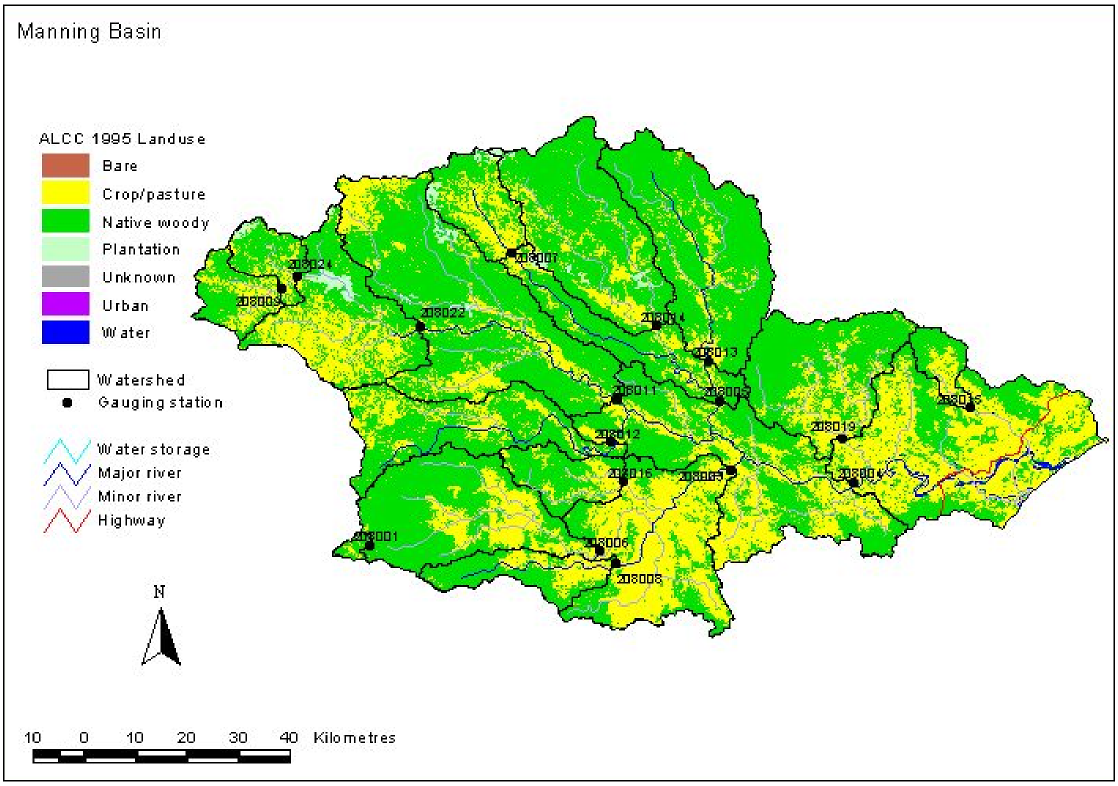


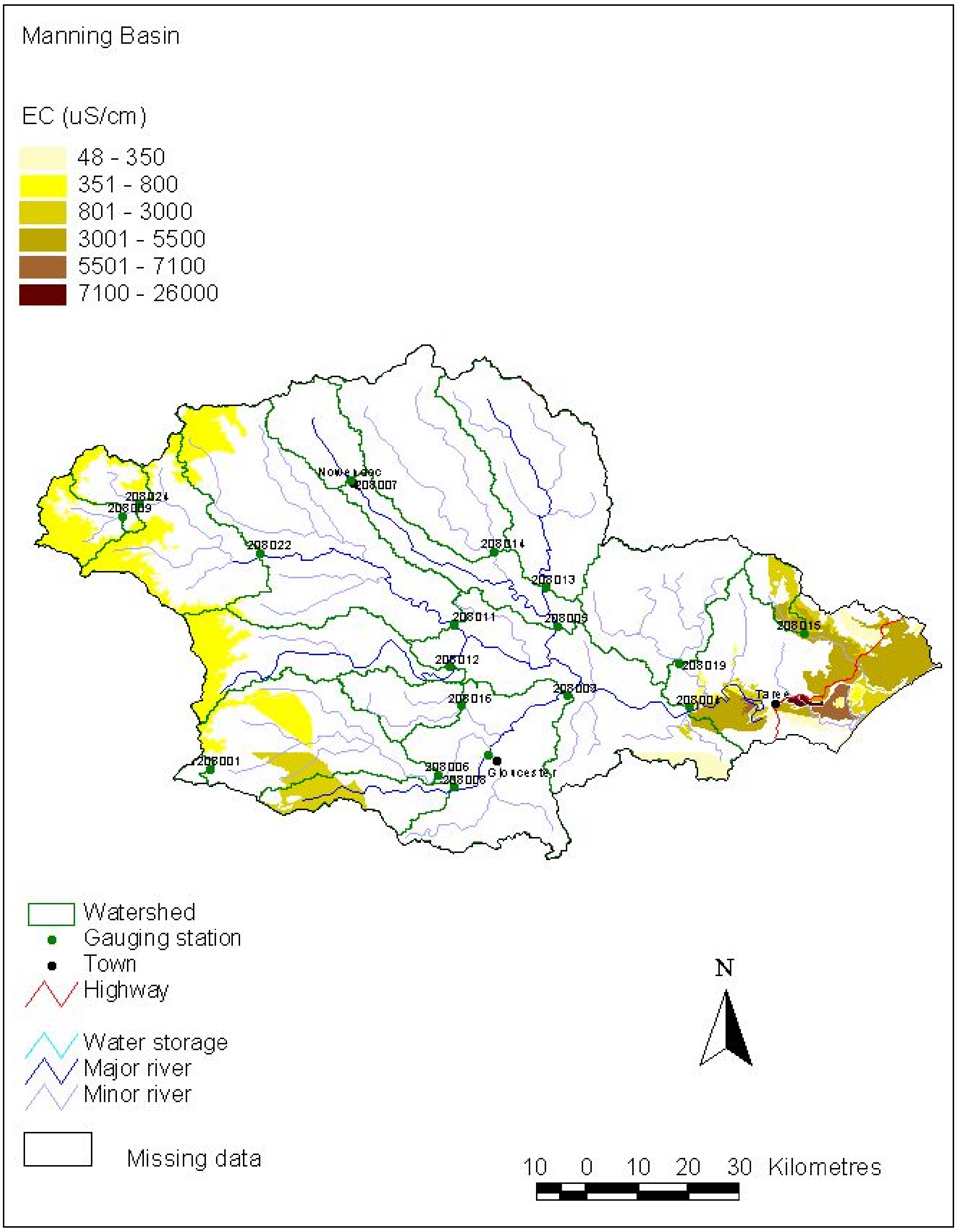
Table 24. Land-use statistics for catchments in the Manning River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
208001	Barrington R @ Bobs XG	85	15	0
208003	Gloucester R @ Doon Ayre	32	68	0
208004	Manning R @ Killawarra	56	44	0
208005	Nowendoc R @ Rocks XG	75	25	0
208006	Barrington R @ Forbesdale	72	28	0
208007	Nowendoc R @ Nowendoc	55	45	0
208008	Gloucester R @ Forbesdale	66	34	0
208009	Barnard R @ Barry	59	41	0
208011	Barnard R @ Mackay	76	24	0
208012	Manning R @ Woko	70	30	0
208013	Rowleys R @ No.1	87	13	0
208014	Cooplacurripa R @ Glamis	81	19	0
208015	Lansdowne R @ Lansdowne	60	40	0
208016	Bowman R @ Wapra	69	31	0
208019	Dingo Ck @ Munyaree	72	28	0

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
208022	Barnard R @ the Pimple	55	45	0
208024	Barnard R D/S Back R Junction	71	29	0
208###	Manning remaining	34	63	3

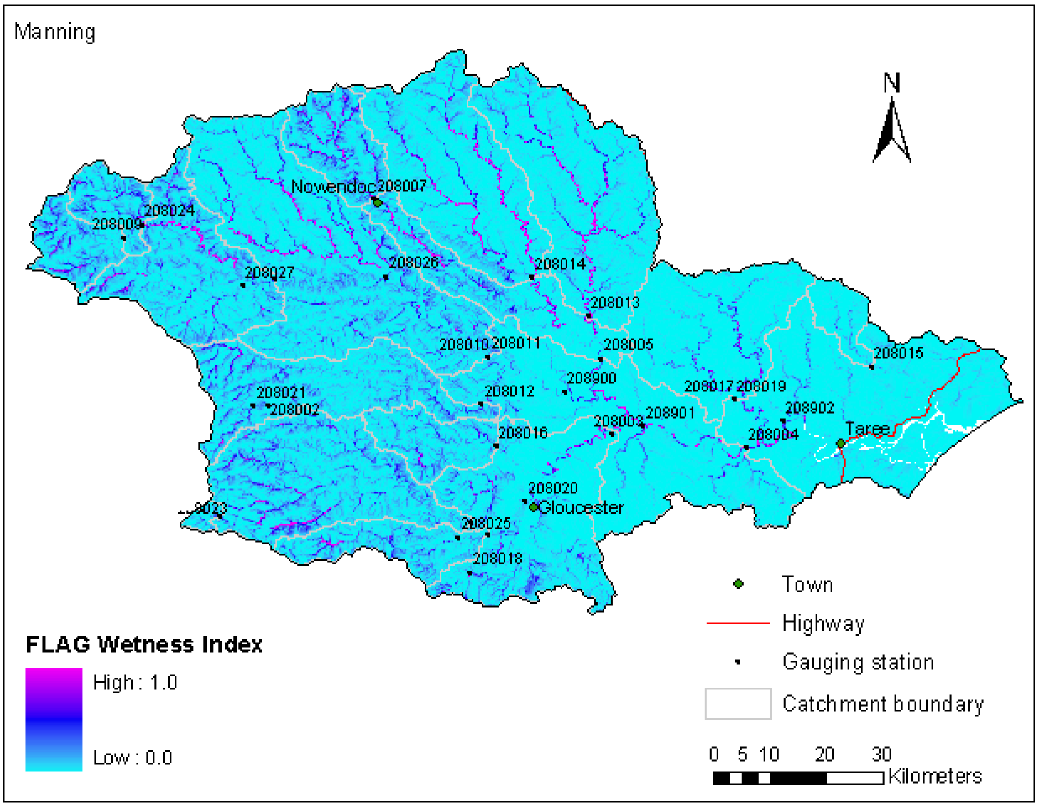
Groundwater salinity

Figure 44. Projected groundwater salinity in the Manning River basin



FLAG wetness map

Figure 45. FLAG wetness map for the Manning River basin



Appendix 8. Karuah River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Karuah River basin.

Stream salinity

Table 25. Stream salinity in the Karuah River basin

Station	Start date	End date	n (days)	Median daily EC (μS.cm^{-1})	80th percentile daily EC (non-exceedance) (μS.cm^{-1})	Mean daily EC (μS.cm^{-1})
209002	21/06/1973	09/12/2001	8310	227	295	236
209003	07/05/1973	19/03/2000	9006	236	264	238
209006	12/03/1977	09/12/2001	6474	564	870	620
209018	19/12/1979	11/08/2001	7489	152	178	155

The Wang Wauk River catchment (209006) in the Karuah River basin equals or exceeds WHO standards about 20% of the time during low flows.

Salt load

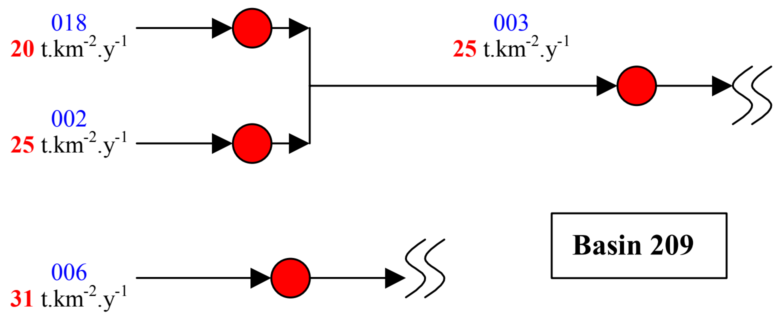
Table 26. Saltloads for the Karuah River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
209002	Mammy Johnson's R @ Pikes Crossing	157	21/06/1973	09/12/2001	3893	3241	21
209003	Karuah R @ Booral	970	07/05/1973	19/03/2000	24447	19820	16
209006	Wang Wauk R @ Willina	148	12/03/1977	09/12/2001	4611	4834	20
209018	Karuah R @ Dam Site	291	19/12/1979	11/08/2001	5762	5599	16

Figure 46. Generated salt load per unit source area for stations in the Karuah River basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 47. Land-use in the Karuah River basin

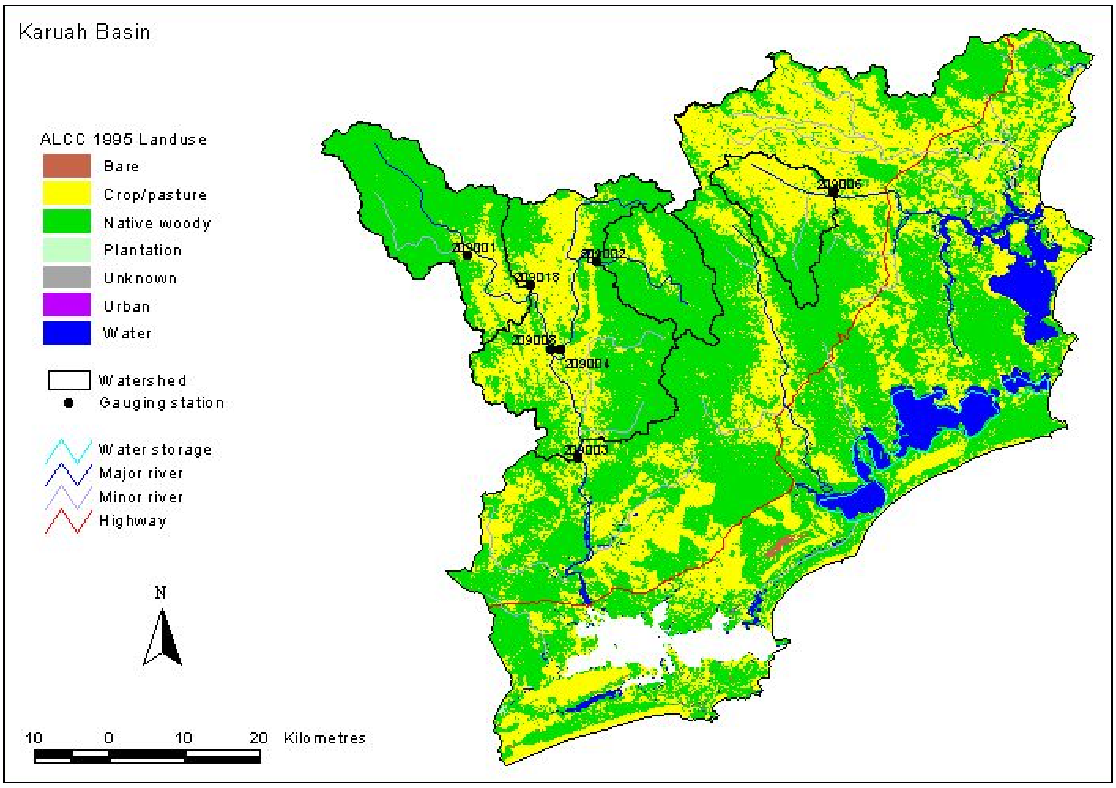
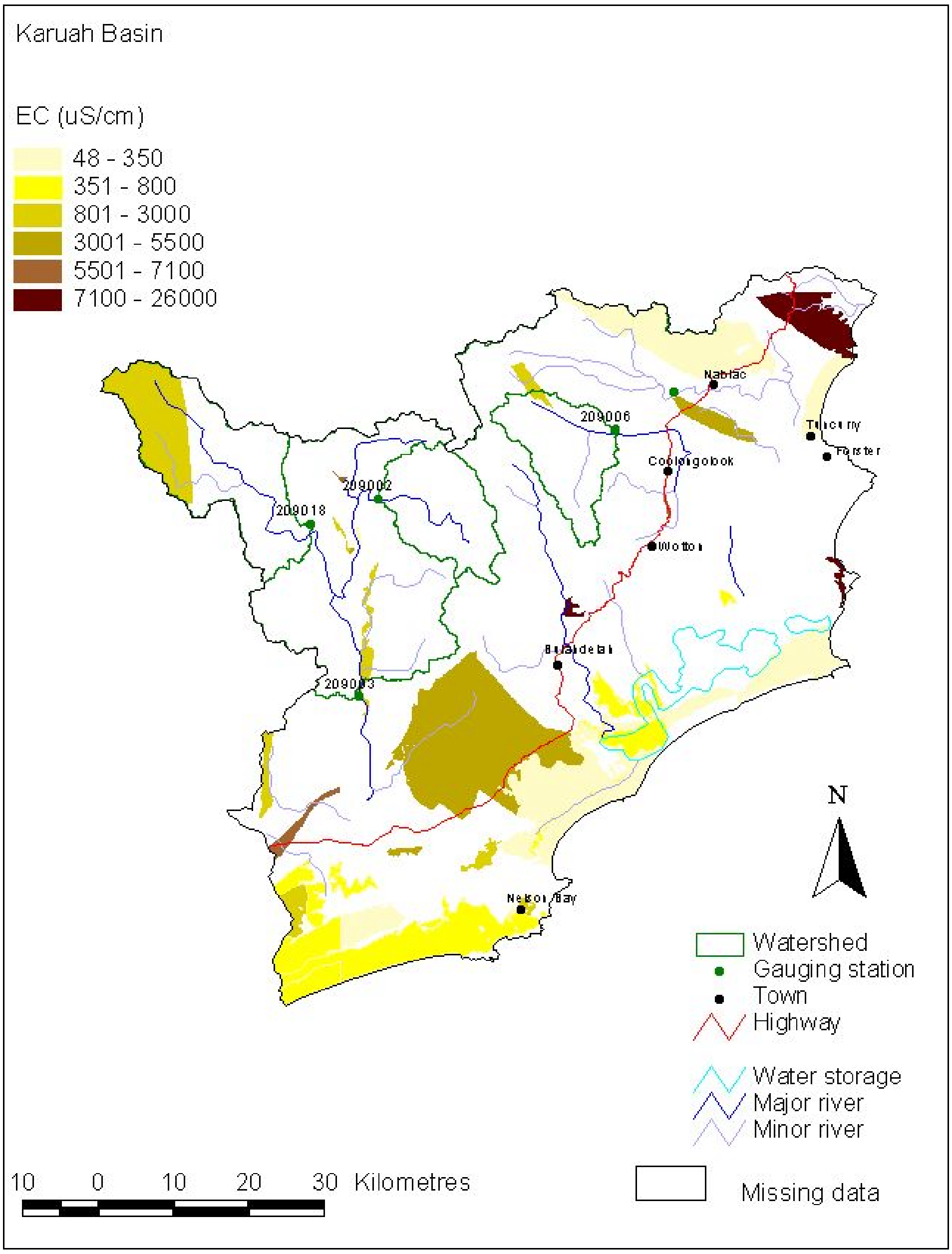


Table 27. Land-use statistics for catchments in the Richmond River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
209002	Mammy Johnson's R @ Pikes XG	86	14	0
209003	Karuah R @ Booral	57	43	0
209006	Wang Wauk R @ Willina	46	54	0
209018	Karuah R @ Dam Site	80	20	0
209	Karuah remaining	54	39	7

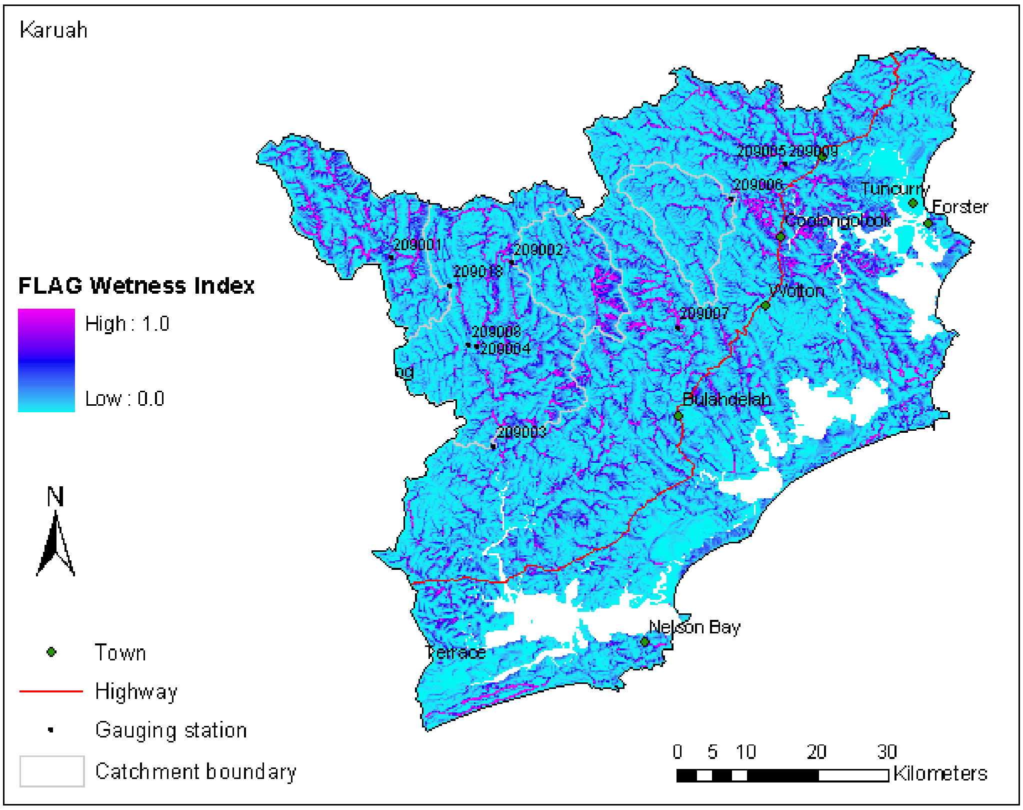
Groundwater salinity

Figure 48. Projected groundwater salinity in the Karuah River basin



FLAG wetness map

Figure 49. FLAG wetness map for the Karuah River basin



Appendix 9. Lake Macquarie and Tuggerah Lake basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Lake Macquarie and Tuggerah Lake basins.

Stream salinity

Table 28. Stream salinity in the Lake Macquarie and Tuggerah Lake basin

Station	Start date	End date	n (days)	Median daily EC (μS.cm^{-1})	80th percentile daily EC (non-exceedance) (μS.cm^{-1})	Mean daily EC (μS.cm^{-1})
211004	16/02/1974	30/12/1988	2567	275	317	275
211005	31/07/1973	25/05/1989	4783	269	316	273
211008	15/11/1973	09/09/2001	7294	627	1041	741
211009	05/12/1978	21/01/2002	8395	233	248	233
211010	31/05/1984	12/01/1994	3056	433	522	425
211013	13/11/1976	04/08/2001	8722	184	194	184
211014	11/11/1976	13/11/2000	8617	241	256	241

The 80th percentile salinity in Jigadee Creek (211008) exceeds the WHO standard but all other streams are fresh.

Salt load

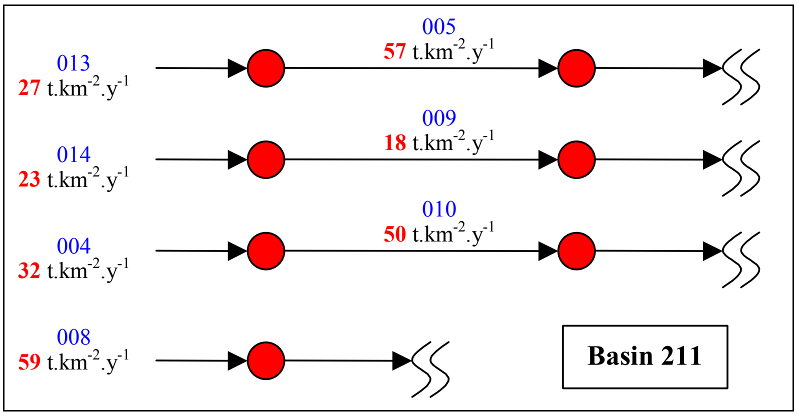
Table 29. Saltloads for the Lake Macquarie and Tuggerah Lake basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
211004	Jilliby Ck @ Olney	4	16/02/1974	30/12/1988	126	117	6
211005	Ourimbah Ck Tuggerah	152	31/07/1973	25/05/1989	8655	6442	5
211008	Jigadee Ck @ Avondale	55	15/11/1973	09/09/2001	3244	3062	19
211009	Wyong R @ Gracemere	236	05/12/1978	21/01/2002	4156	3499	17
211010	Jilliby Ck U/S Wyong	92	31/05/1984	12/01/1994	4639	4741	6
211013	Ourimbah Ck U/S Weir	83	13/11/1976	04/08/2001	2255	2010	21
211014	Wyong R @ Yarramalong	180	11/11/1976	13/11/2000	4113	3596	16
212008	Coxs R @ Bathurst Rd	198	02/09/1951	23/01/2002	4349	3140	41

Figure 50. Generated salt load per unit source area for stations in the Lake Macquarie and Tuggerah Lake basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 51. Land-use in the Lake Macquarie and Tuggerah Lake basin

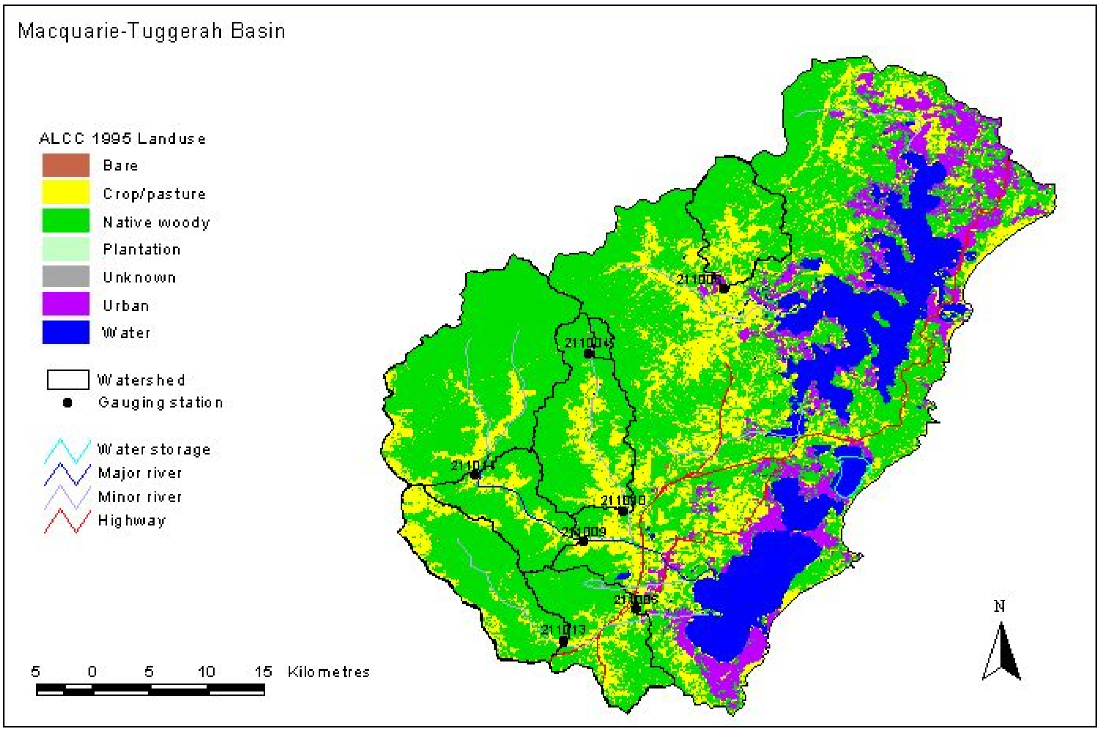


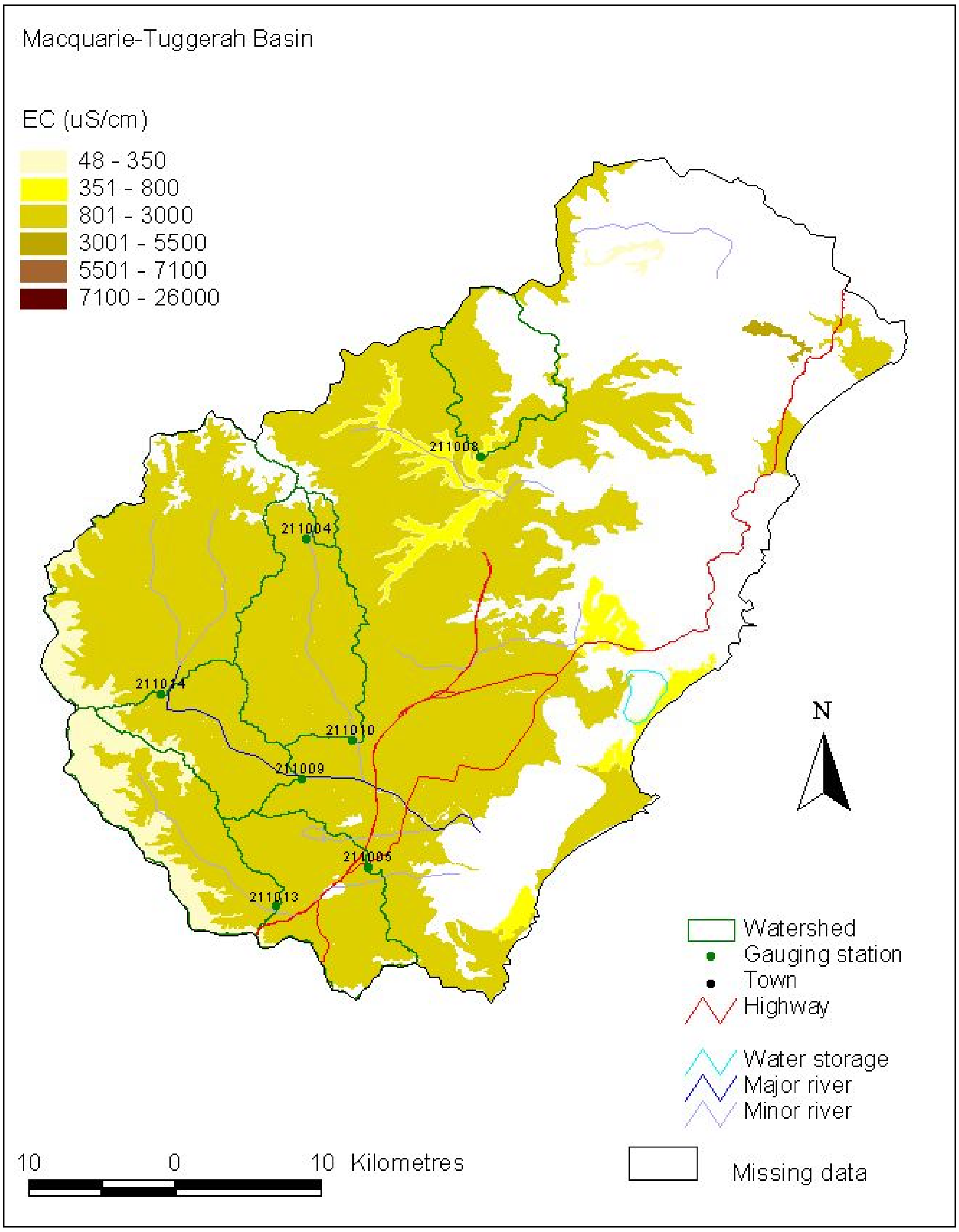
Table 30. Land-use statistics for catchments in the Lake Macquarie and Tuggerah Lake basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
211004	Jilliby Ck @ Olney	100	0	0
211005	Ourimbah Ck Tuggerah	77	22	0
211008	Jigadee Ck @ Avondale	73	25	1

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
211009	Wyong R @ Gracemere	76	24	0
211010	Jilliby Ck U/S Wyong	74	26	0
211013	Ourimbah Ck U/S Weir	77	23	0
211014	Wyong R @ Yarramalong	88	12	0
211###	Macquarie-Tuggerah remaining	46	23	32

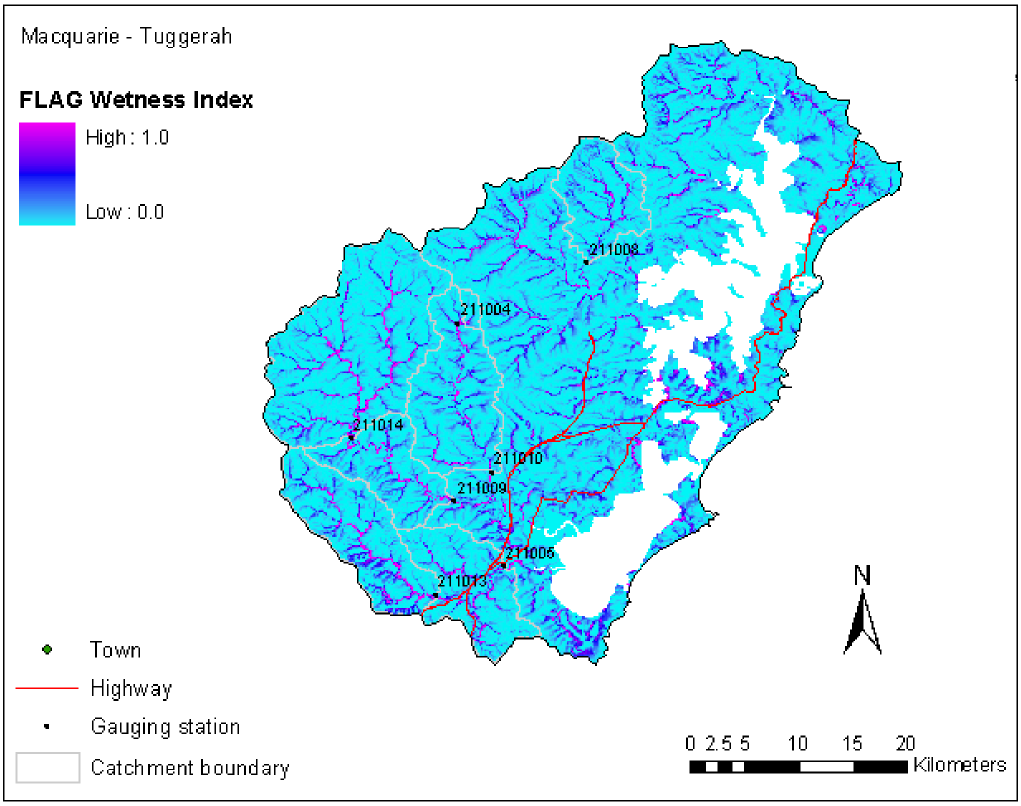
Groundwater salinity

Figure 52. Projected groundwater salinity in the Lake Macquarie and Tuggerah Lake basin



FLAG wetness map

Figure 53. FLAG wetness map for the Lake Macquarie and Tuggerah Lake basin



Appendix 10. Hawkesbury River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Hawkesbury River basin.

Stream salinity

Table 31. Stream salinity in the Hawkesbury River basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
212008	02/09/1951	23/01/2002	17480	397	559	492
212010	05/03/1972	17/07/1990	5589	219	264	225
212011	27/05/1960	23/01/2002	14581	206	272	219
212013	20/11/1968	16/10/2001	9945	41	61	34
212014	22/11/1968	31/03/1993	5906	98	119	109
212018	15/08/1970	10/12/2001	8695	1306	1650	1358
212019	18/04/1984	30/05/1991	2343	188	202	181
212020	27/12/1977	23/03/1993	4502	450	603	475
212021	02/10/1976	01/12/1993	4356	170	202	167
212028	07/07/1973	18/04/1993	6564	111	136	117
212038	04/03/1976	01/08/1983	2315	55	66	59
212039	16/11/1976	03/04/1992	4418	309	472	342
212040	06/09/1979	20/11/2001	7715	503	628	495
212042	24/09/1980	24/01/2002	7320	206	244	205
212320	06/01/1970	09/08/2001	4710	1214	1584	1144

Streams are generally relatively fresh except for South Creek (212320) and the Capertee River (212018).

Salt load

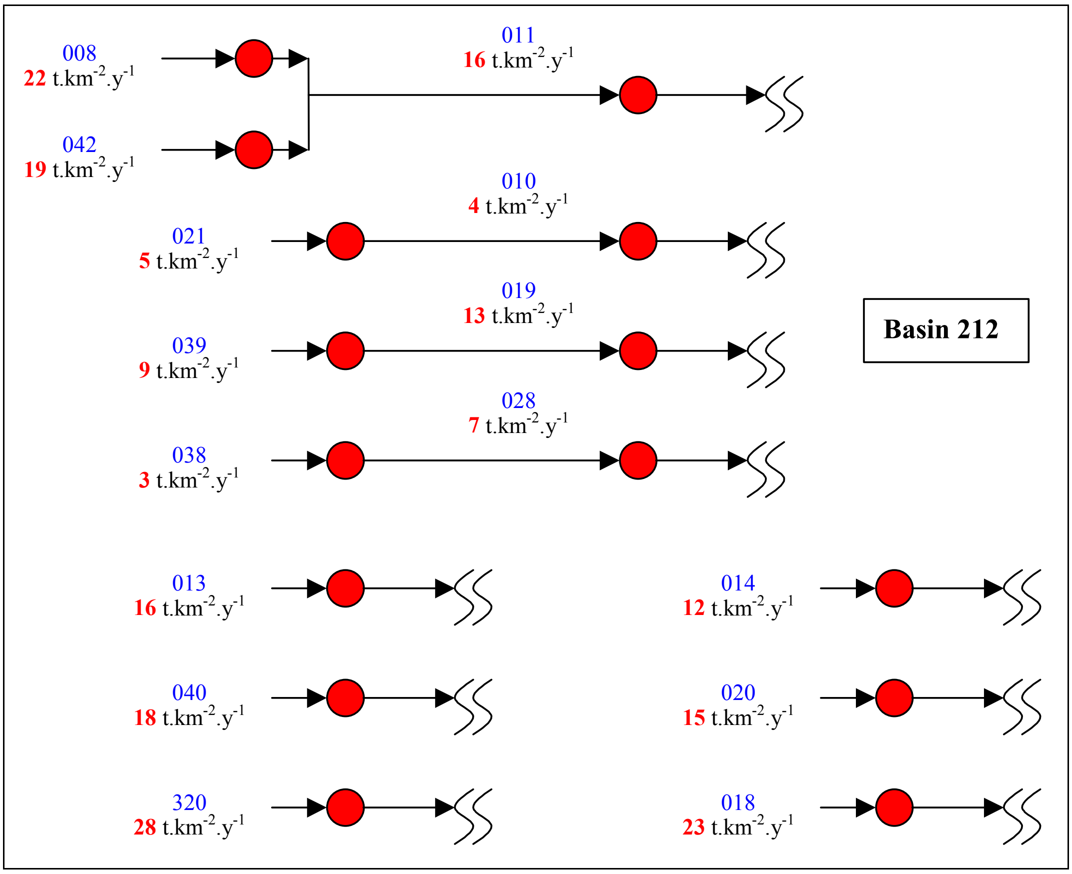
Table 32. Saltloads for the Hawkesbury River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
212008	Coxs R @ Bathurst Rd	198	02/09/1951	23/01/2002	4349	3140	41
212010	McDonald R @ St Albns	1732	05/03/1972	17/07/1990	6360	4174	21
212011	Coxs R R @ Lithgow	378	27/05/1960	23/01/2002	6100	5460	29
212013	Megalong Ck @ N'Neck	25	20/11/1968	16/10/2001	394	356	22
212014	Blckhth Ck @ Mt Boyce	20	22/11/1968	31/03/1993	241	220	15
212018	Capertee R @ G. Davis	1023	15/08/1970	10/12/2001	23600	11912	16
212019	Mangrove Ck @ Mngrv Mt	213	18/04/1984	30/05/1991	2739	2739	2
212020	Tarlo R Swallowtail	590	27/12/1977	23/03/1993	9062	7534	8

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
212021	McDonald R @ Howes Va	295	02/10/1976	01/12/1993	1564	1639	10
212028	Wolgan R @ Newnes	233	07/07/1973	18/04/1993	1525	1329	11
212038	Wolgan Cape Pinnacle	45	04/03/1976	01/08/1983	153	153	1
212039	Mangrove Ck D/S Dam	100	16/11/1976	03/04/1992	870	643	11
212040	Kialla Ck @ Pomeroy	93	06/09/1979	20/11/2001	1657	1551	15
212042	Farmers Ck @ Mt Walkr	67	24/09/1980	24/01/2002	1273	1352	11
212320	South Ck @ Mulgoa Rd	90	06/01/1970	09/08/2001	2555	1993	20

Figure 54. Generated salt load per unit source area for stations in the Hawkesbury River basins
Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 55. Land-use in the Hawkesbury River basin

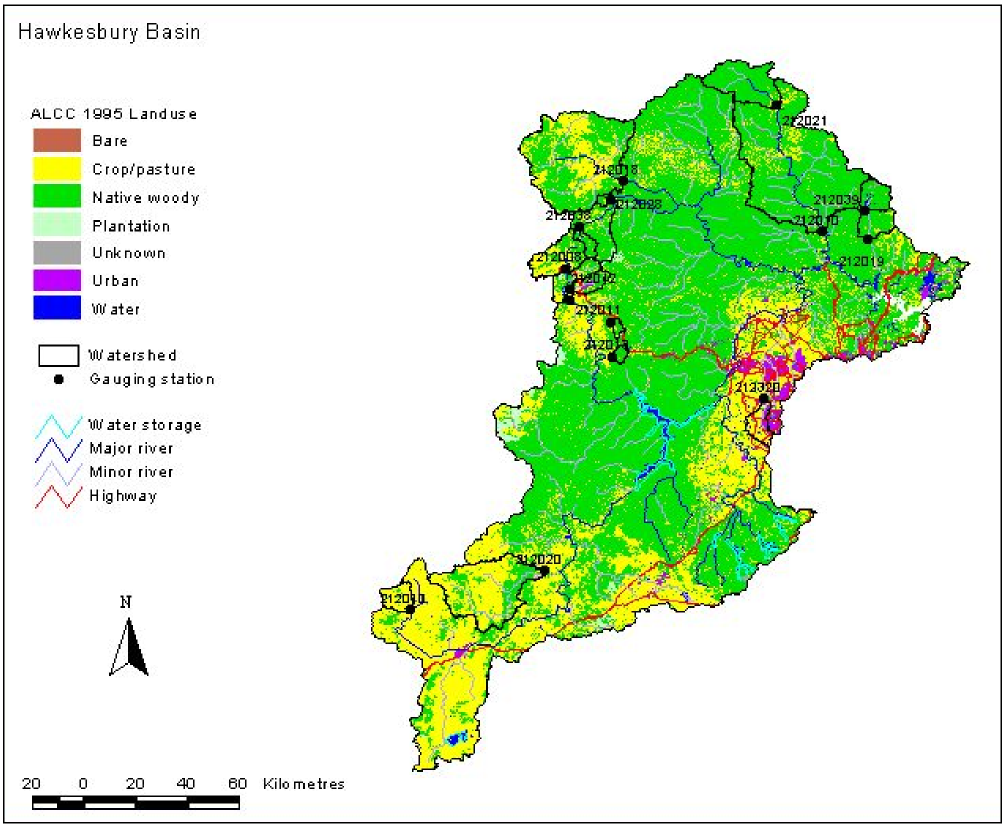
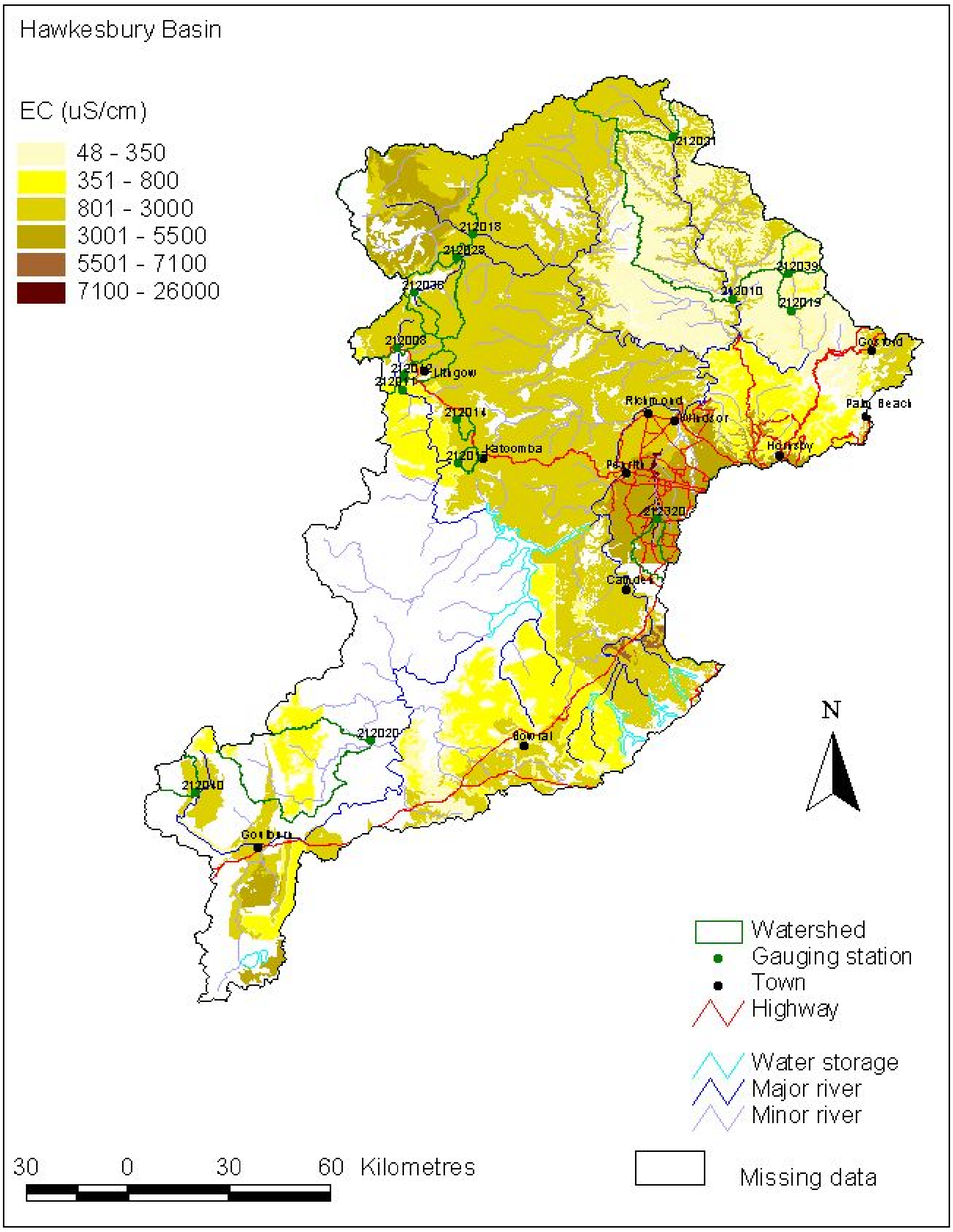


Table 33. Land-use statistics for catchments in the Hawkesbury River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
212008	Coxs R @ Bathurst Rd	46	53	1
212010	McDonald R @ St Albns	90	10	0
212011	Coxs R R @ Lithgow	64	34	1
212013	Megalong Ck @ N'Neck	93	7	0
212014	Blckhth Ck @ Mt Boyce	79	20	0
212018	Capertee R @ G. Davis	59	41	0
212019	Mangrove Ck @ Mngrv Mt	88	12	0
212020	Tarlo R Swallowtail	35	65	0
212021	McDonald R @ Howes Va	97	3	0
212028	Wolgan R @ Newnes	81	19	0
212038	Wolgan Cape Pinnacle	89	11	0
212039	Mangrove Ck D/S Dam	90	4	6
212040	Kialla Ck @ Pomeroy	6	94	0
212042	Farmers Ck @ Mt Walkr	62	25	13
212320	South Ck @ Mulgoa Rd	6	71	23
212###	Hawkesbury remaining	65	31	4

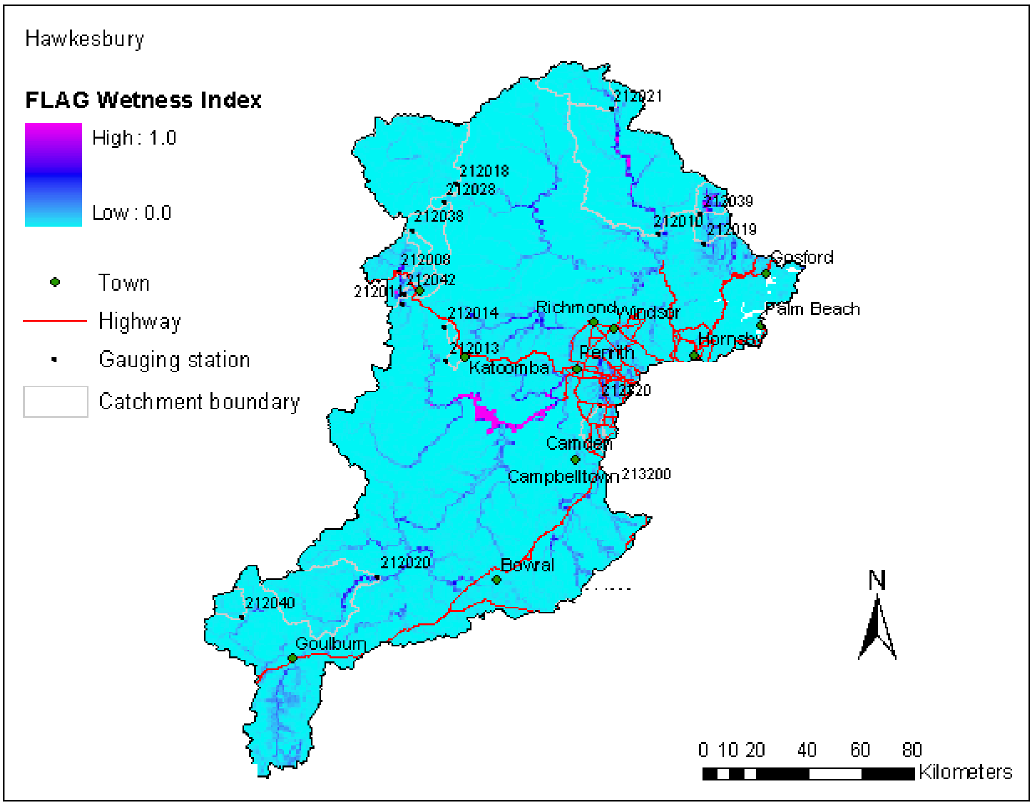
Groundwater salinity

Figure 56. Projected groundwater salinity in the Hawkesbury River basin



FLAG wetness map

Figure 57. FLAG wetness map for the Hawkesbury River basin



Appendix 11. Sydney basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Sydney basin.

Stream salinity

Table 34. Stream salinity in the Sydney basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
213004	02/07/1979	25/11/2000	7339	527	753	575
213005	17/03/1979	11/04/2001	7902	863	1322	980
213006	17/12/1980	06/05/2000	1762	541	578	530
213200	02/02/1978	17/08/2000	7418	138	166	139

Generally higher values of salinity are noted but still considered fresh except for Toongabbie Creek (213005).

Salt load

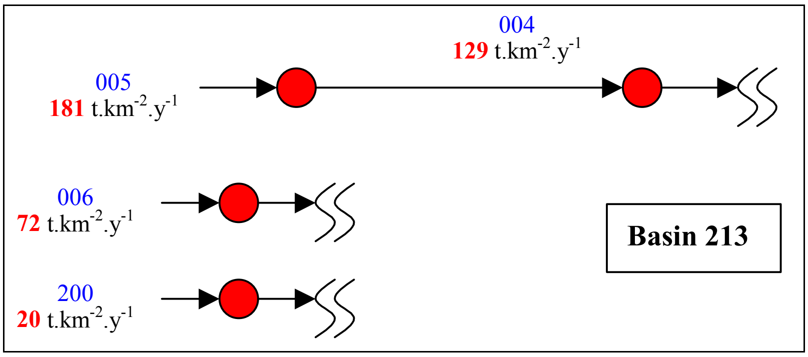
Table 35. Saltloads for the Sydney basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
213004	Parramatta R @ Parramatta	104	02/07/1979	25/11/2000	13465	11548	8
213005	Toongabbie Ck @ Briens	63	17/03/1979	11/04/2001	11399	10147	13
213006	Fisherghost Ck @ Brad.P	2	17/12/1980	06/05/2000	143	160	8
213200	O'Hare Ck Wedderburn	74	02/02/1978	17/08/2000	1511	1619	12

Figure 58. Generated salt load per unit source area for stations in the Sydney basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 59. Land-use in the Sydney basin

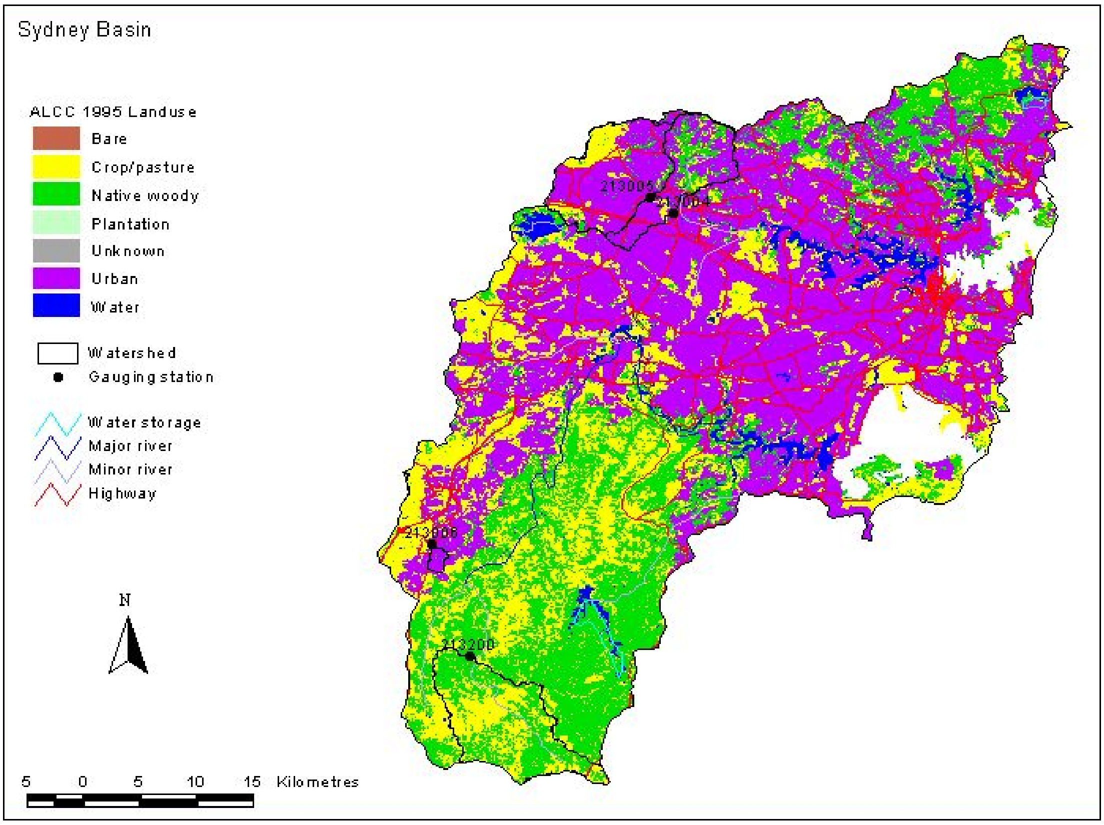
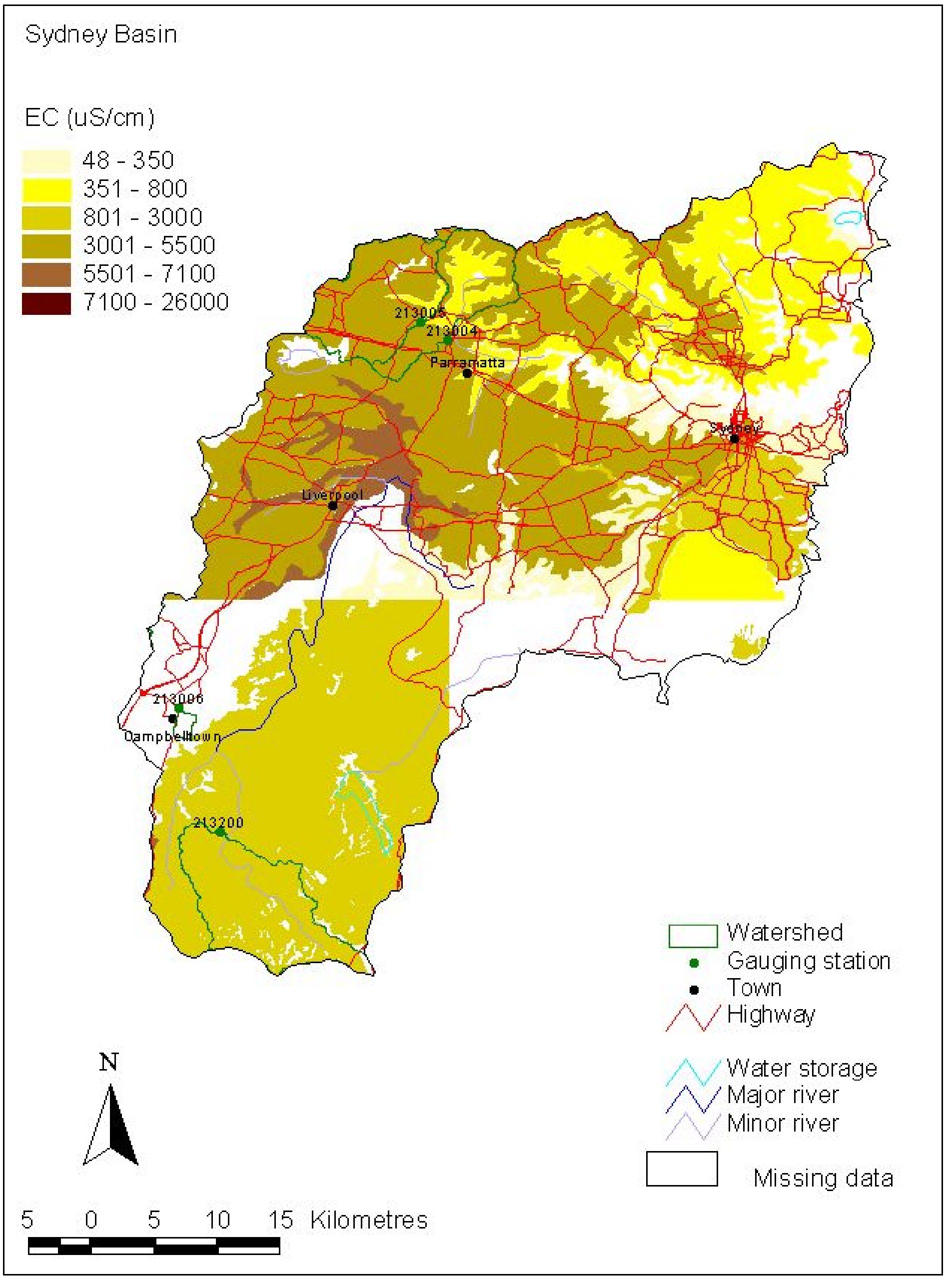


Table 36. Land-use statistics for catchments in the Sydney basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
213004	Parramatta R @ Parramatta	22	12	67
213005	Toongabbie Ck @ Briens	5	22	74
213006	Fisherghost Ck @ Brad.P	2	2	96
213200	O'Hare Ck Wedderburn	51	49	0
213###	Sydney remaining	25	25	50

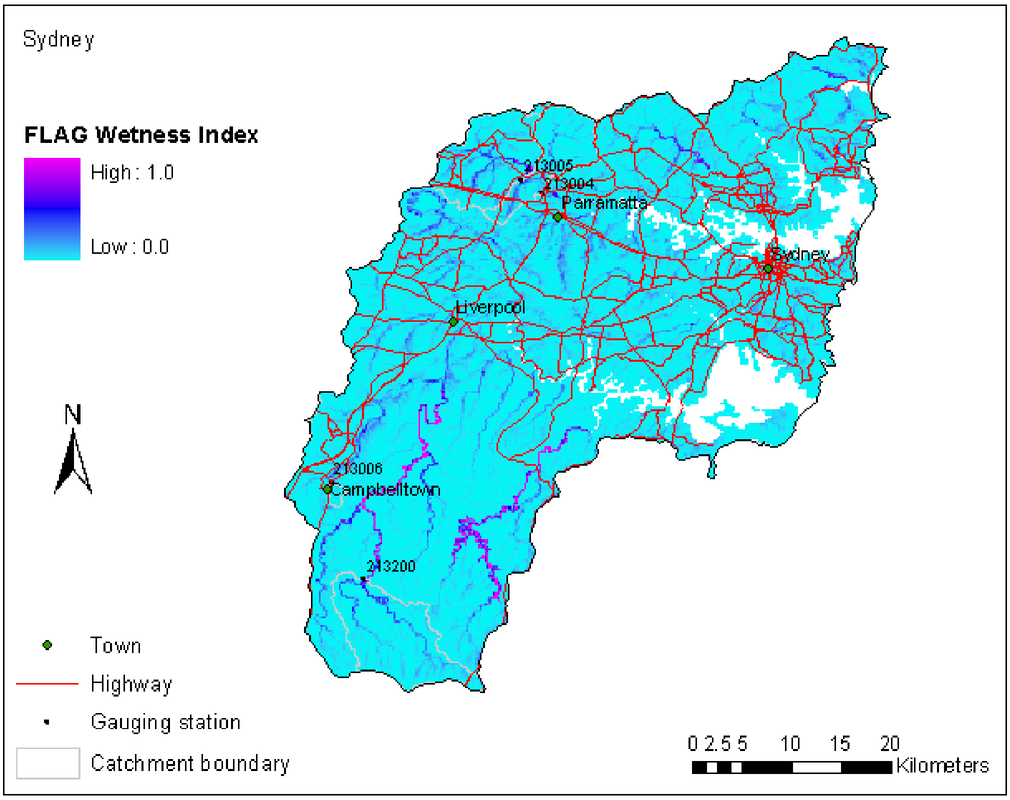
Groundwater salinity

Figure 60. Projected groundwater salinity for the Sydney basin



FLAG wetness map

Figure 61. FLAG wetness map for the Sydney basin



Appendix 12. Wollongong basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Wollongong basin.

Stream salinity

Table 37. Stream salinity in the Wollongong basin

Station	Start date	End date	n (days)	Median daily EC (µS.cm^{-1})	80th percentile daily EC (non-exceedance) (µS.cm^{-1})	Mean daily EC (µS.cm^{-1})
214003	12/05/1978	26/03/2002	8112	125	141	127

Salt load

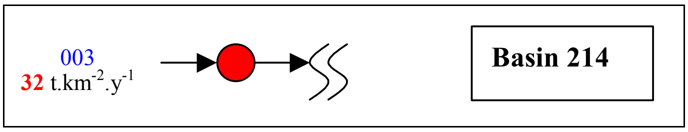
Table 38. Saltloads for the Wollongong basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
214003	Macquarie Rvt @ Albion	34	12/05/1978	26/03/2002	1098	1104	17

Figure 62. Generated salt load per unit source area for stations in the Wollongong basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 63. Land-use in the Wollongong basin

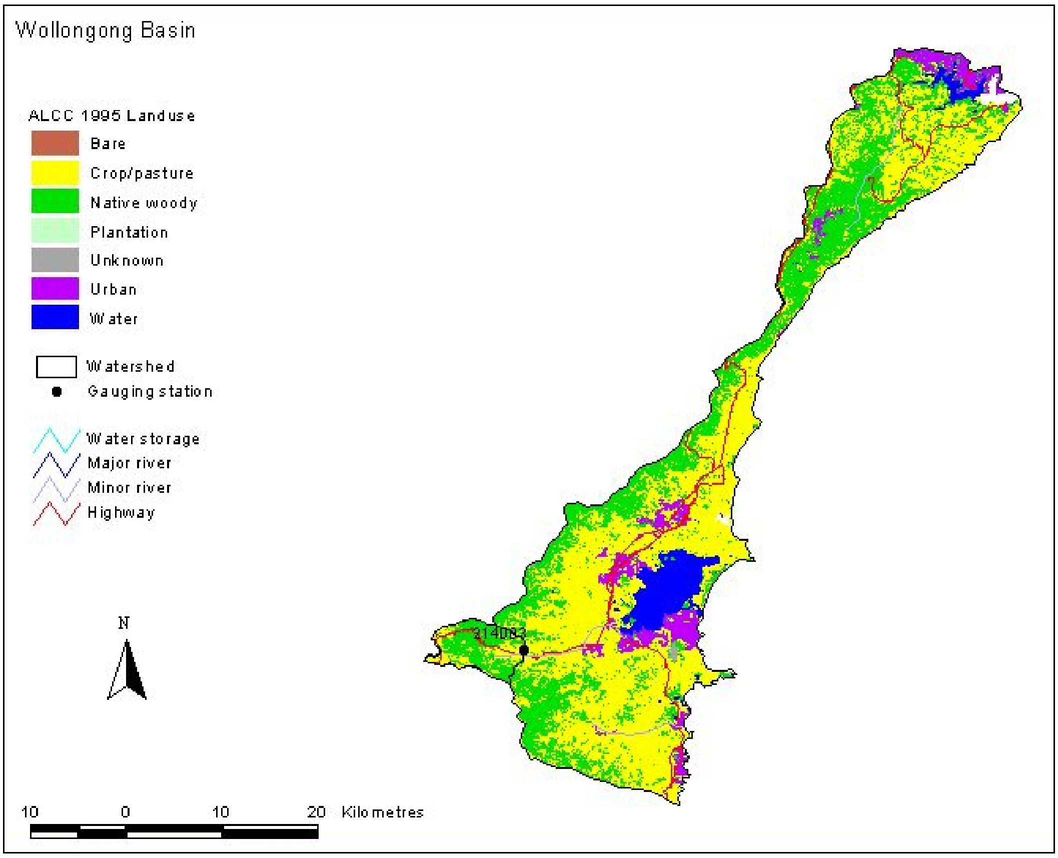
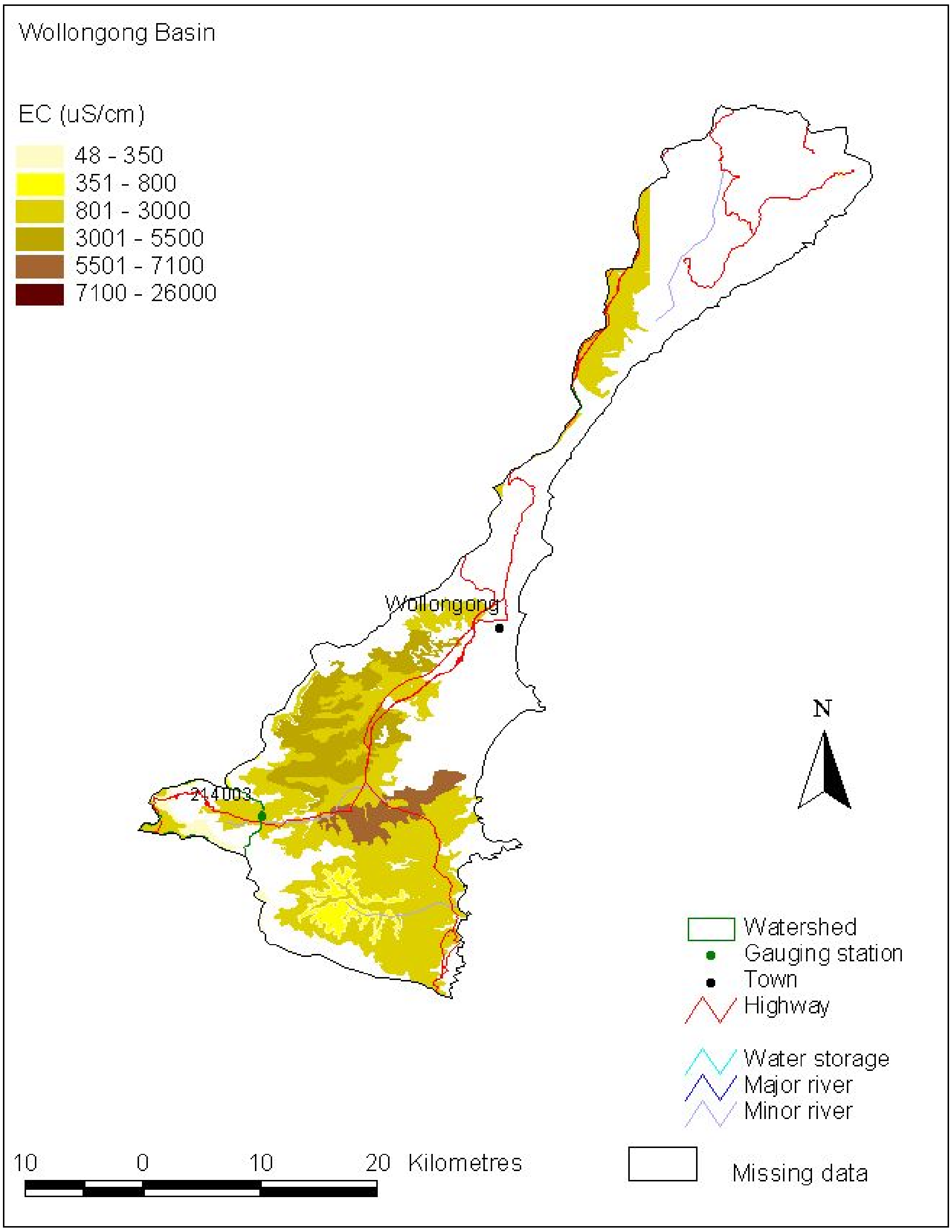


Table 39. Land-use statistics for catchments in the Wollongong basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
214003	Macquarie Rvt @ Albio	64	36	0
214###	Wollongong remaining	32	55	13

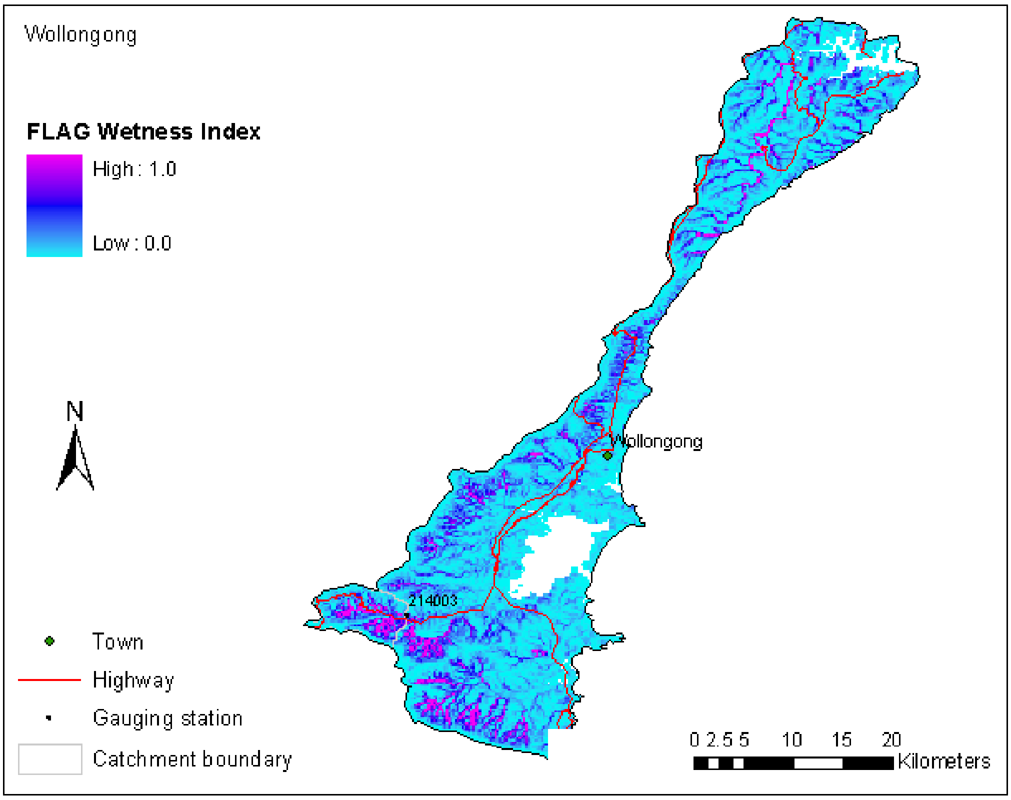
Groundwater salinity

Figure 64. Projected groundwater salinity in the Wollongong basin



FLAG wetness map

Figure 65. Projected groundwater salinity in the Wollongong basin



Appendix 13. Shoalhaven River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Shoalhaven River basin.

Stream salinity

Table 40. Stream salinity in the Shoalhaven River basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
215002	06/11/1969	20/11/2001	10903	109	131	113
215004	09/08/1924	25/09/2001	26084	80	100	83
215005	23/03/1973	31/12/1984	3774	94	114	95
215008	17/09/1950	26/09/2001	11369	67	75	67
215009	24/02/1970	20/03/1978	2894	64	77	66
215014	14/04/1981	26/09/2001	5598	739	986	720

Streams in this basin are generally very fresh. However, Bungonia Creek (215014) has a relatively high median EC and exceeds the WHO standard during low flows.

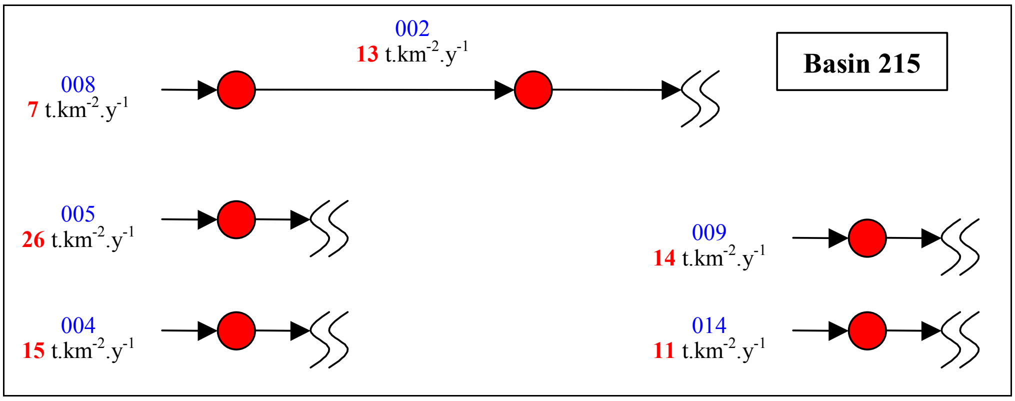
Salt load

Table 41. Saltloads for the Shoalhaven River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
215002	Shoalhaven R @ Warri	1394	06/11/1969	20/11/2001	17976	10412	20
215004	Corang R @ Hockeys	164	09/08/1924	25/09/2001	2423	1913	49
215005	Mongarlowe R Marlowe	414	23/03/1973	31/12/1984	10759	4780	5
215008	Shoalhaven R @ Kado	283	17/09/1950	26/09/2001	2027	1509	21
215009	Endrick R @ Nowra Rd	207	24/02/1970	20/03/1978	2838	1887	5
215014	Bungonia Ck @ Bungon	164	14/04/1981	26/09/2001	1732	866	12

Figure 66. Generated salt load per unit source area for stations in the Shoalhaven River basin
Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 67. Land-use in the Shoalhaven River basin

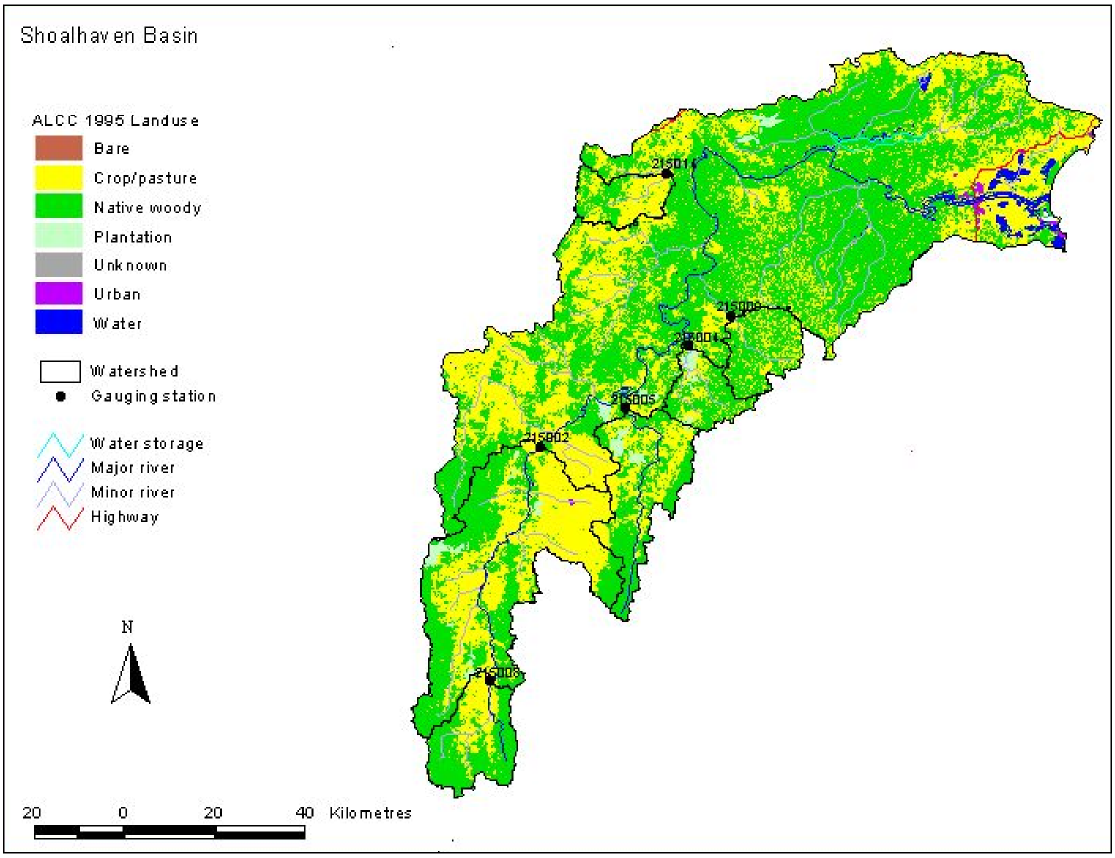
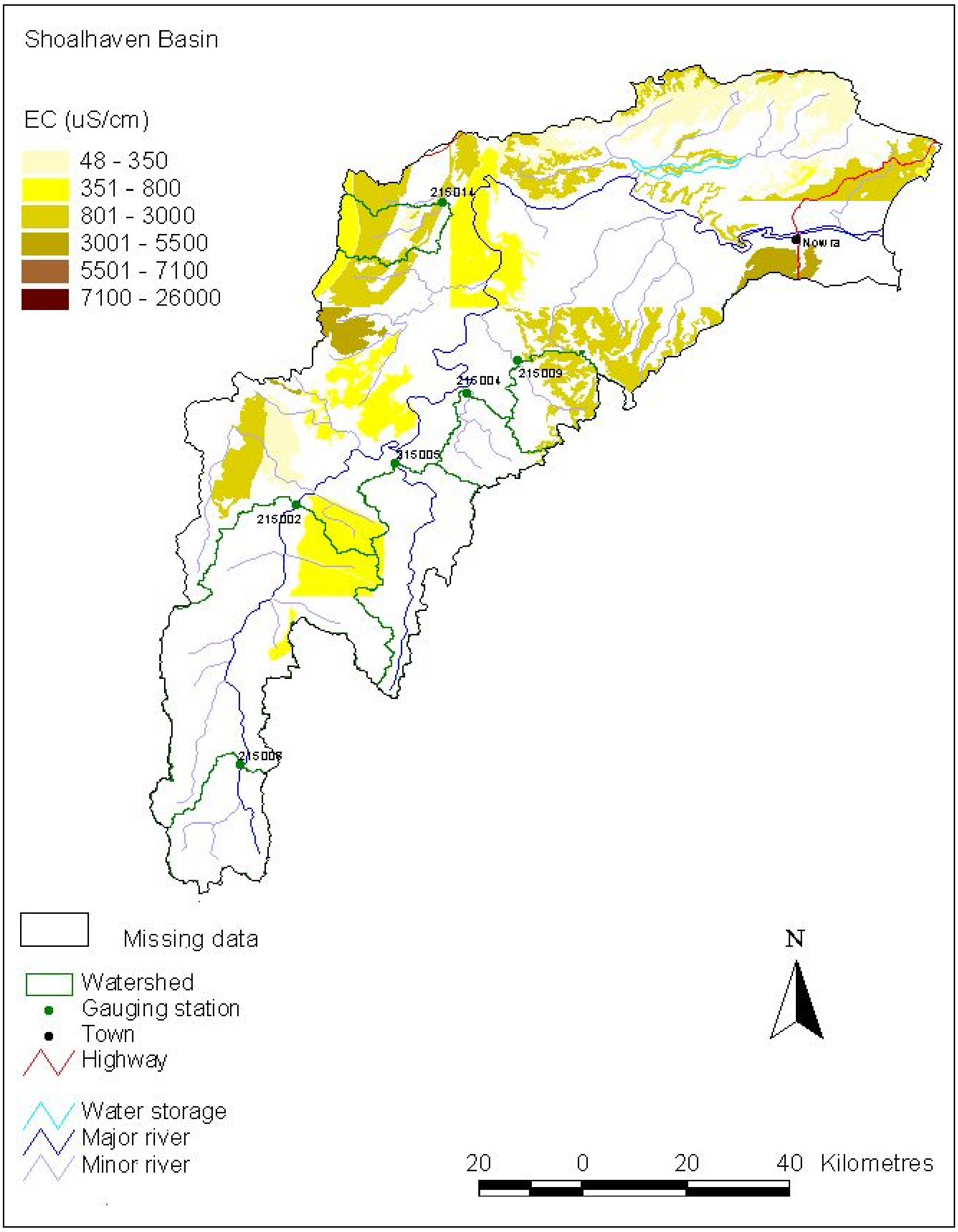


Table 42. Land-use statistics for catchments in the Richmond River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
215002	Shoalhaven R @ Warri	47	52	0
215004	Corang R @ Hockeys	70	30	0
215005	Mongarlowe R Marlowe	59	41	0
215008	Shoalhaven R @ Kado	68	32	0
215009	Endrick R @ Nowra Rd	66	34	0
215014	Bungonia Ck @ Bungon	38	62	0
215###	Shoalhaven remaining	59	38	2

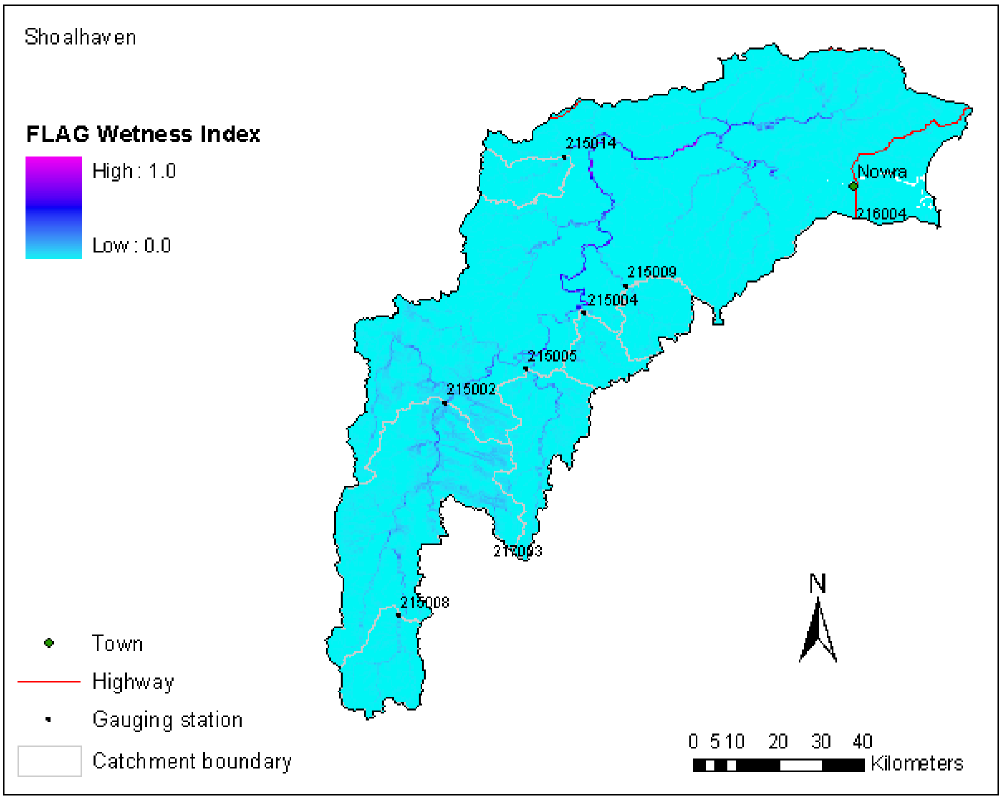
Groundwater salinity

Figure 68. Projected groundwater salinity in the Shoalhaven River basin



FLAG wetness map

Figure 69. FLAG wetness map for the Shoalhaven River basin



Appendix 14. Clyde River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Clyde River basin.

Stream salinity

Table 43. Stream salinity in the Clyde River basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
216002	07/09/1960	12/03/2001	14386	94	119	98
216004	04/10/1970	05/06/2001	9329	297	377	306
216005	21/10/1975	06/04/1985	3003	102	116	102

Salt load

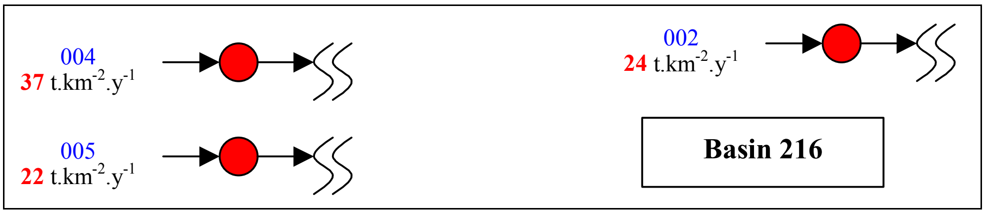
Table 44. Saltloads for the Clyde River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
216002	Clyde R @ Brooman	858	07/09/1960	12/03/2001	20909	12178	26
216004	Currambene Ck @ Falls	96	04/10/1970	05/06/2001	3599	2904	14
216005	Buckenbowra No 2	176	21/10/1975	06/04/1985	3892	3716	6

Figure 70. Generated salt load per unit source area for stations in the Clyde River basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 71. Land-use in the Clyde River basin

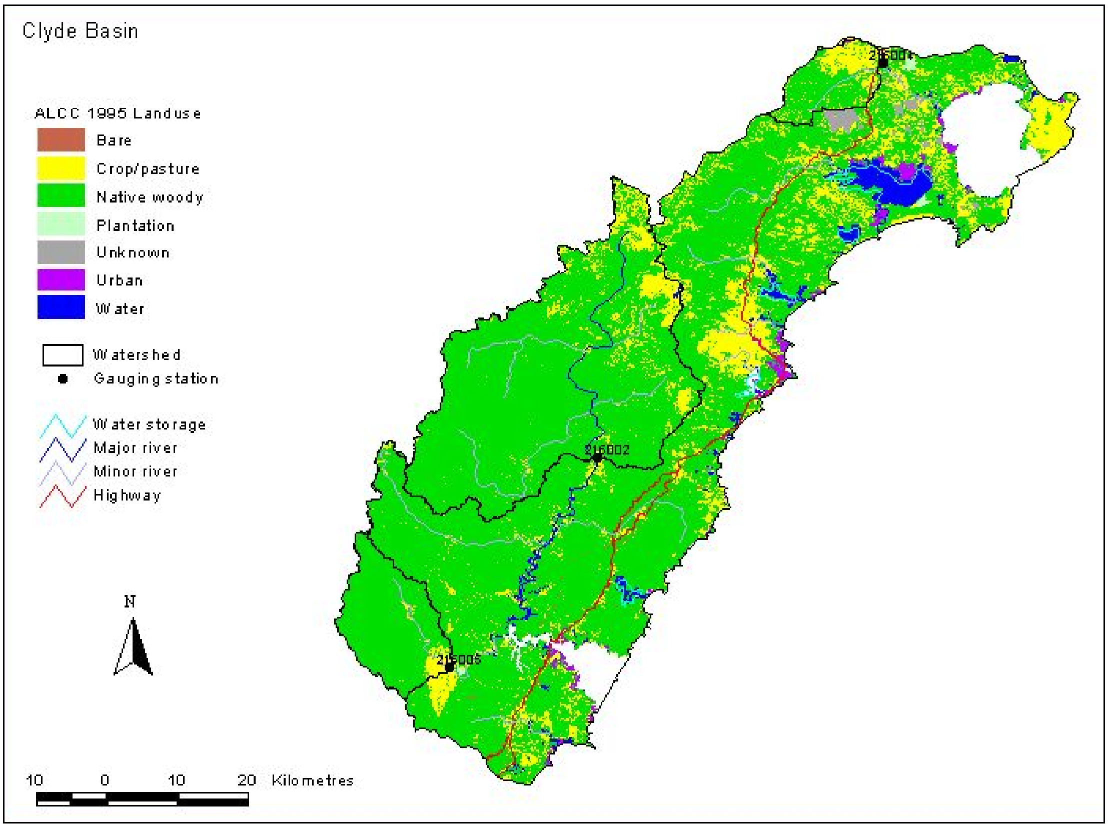
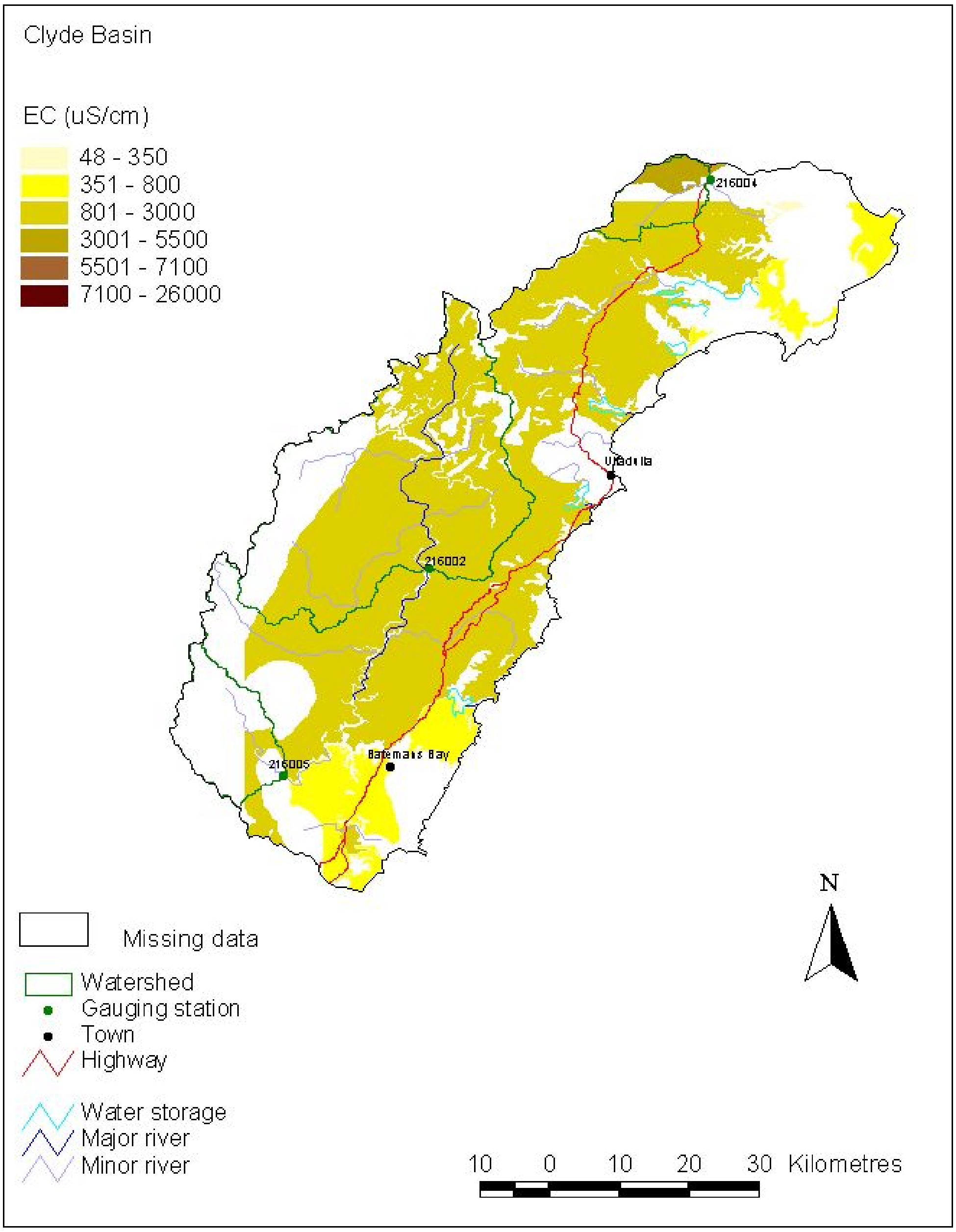


Table 45. Land-use statistics for catchments in the Clyde River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
216002	Clyde R @ Brooman	90	10	0
216004	Currambene Ck @ Falls	65	34	1
216005	Buckenbowra No 2	94	6	0
216###	Clyde remaining	76	19	6

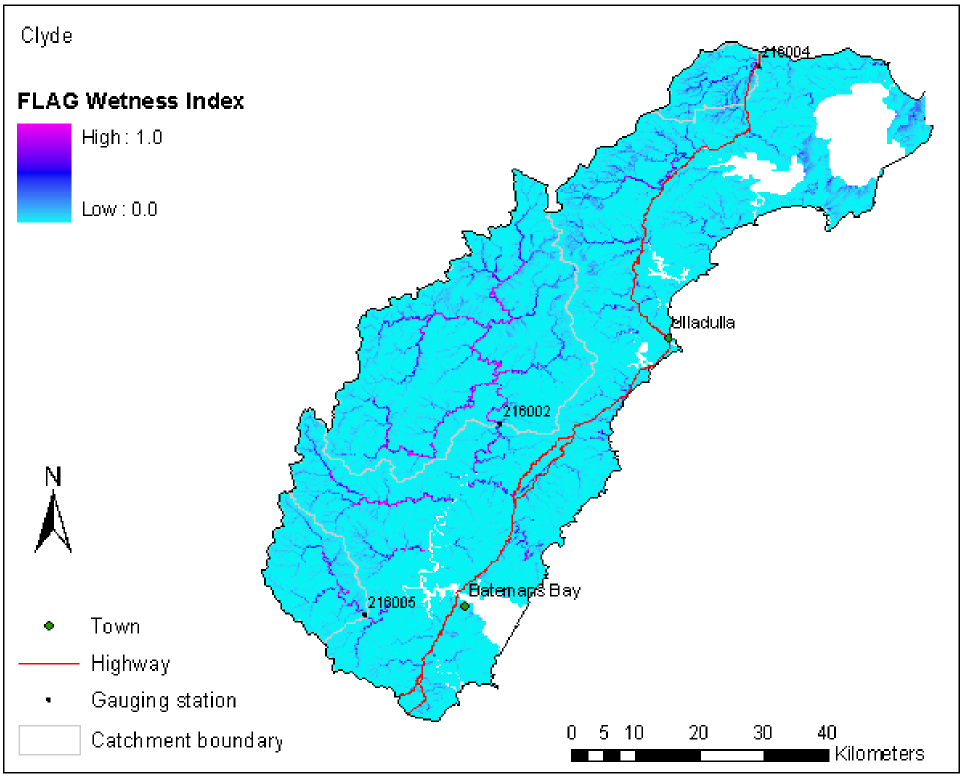
Groundwater salinity

Figure 72. Projected groundwater salinity in the Clyde River basin



FLAG wetness map

Figure 73. FLAG wetness map for the Clyde River basin



Appendix 15. Moruya River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Moruya River basin.

Stream salinity

Table 46. Stream salinity in the Moruya River basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
217002	25/09/1959	12/02/2001	14976	128	150	130
217003	09/04/1969	26/04/1983	4663	284	350	289

Salt load

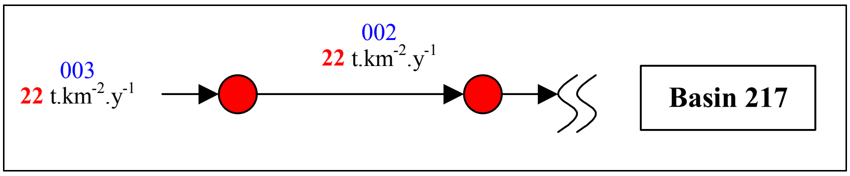
Table 47. Saltloads for the Moruya River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
217002	Deva R @ Wamban	1212	25/09/1959	12/02/2001	19316	12396	33
217003	Lower Araluen Ck	128	09/04/1969	26/04/1983	3844	1765	12

Figure 74. Generated salt load per unit source area for stations in the Moruya River basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 75. Land-use in the Moruya River basin

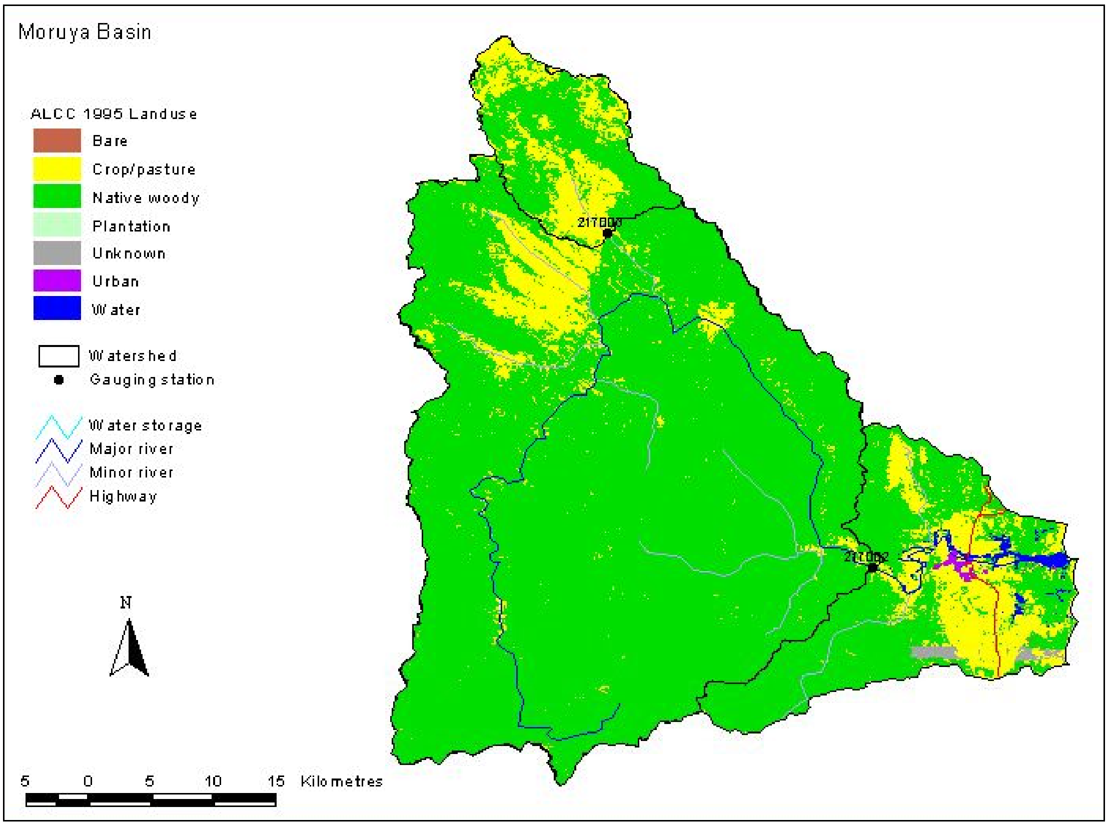
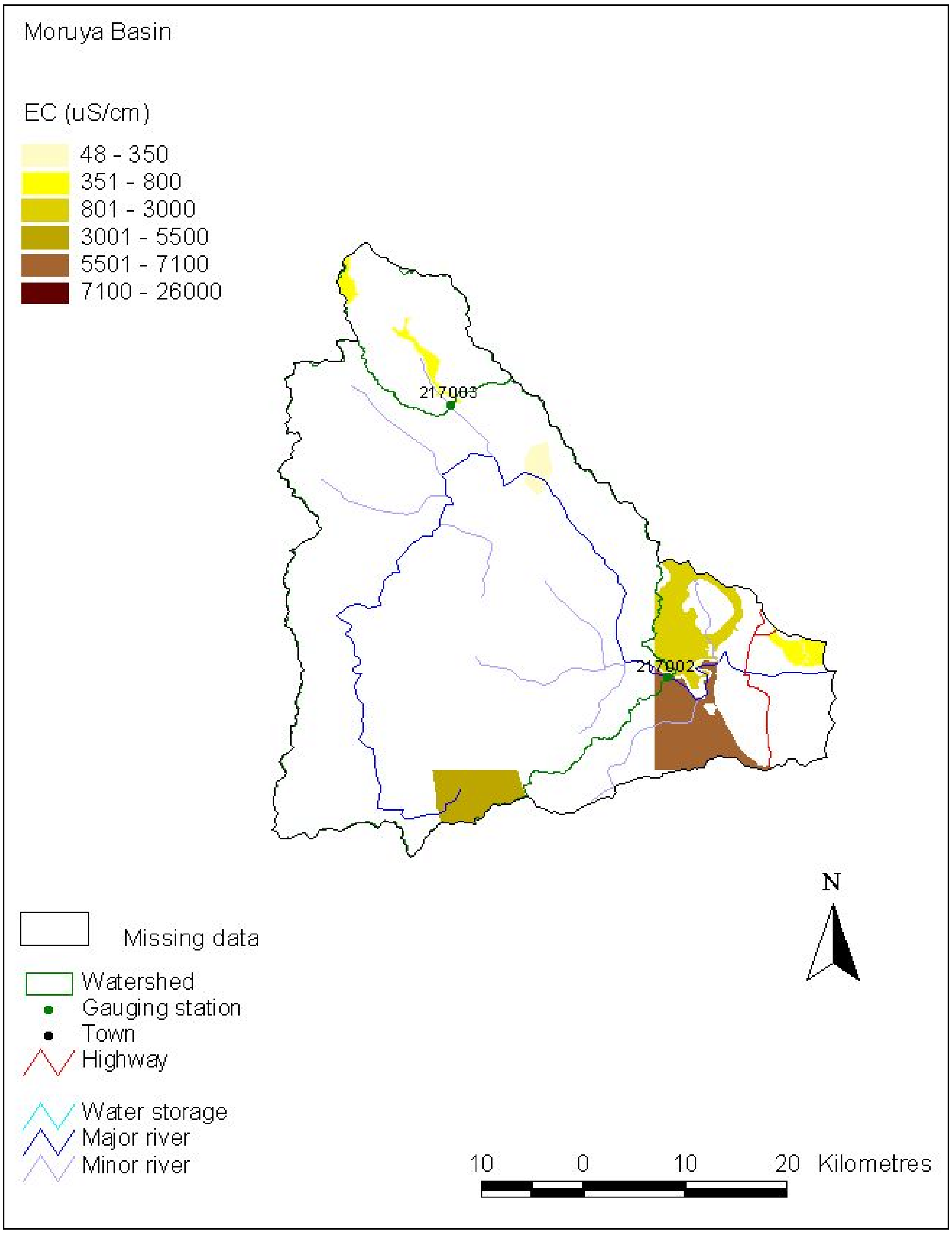


Table 48. Land-use statistics for catchments in the Moruya River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
217002	Deva R @ Wamban	93	7	0
217003	Lower Araluen Ck	58	42	0
217###	Moruya remaining	66	30	4

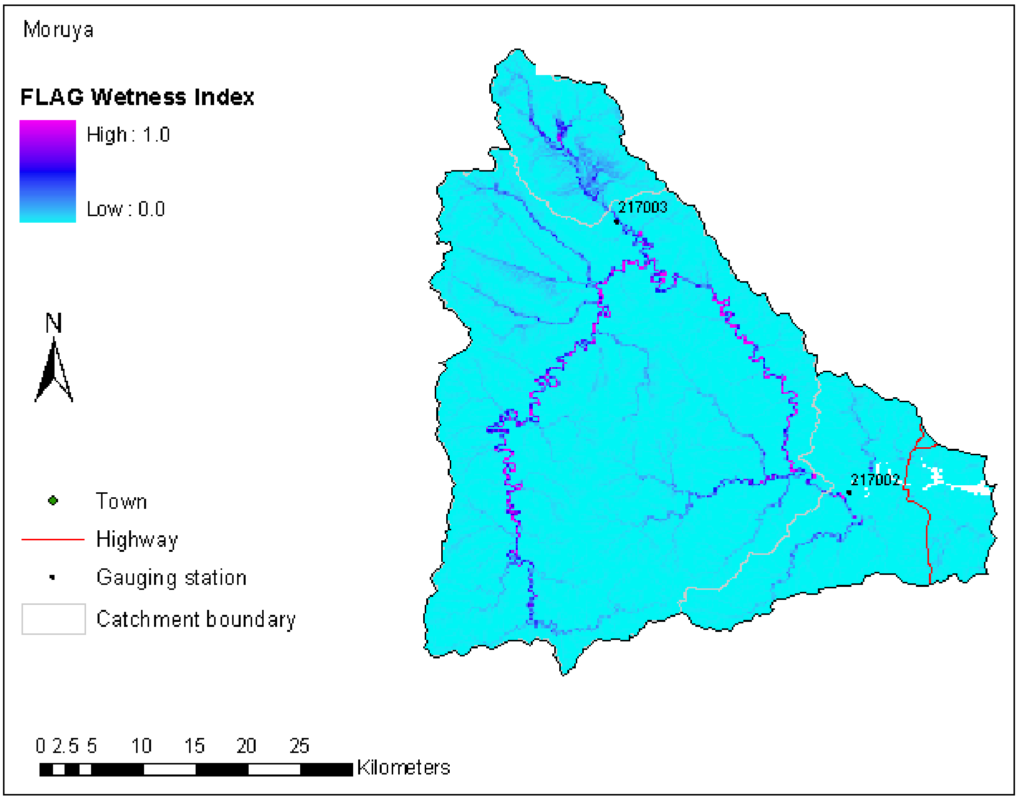
Groundwater salinity

Figure 76. Projected groundwater salinity in the Moruya River basin



FLAG wetness map

Figure 77. FLAG wetness map for the Moruya River basin



Appendix 16. Tuross River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Tuross River basin.

Stream salinity

Table 49. Stream salinity in the Tuross River basin

Station	Start date	End date	n (days)	Median daily EC ($\mu S.cm^{-1}$)	80th percentile daily EC (non-exceedance) ($\mu S.cm^{-1}$)	Mean daily EC ($\mu S.cm^{-1}$)
218001	25/06/1948	12/11/2001	15704	39	47	41
218002	06/02/1954	09/03/1984	10932	61	70	63
218003	09/02/1958	15/10/1984	9471	103	122	105
218005	06/11/1964	12/02/2001	13593	75	91	77
218006	07/07/1966	26/06/1985	5674	188	233	191
218007	13/06/1974	12/10/2001	9647	66	78	67
218008	15/04/1977	12/02/2001	8761	94	108	95

Salt load

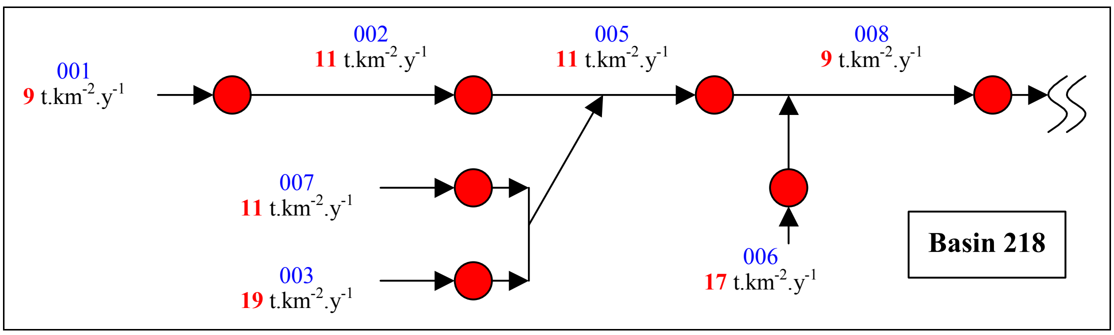
Table 50. Saltloads for the Tuross River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload ($t.yr^{-1}$)	Median annual saltload ($t.yr^{-1}$)	n
218001	Tuross @ Tuross Vale	91	25/06/1948	12/11/2001	778	565	40
218002	Tuross R @ Belowra	569	06/02/1954	09/03/1984	6079	4334	28
218003	Yowri R @ Yowrie	101	09/02/1958	15/10/1984	1874	1287	25
218005	D/S Wadbilliga Jn	919	06/11/1964	12/02/2001	9707	5938	36
218006	Wandella Ck Wandella	57	07/07/1966	26/06/1985	954	805	17
218007	Wadbiliga Wadbilliga	123	13/06/1974	12/10/2001	1333	764	26
218008	Tuross @ Eurobodalla	1605	15/04/1977	12/02/2001	15118	9135	22

Figure 78. Generated salt load per unit source area for stations in the Tuross River basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 79. Land-use in the Tuross River basin

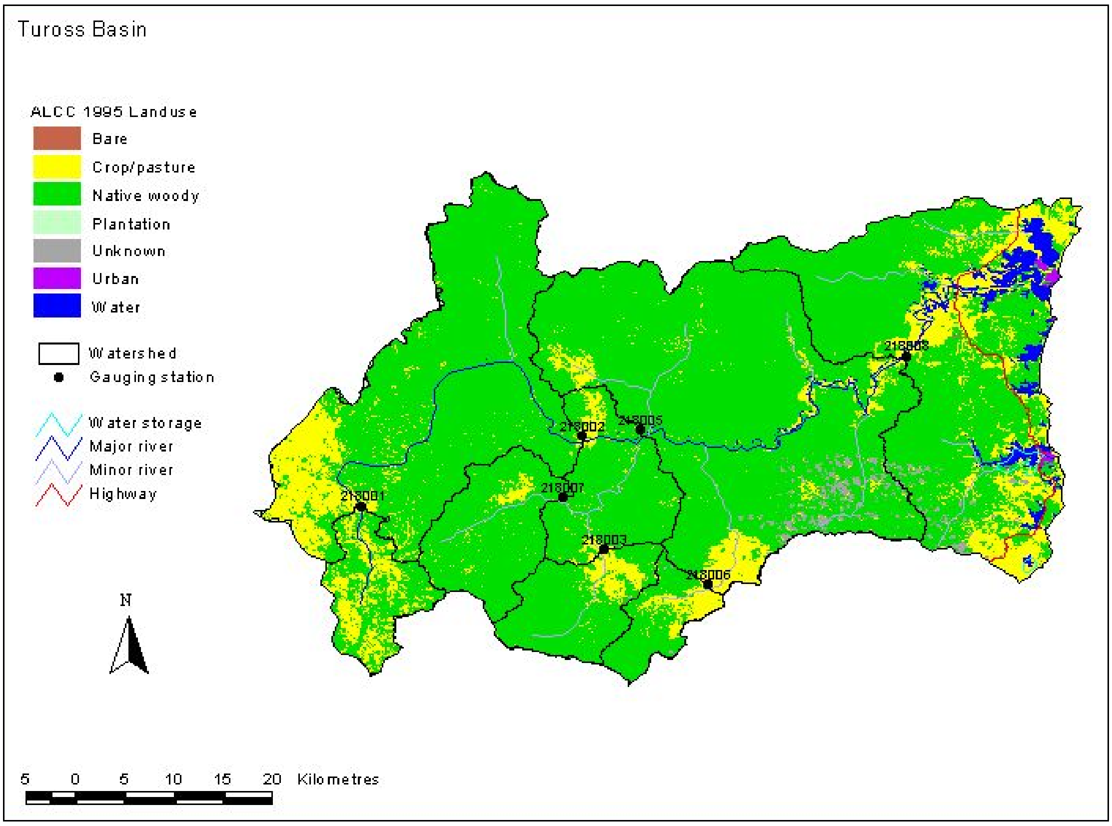
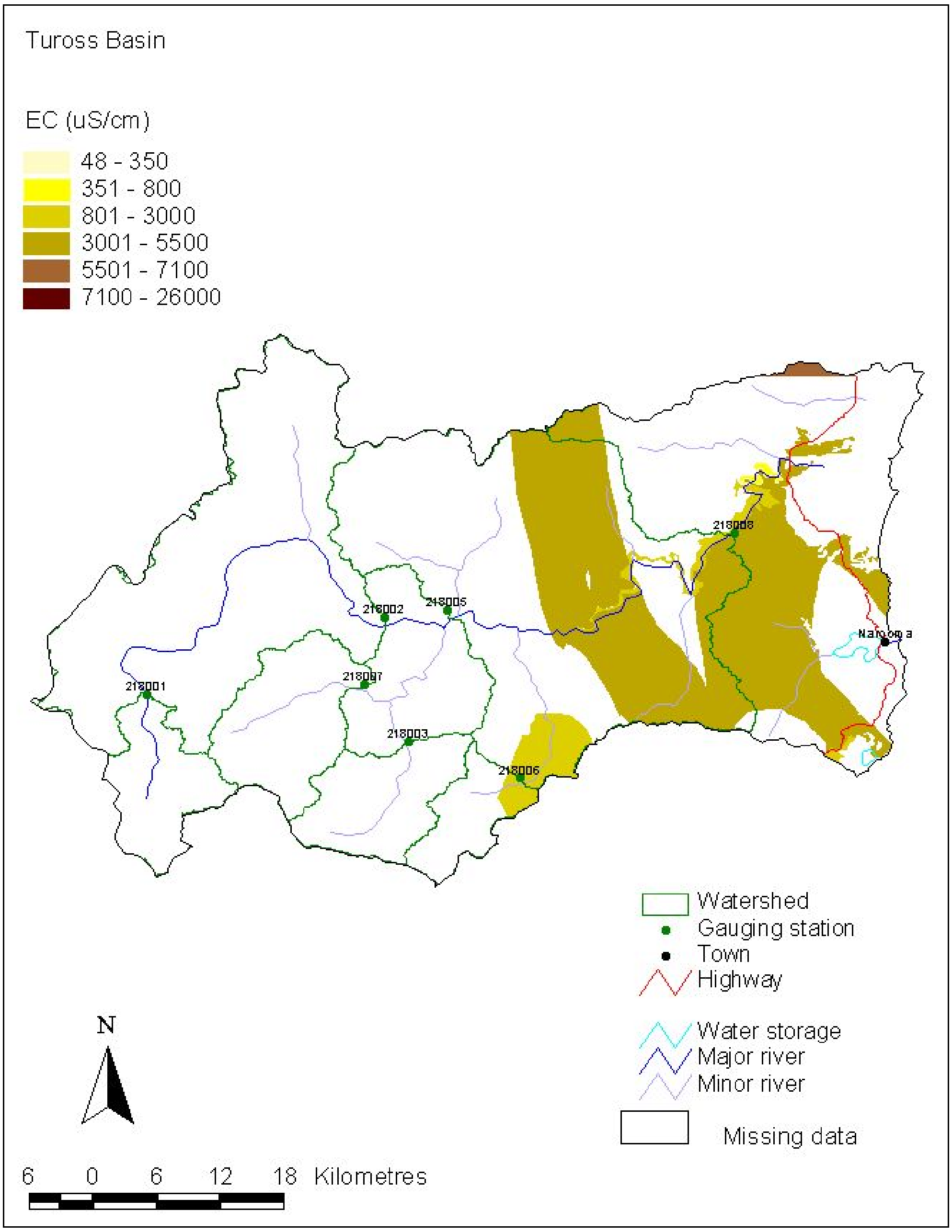


Table 51. Land-use statistics for catchments in the Tuross River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
218001	Tuross @ Tuross Vale	61	39	0
218002	Tuross R @ Belowra	84	16	0
218003	Yowri R @ Yowrie	85	15	0
218005	D/S Wadbilliga Jn	91	9	0
218006	Wandella Ck Wandella	74	26	0
218007	Wadbiliga Wadbilliga	95	5	0
218008	Tuross @ Eurobodalla	92	8	1
218###	Tuross remaining	69	22	9

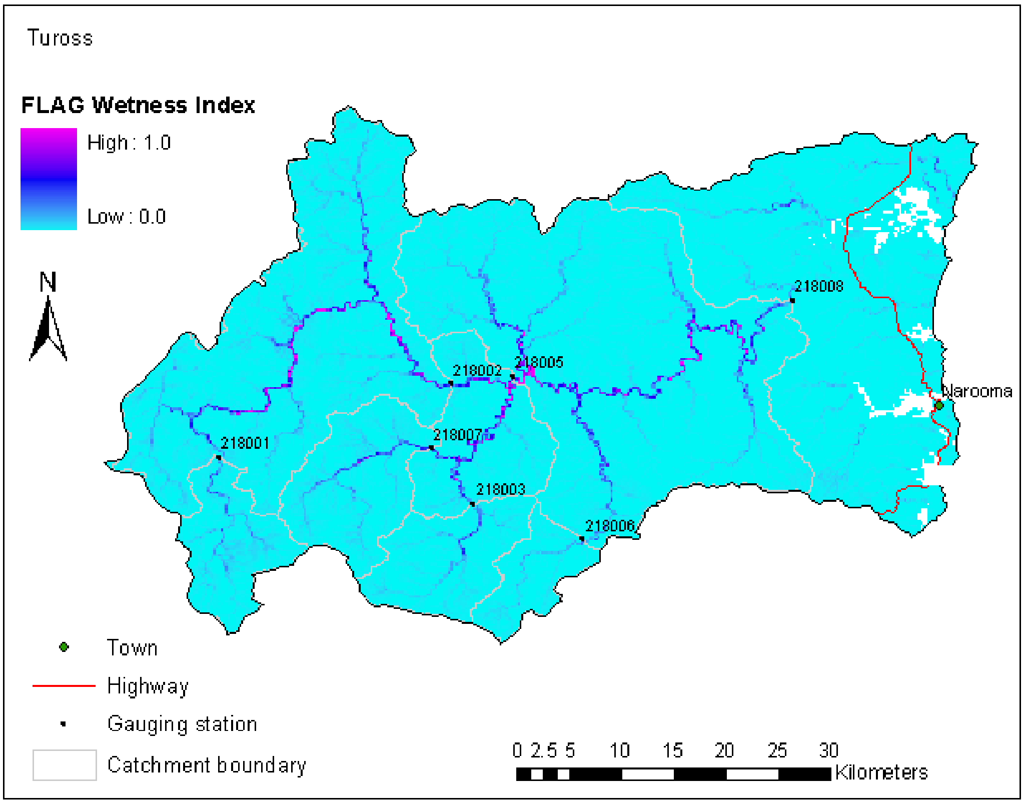
Groundwater salinity

Figure 80. Projected groundwater salinity in the Tuross River basin



FLAG wetness map

Figure 81. FLAG wetness map for the Tuross River basin



Appendix 17. Bega River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Bega River basin.

Stream salinity

Table 52. Stream salinity in the Bega River basin

Station	Start date	End date	n (days)	Median daily EC (µS.cm^{-1})	80th percentile daily EC (non-exceedance) (µS.cm^{-1})	Mean daily EC (µS.cm^{-1})
219001	04/03/1924	15/10/2001	22183	59	64	59
219003	17/04/1943	17/12/2001	21426	131	167	136
219004	18/04/1943	11/05/1974	11483	105	127	106
219006	18/02/1951	12/06/2001	18542	86	100	88
219010	08/06/1954	31/07/1974	6876	34	36	34
219012	10/06/1960	05/03/1978	4078	111	138	114
219013	11/12/1961	12/12/2001	9190	78	91	78
219014	23/07/1963	04/05/1978	4958	275	353	283
219015	13/06/1965	20/04/1989	4165	303	413	317
219016	18/06/1965	12/10/2001	7852	605	808	609
219017	07/08/1966	12/12/2001	12211	234	295	238
219018	13/07/1966	12/10/2001	5961	308	375	311
219019	07/12/1966	03/09/1978	4225	189	225	192
219020	19/07/1966	29/08/1985	6018	403	514	414
219021	20/07/1966	20/02/1983	5467	73	88	75
219022	12/01/1971	17/12/2001	10771	158	194	164
219023	03/08/1972	03/11/1975	837	216	291	219
219025	11/04/1976	12/10/2001	9166	125	150	127
219028	11/06/1974	30/06/1978	1278	95	109	95

Stream salinities in the basin generally do not present any water quality problems except for Narira River (219016) which approached the WHO threshold at times.

Salt load

Table 53. Saltloads for the Bega River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
219001	Rutherford Brown Mtn	15	04/03/1924	15/10/2001	287	228	58
219003	Bemboka @ Morans Crossing	314	17/04/1943	17/12/2001	7177	5207	57
219004	Tantawangalo School	158	18/04/1943	11/05/1974	3114	2040	29
219006	Tantawangalo Mtn	83	18/02/1951	12/06/2001	1318	992	49
219010	Bonar Ck @ Brown Mtn	9	08/06/1954	31/07/1974	33	17	18
219012	Devils @ Tantawangalo	27	10/06/1960	05/03/1978	693	682	8
219013	Brogo @ North Brogo	454	11/12/1961	12/12/2001	4842	3213	24
219014	Candelo @ Yurammie	50	23/07/1963	04/05/1978	1524	1146	11
219015	Nutleys @ Bermagui	31	13/06/1965	20/04/1989	509	302	22
219016	Narira Rv @ Cobargo	91	18/06/1965	12/10/2001	2764	2188	25
219017	Double Ck Near Brogo	152	07/08/1966	12/12/2001	2374	1637	38
219018	Murrah Rv @ Quaama	66	13/07/1966	12/10/2001	1012	685	19
219019	Tantawanglo Kameruka	323	07/12/1966	03/09/1978	7336	4547	10
219020	Sandy Ck @ Mogilla	34	19/07/1966	29/08/1985	952	607	18
219021	Bemboka R @ Bemboka	121	20/07/1966	20/02/1983	3478	3127	8
219022	Candelo Damsite	200	12/01/1971	17/12/2001	3252	2559	28
219023	House Ck @ Brogo Nth	29	03/08/1972	03/11/1975	628	628	2
219025	Brogo R @ Angledale	719	11/04/1976	12/10/2001	10476	7000	24
219028	Tantawagalo Ck @ Tantawangalo	151	11/06/1974	30/06/1978	3078	3078	2

Figure 82. Generated salt load per unit source area for stations in the Bega River basin
Schematic diagram of stations and stream networks of available generated salt load.

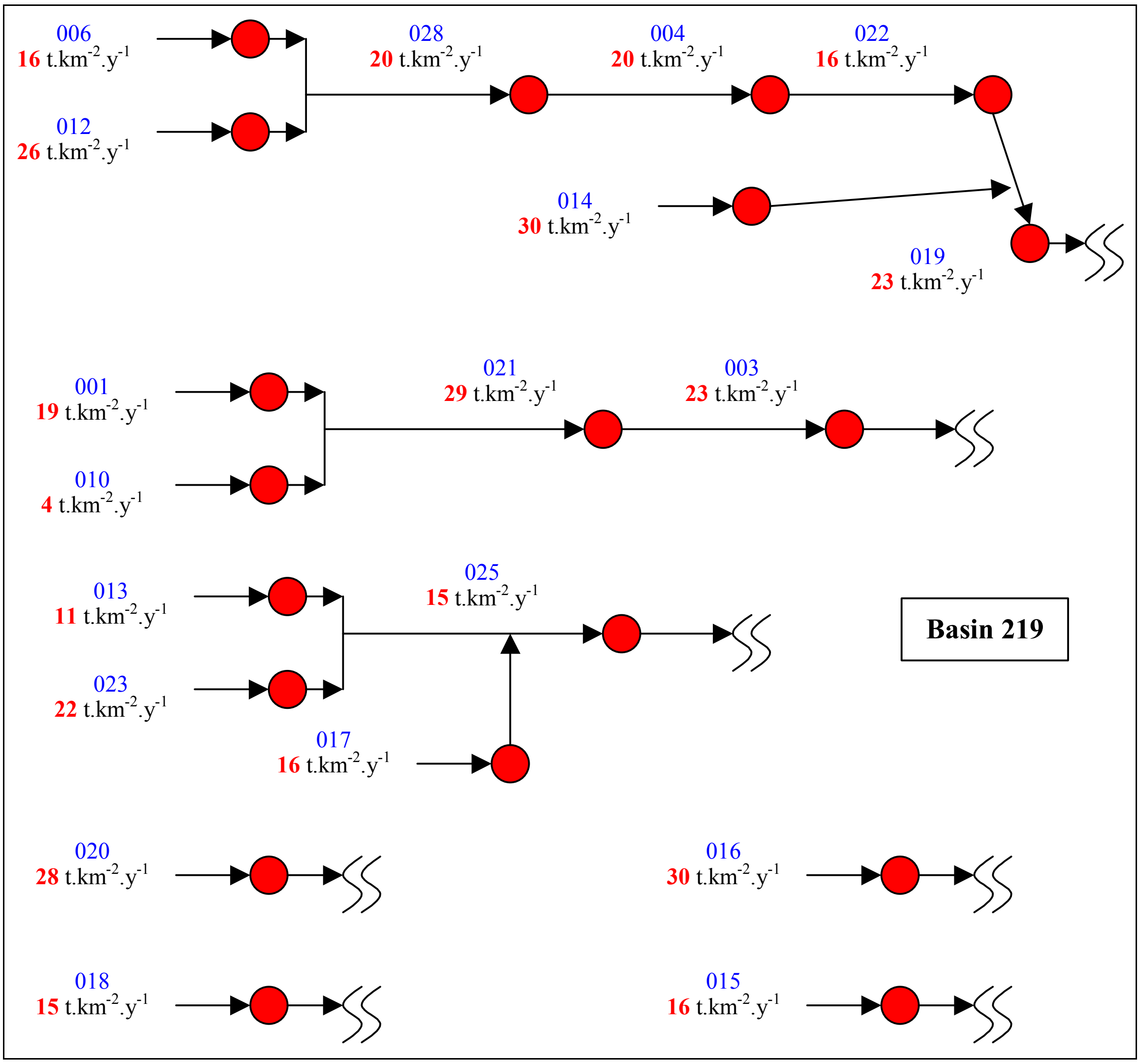


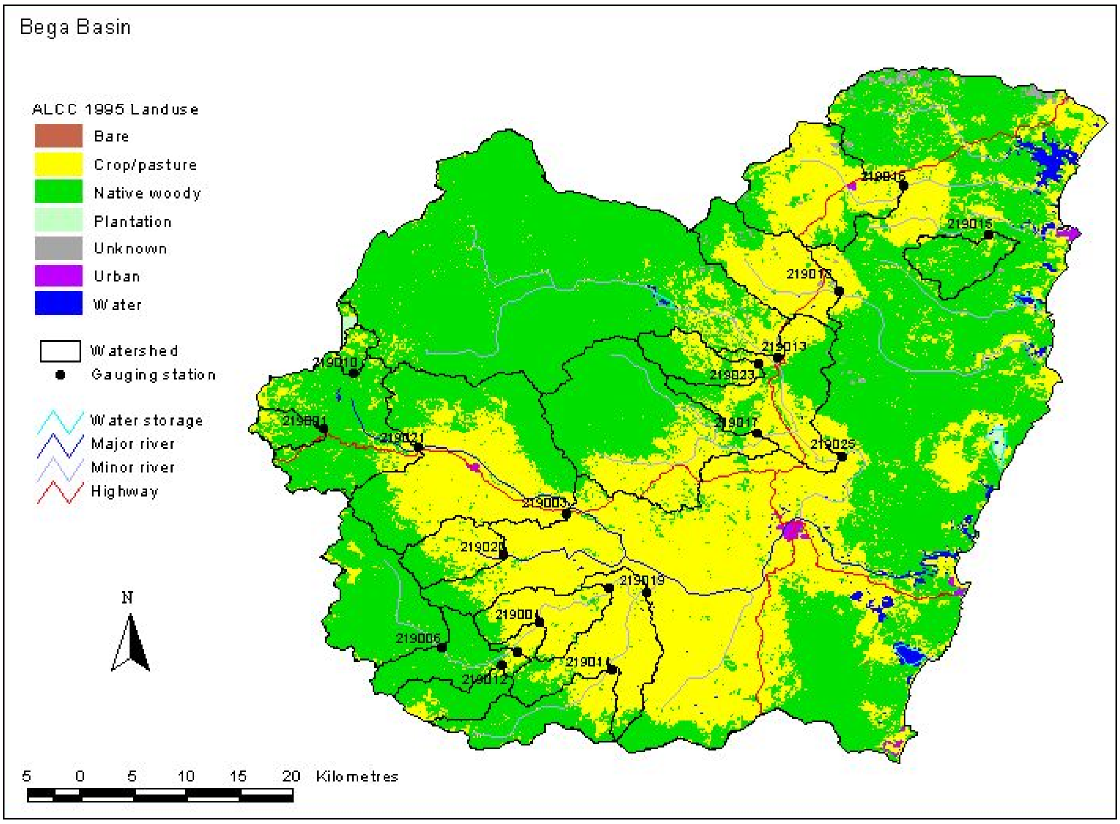
Table 54. Land-use statistics for catchments in the Bega River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
219001	Rutherford Brown Mtn	76	24	0
219003	Bemboka @ Morans Crossing	46	54	0
219004	Tantawangalo School	17	83	0
219006	Tantawangalo Mtn	95	5	0
219010	Bonar Ck @ Brown Mtn	72	28	0
219012	Devils @ Tantawangalo	85	15	0
219013	Brogo @ North Brogo	93	7	0
219014	Candelo @ Yurammie	69	31	0

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
219015	Nutleys @ Bermagui	88	12	0
219016	Narira R @ Cobargo	27	73	0
219017	Double Ck Near Brogo	64	36	0
219018	Murrah R @ Quaama	28	72	0
219019	Tantawanglo Kameruka	19	81	0
219020	Sandy Ck @ Mogilla	35	65	0
219021	Bemboka R @ Bemboka	81	18	0
219022	Candelo Damsite	14	86	0
219023	House Ck @ Brogo Nth	63	37	0
219025	Brogo R @ Angledale	42	58	0
219028	Tantawagalo Ck @ Tantawangalo	92	8	0
219###	Bega remaining	52	45	3

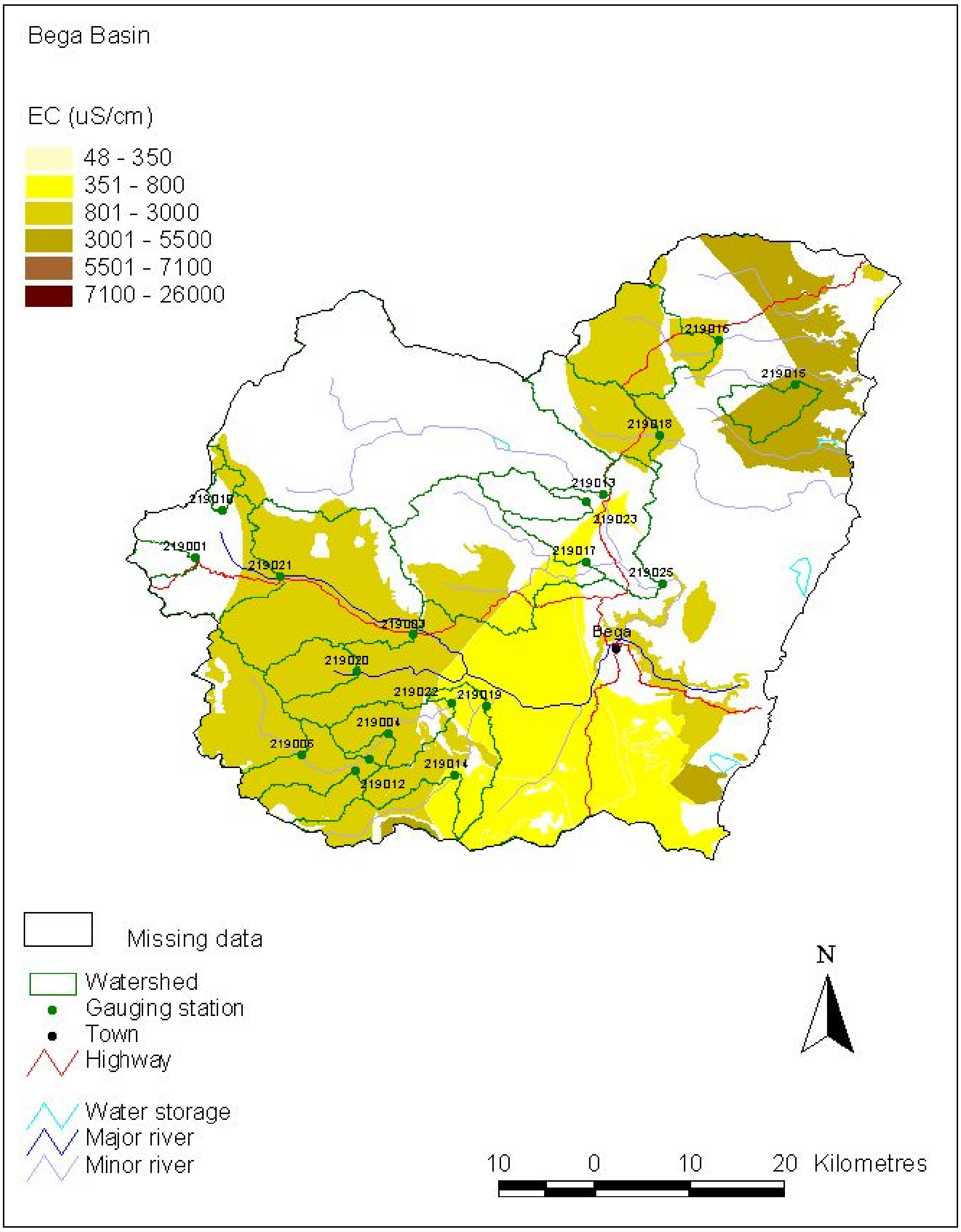
Land-use

Figure 83. Land-use in the Bega River basin



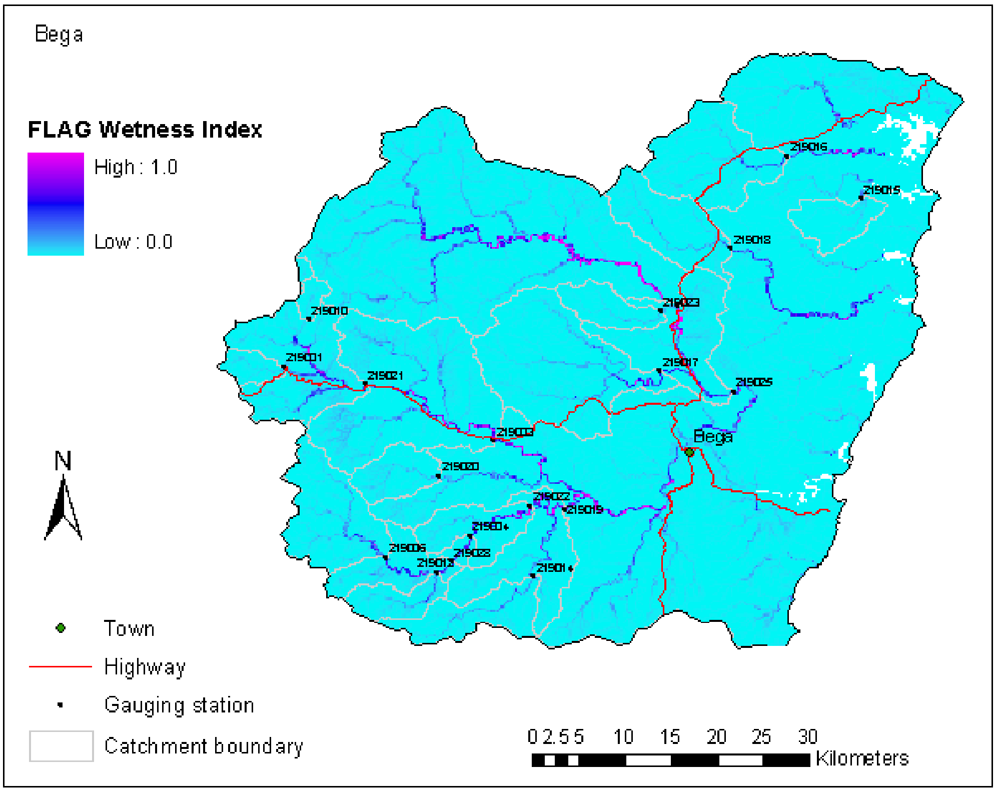
Groundwater salinity

Figure 84. Projected groundwater salinity in the Bega River basin



FLAG wetness map

Figure 85. FLAG wetness map for the Bega River basin



Appendix 18. Towamba River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Towamba River basin.

Stream salinity

Table 55. Stream salinity in the Towamba River basin

Station	Start date	End date	n (days)	Median daily EC (μS.cm^{-1})	80th percentile daily EC (non-exceedance) (μS.cm^{-1})	Mean daily EC (μS.cm^{-1})
220001	14/05/1954	06/11/1981	9796	169	198	170
220002	16/02/1960	07/04/1985	8846	127	153	128
220003	09/01/1966	12/09/2001	11343	308	409	313
220004	04/06/1970	12/04/2001	11147	186	234	194
220005	06/06/1979	14/09/1999	2315	378	456	364
220006	16/03/1984	12/09/2001	5889	141	158	141

Salt load

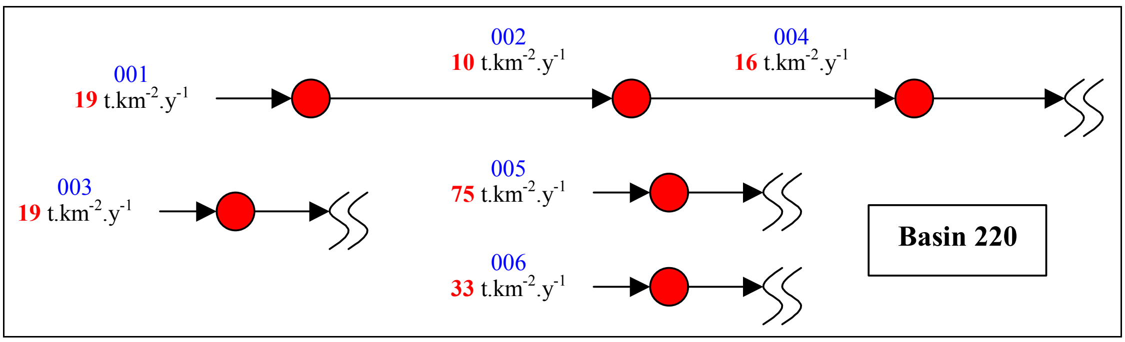
Table 56. Saltloads for the Towamba River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
220001	Towamba River @ New Buildings Bridge	274	14/05/1954	06/11/1981	5306	4068	26
220002	Stockyard Ck @ Rocky Hill	82	16/02/1960	07/04/1985	858	533	24
220003	Pambula R @ Lochiel	107	09/01/1966	12/09/2001	1992	1300	34
220004	Towamba R @ Towamba	766	04/06/1970	12/04/2001	12008	6038	28
220005	Merimbula Ck @ Merimbula	27	06/06/1979	14/09/1999	2031	1318	17
220006	Merrica @ Nadgee	49	16/03/1984	12/09/2001	1626	1261	18

Figure 86. Generated salt load per unit source area for stations in the Towamba River basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 87. Land-use in the Towamba River basin

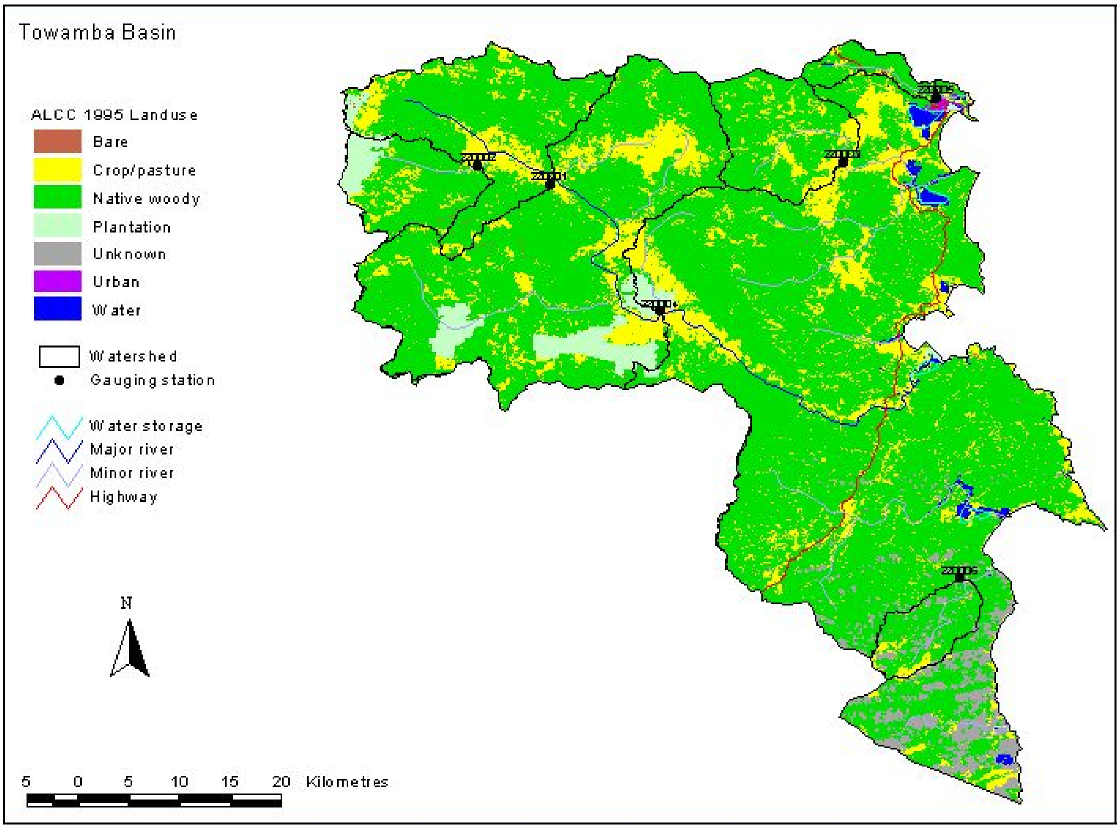
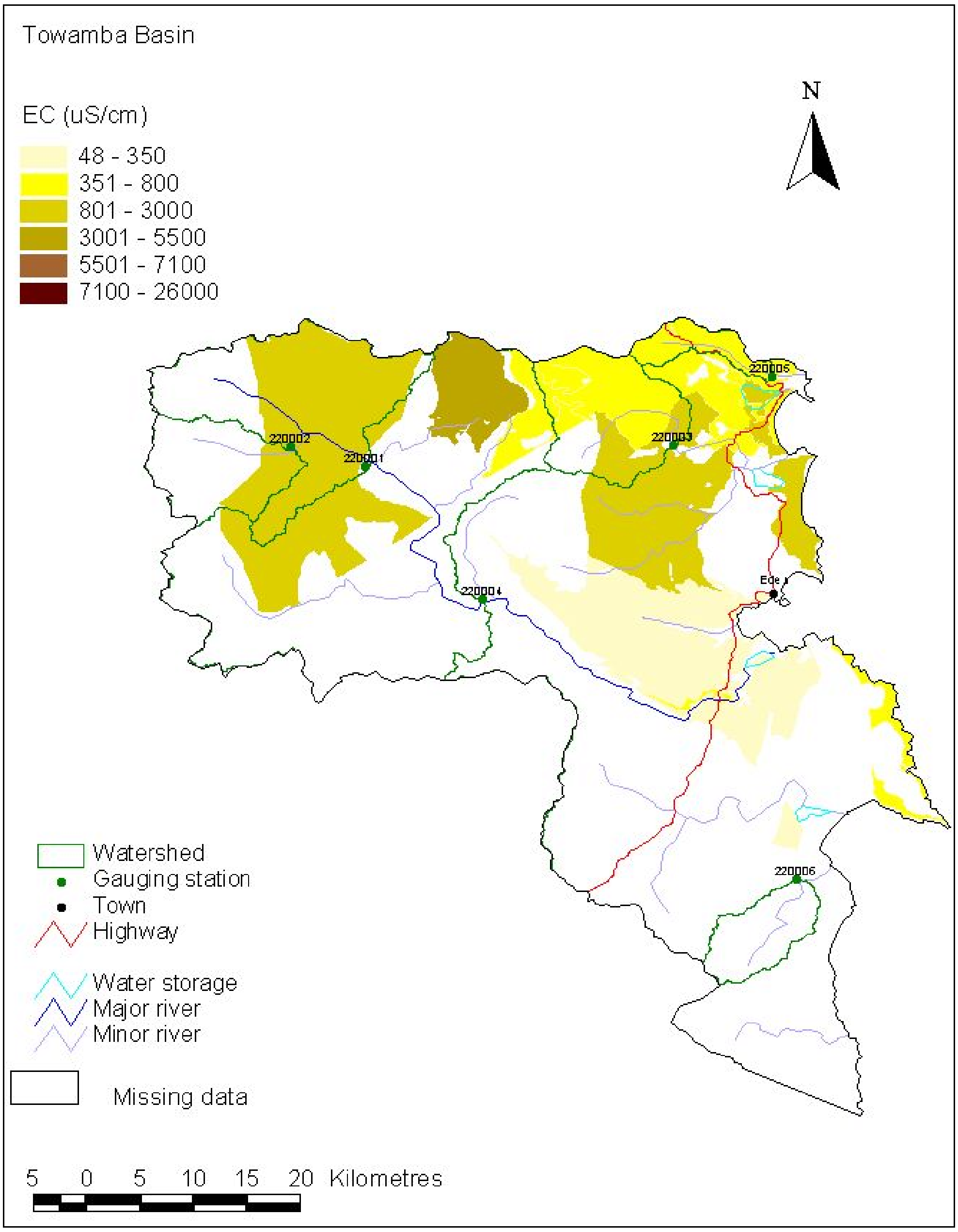


Table 57. Land-use statistics for catchments in the Towamba River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
220001	Towamba River @ New Buildings Bridge	77	23	0
220002	Stockyard Ck @ Rocky Hill	88	12	0
220003	Pambula R @ Lochiel	78	22	0
220004	Towamba R @ Towamba	82	18	0
220005	Merimbula Ck @ Merimbula	88	11	1
220006	Merrica @ Nadgee	89	11	0
220###	Towamba remaining	82	16	2

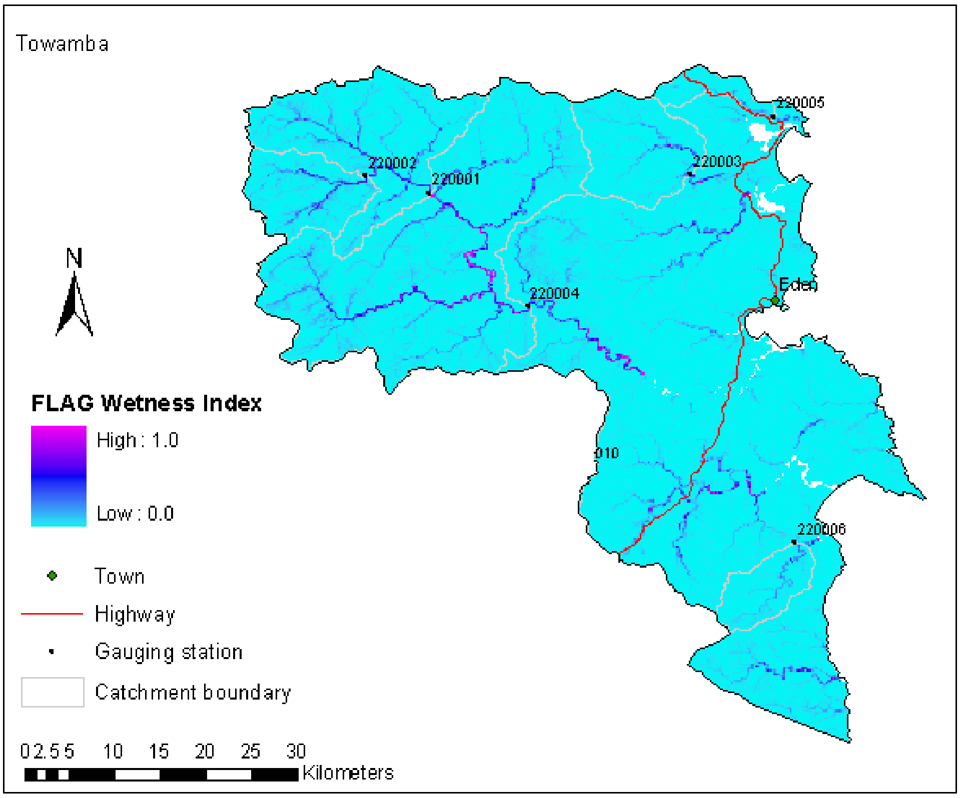
Groundwater salinity

Figure 88. Projected groundwater salinity for the Towamba River basin



FLAG wetness map

Figure 89. Projected groundwater salinity for the Towamba River basin



Appendix 19. East Gippsland basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the East Gippsland basin.

Stream salinity

Table 58. Stream salinity in the East Gippsland basin.

Station	Start date	End date	n (days)	Median daily EC (µS.cm^{-1})	80th percentile daily EC (non-exceedance) (µS.cm^{-1})	Mean daily EC (µS.cm^{-1})
221001	06/05/1965	07/03/1995	8393	109	130	111
221002	12/01/1971	12/09/2001	10778	150	178	153
221003	27/11/1971	04/12/1989	6326	113	141	119
221010	07/11/1981	12/09/2001	6882	109	123	109

Salt load

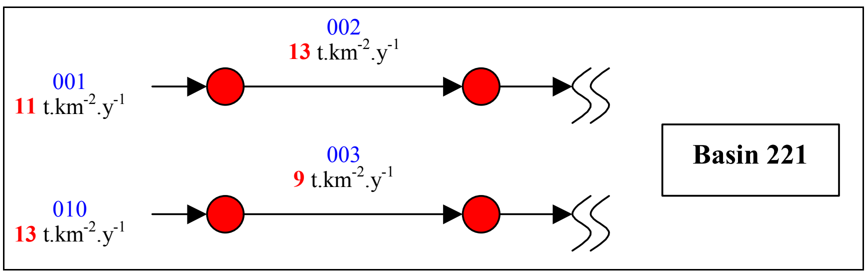
Table 59. Saltloads for the East Gippsland basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
221001	Genoa R @ Rockton	120	06/05/1965	07/03/1995	1362	1199	20
221002	Wallagaraugh Pr Hwy	481	12/01/1971	12/09/2001	6065	3067	26
221003	Genoa R @ Bondi	234	27/11/1971	04/12/1989	2180	1353	16
221010	Imlay Ck @ Imlay Rd	71	07/11/1981	12/09/2001	950	671	18

Figure 90. Generated salt load per unit source area for stations in the East Gippsland basin

Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 91. Land-use in the East Gippsland basin

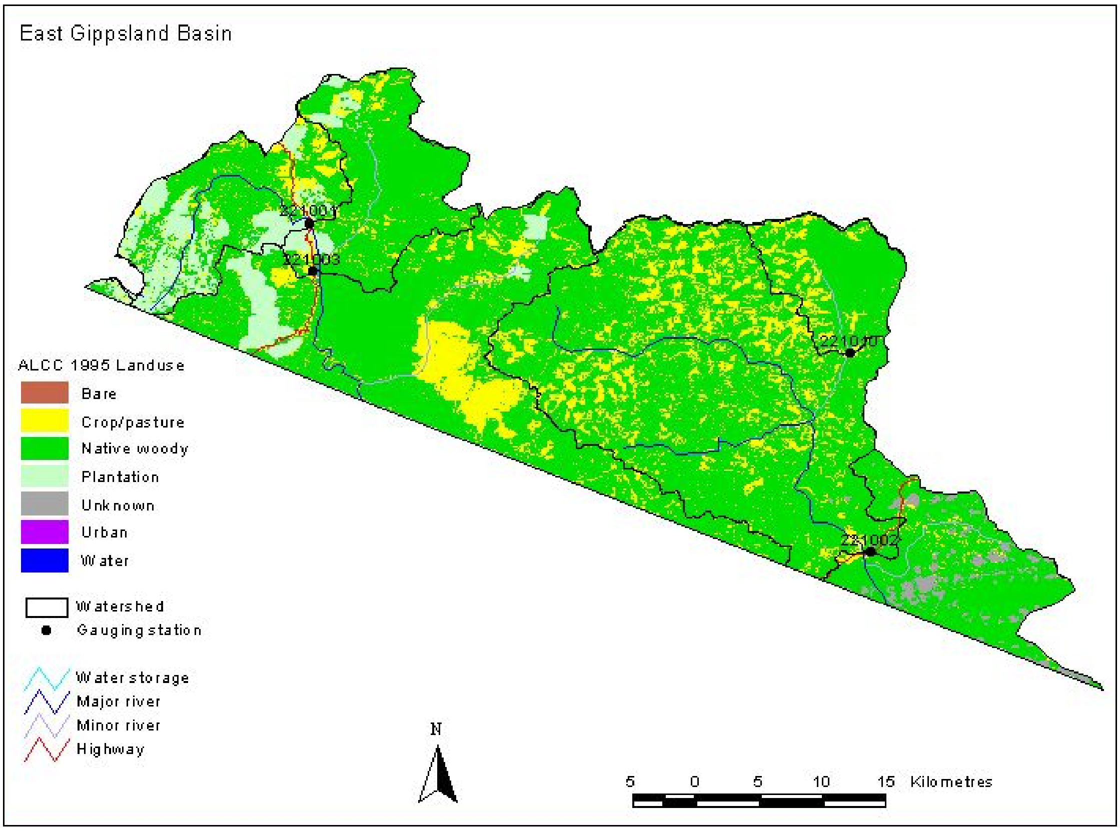
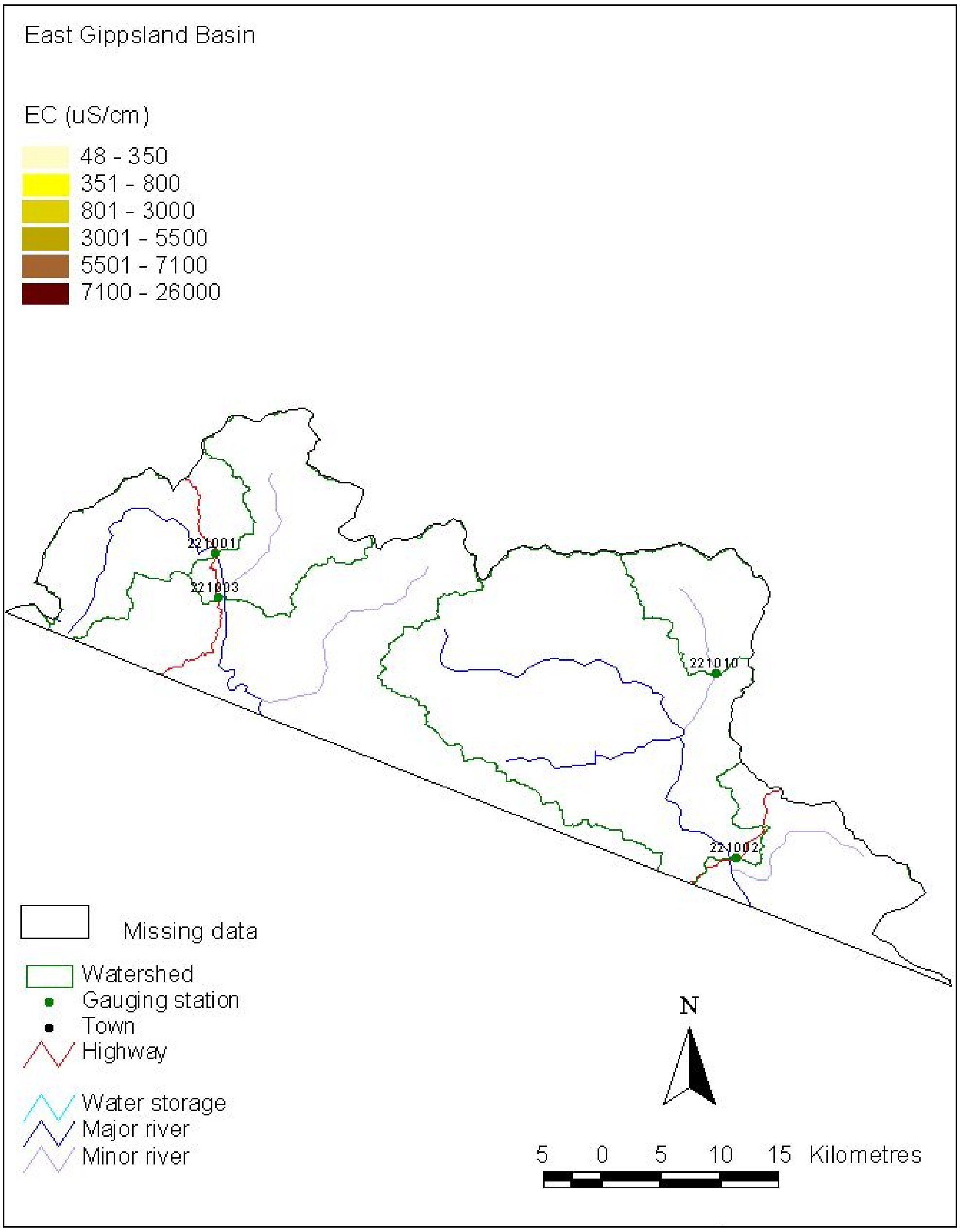


Table 60. Land-use statistics for catchments in the East Gippsland basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
221001	Genoa R @ Rockton	85	15	0
221002	Wallagaraugh Pr Hwy	79	21	0
221003	Genoa R @ Bondi	90	10	0
221010	Imlay Ck @ Imlay Rd	82	18	0
221###	East Gippsland remaining	85	15	0

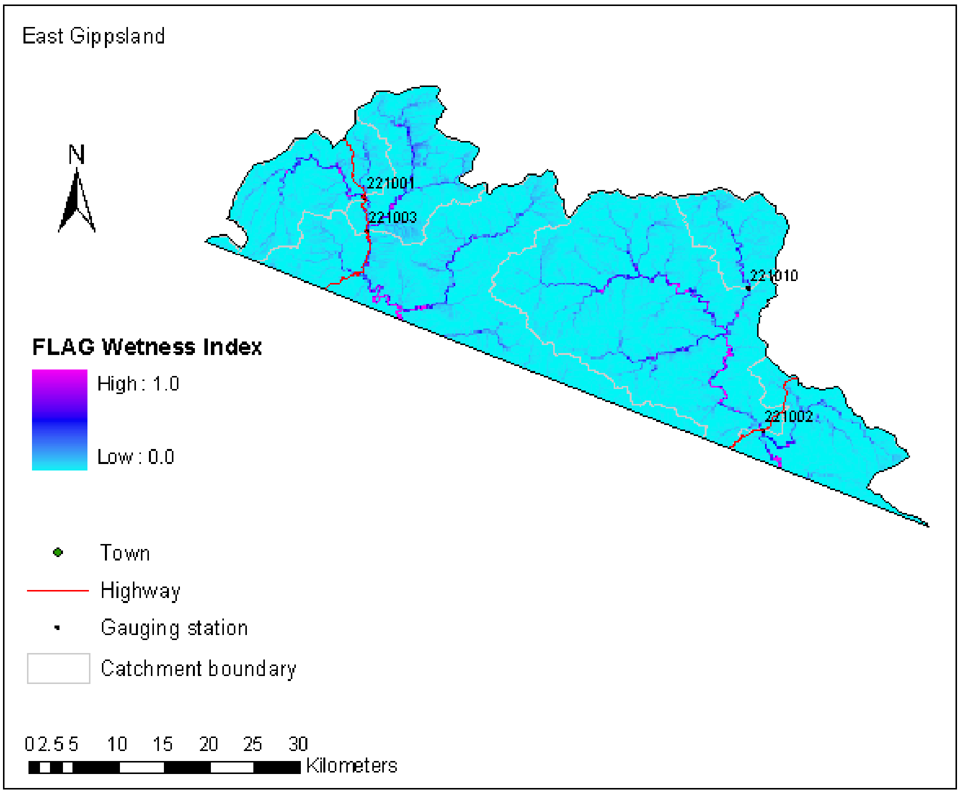
Groundwater salinity

Figure 92. Projected groundwater salinity in the East Gippsland basin



FLAG wetness map

Figure 93. FLAG wetness map for the East Gippsland basin



Appendix 20. Snowy River basin

Results summary for instream salinity and salt load, groundwater salinity and land-use for the Snowy River basin.

Stream salinity

Table 61. Stream salinity in the Snowy River basin.

Station	Start date	End date	n (days)	Median daily EC (µS.cm^{-1})	80th percentile daily EC (non-exceedance) (µS.cm^{-1})	Mean daily EC (µS.cm^{-1})
222004	03/12/1941	12/04/2001	22178	91	111	94
222006	22/03/1949	06/03/1997	17603	225	236	227
222007	25/03/1949	16/01/2002	17409	363	438	367
222008	22/02/1951	12/04/2001	18548	98	122	102
222009	29/05/1951	09/12/1995	15666	173	238	186
222010	22/07/1965	26/07/1982	5524	444	505	450
222012	27/08/1966	05/09/1982	5313	136	181	144
222013	13/06/1975	12/04/2001	9585	183	225	188
222014	06/11/1975	09/05/1985	3684	67	81	75
222015	06/12/1975	15/01/2002	9714	38	52	41
222016	18/03/1975	15/01/2002	9630	27	33	28
222017	09/01/1978	12/06/2001	8057	356	417	369

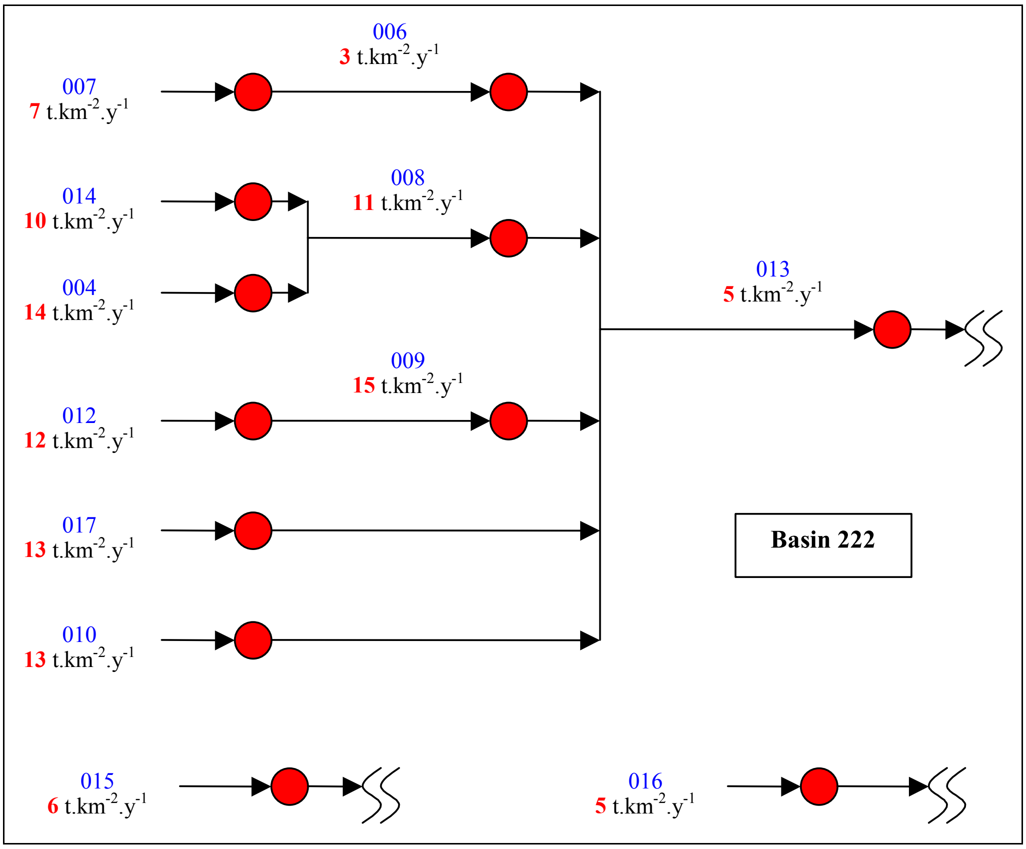
Salt load

Table 62. Saltloads for the Snowy River basin

Number of full years (n) for which annual statistics of generated saltloads have been compiled.

Station	Station name	Area (km^2)	Start date	End date	Average annual saltload (t.yr^{-1})	Median annual saltload (t.yr^{-1})	n
222004	Wellesley (Rowes)	420	03/12/1941	12/04/2001	5718	4339	59
222006	Snowy @ Dalgety	3072	22/03/1949	06/03/1997	10646	4869	32
222007	Wullwye Ck @ Woolway	538	25/03/1949	16/01/2002	3502	1604	52
222008	Delegate R @ Quidong	826	22/02/1951	12/04/2001	9441	7903	50
222009	Bombala @ The Falls	563	29/05/1951	09/12/1995	8709	7259	39
222010	Bobundara @ Dalgety	366	22/07/1965	26/07/1982	4854	3057	16
222012	Coolumbooka R	180	27/08/1966	05/09/1982	2239	1499	15
222013	Snowy @ Burnt Hut	6781	13/06/1975	12/04/2001	31883	21774	23
222014	Delegate @ Delegate	202	06/11/1975	09/05/1985	2032	1726	8
222015	Jacobs Ladder	186	06/12/1975	15/01/2002	1075	1022	26
222016	Pinch R @ Barry Way	157	18/03/1975	15/01/2002	848	878	22
222017	Maclaughlin @ The Hut	314	09/01/1978	12/06/2001	3985	3182	19

Figure 94. Generated salt load per unit source area for stations in the Snowy River basin
Schematic diagram of stations and stream networks of available generated salt load.



Land-use

Figure 95. Land-use in the Snowy River basin

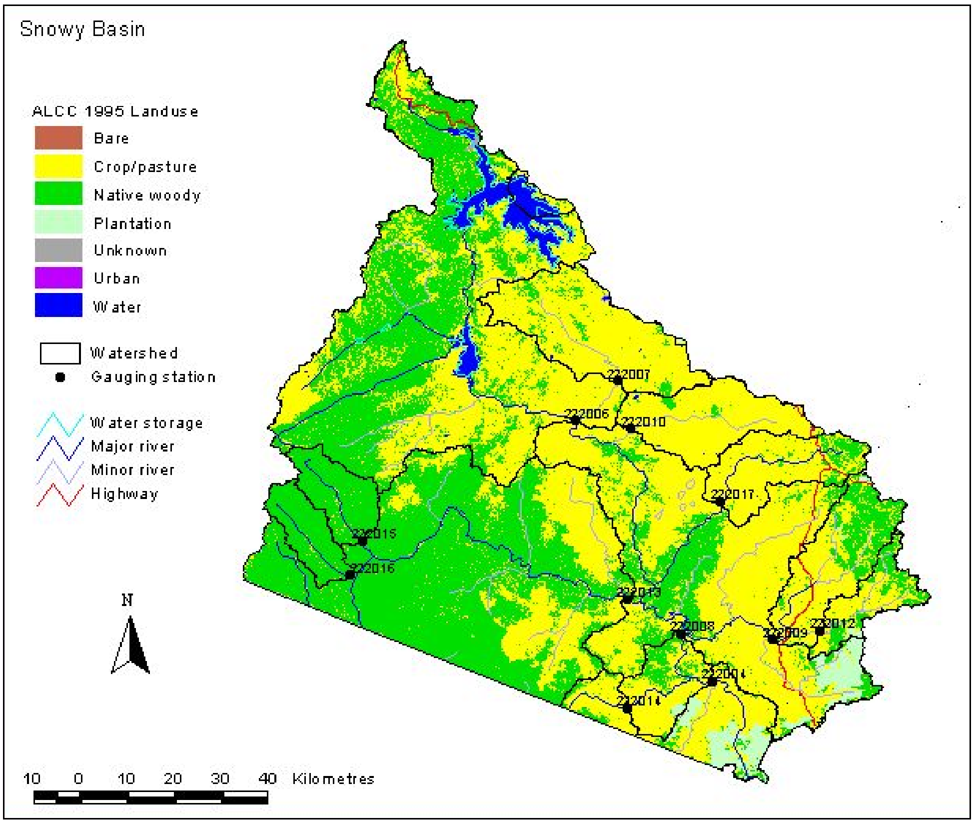
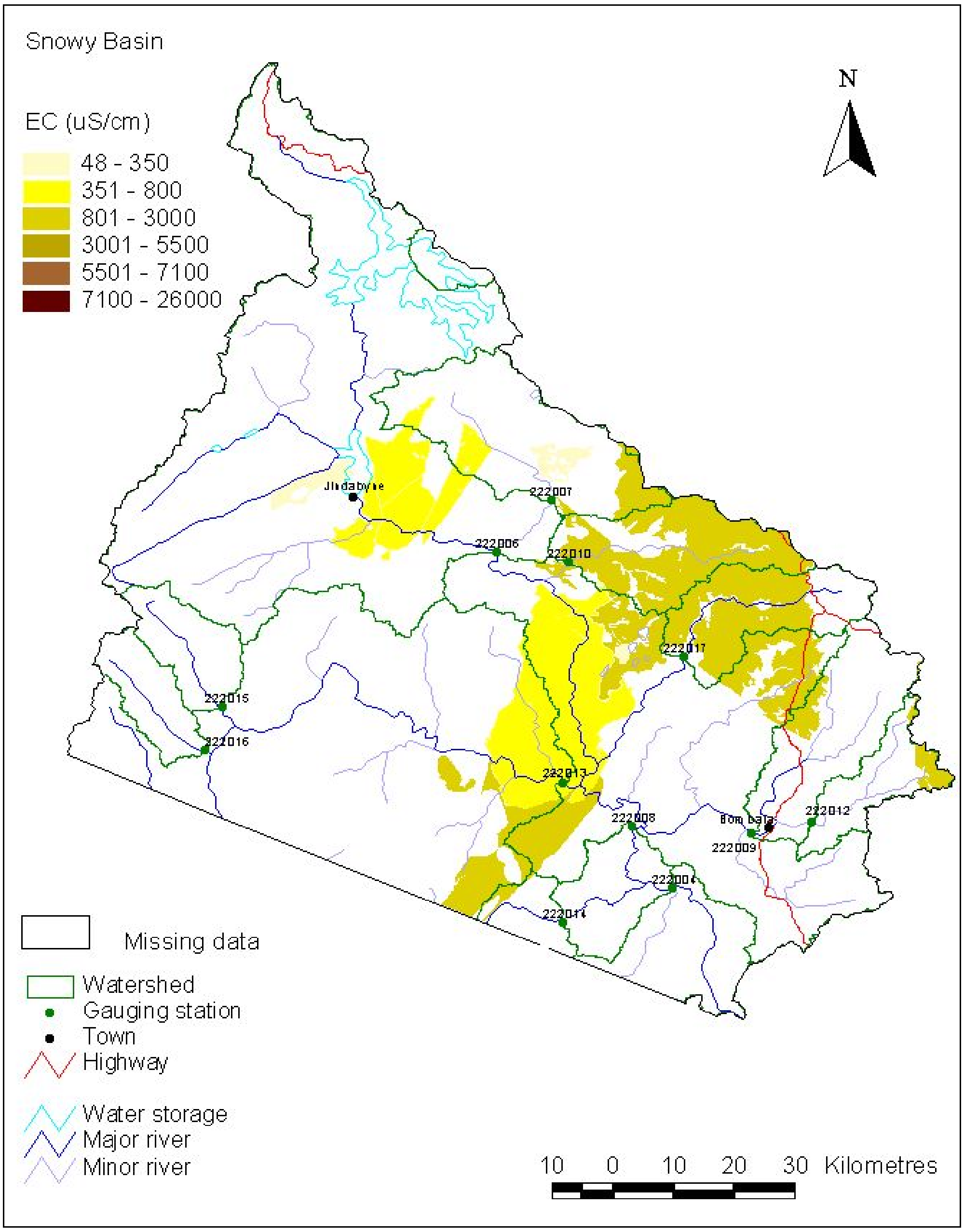


Table 63. Land-use statistics for catchments in the Snowy River basin

Station	Station name	Woody (%)	Crop/pasture (%)	Other (%)
222004	Wellesley (Rowes)	40	60	0
222006	Snowy @ Dalgety	48	46	6
222007	Wullwye Ck @ Woolway	8	91	0
222008	Delegate R @ Quidong	27	73	0
222009	Bombala @ The Falls	35	65	0
222010	Bobundara @ Dalgety	3	97	0
222012	Coolumbooka R	41	59	0
222013	Snowy @ Burnt Hut	26	74	0
222014	Delegate @ Delegate	16	84	0
222015	Jacobs Ladder	98	2	0
222016	Pinch R @ Barry Way	98	2	0
222017	Maclaughlin @ The Hut	15	85	0
222###	Snowy remaining	71	28	2

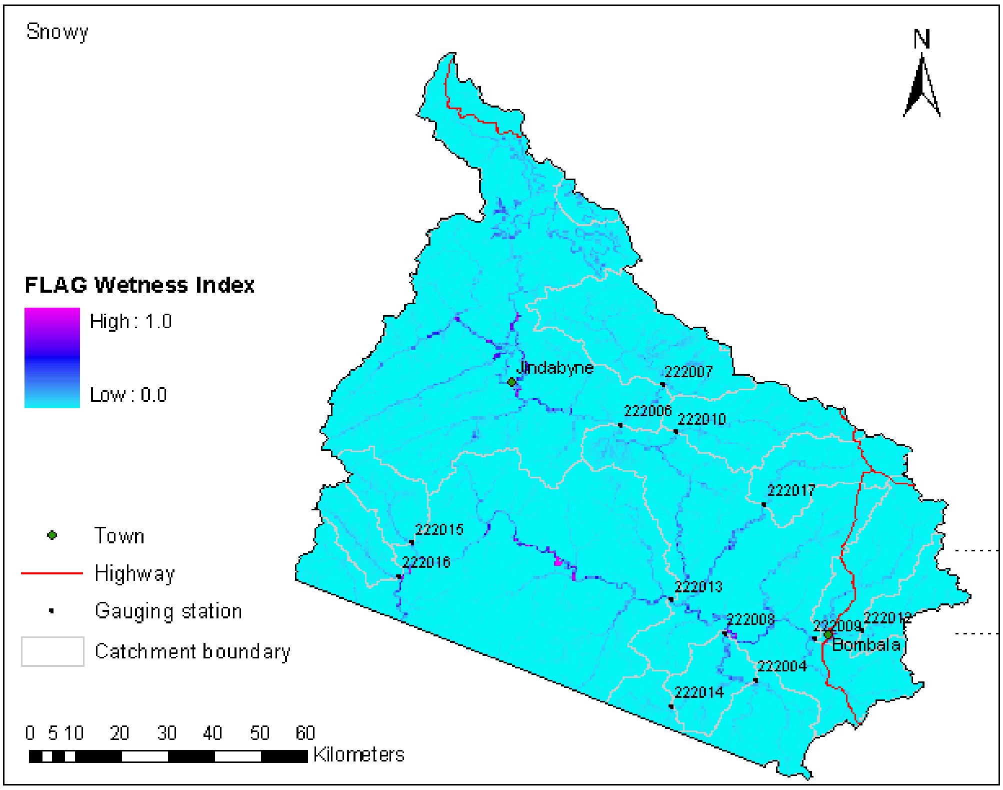
Groundwater salinity

Figure 96. Projected groundwater salinity in the Snowy River basin



FLAG wetness map

Figure 97. FLAG wetness map for the Snowy River basin.



Appendix 21. Slope class areas

Table 64. Percent area of coastal river basins by slope class

Basin	Area of each slope class (%)					
	0E ! 2E slope	**2E ! 5E slope**	**5E ! 10E slope**	**10E ! 15E slope**	**15E ! 20E slope**	**> 20E slope**
Hunter Region						
Manning R.	2	6	17	21	20	34
Karuah R.	26	16	20	15	11	13
Macquarie-Tuggerah	24	21	18	12	11	14
Hunter R.	19	21	20	13	11	17
North Coast Region						
Tweed R.	17	9	18	19	15	22
Richmond R.	35	15	19	14	8	9
Brunswick R.	38	12	13	12	10	14
Clarence R.	13	19	23	16	11	18
Bellinger R.	18	14	16	13	12	27
Hastings R.	19	13	18	15	13	22
Macleay R.	17	22	21	10	7	23
Sydney South Coast Region						
Snowy R.	13	25	28	15	9	10
East Gippsland	5	16	35	23	12	9
Towamba R.	6	12	25	22	17	19
Bega R.	6	13	26	19	13	22
Tuross R.	6	11	17	16	16	34
Moruya R.	5	8	13	12	13	49
Shoalhaven R.	18	28	23	12	7	12
Clyde R.	15	19	20	15	12	20
Wollongong	21	20	23	15	9	11
Sydney	36	30	18	8	4	4
Hawkesbury R.	13	18	18	13	12	26

Appendix 22. Discussion of hazard mapping

Feedback from review and evaluation of the draft hazard maps by regional experts is incorporated in the following summary. The draft salinity hazard maps required further review so they have not been published. In addition, only a small amount of field checking was carried out. Under the NSW Salinity Strategy, a project is currently underway to develop a consistent, statewide salinity hazard and risk data set. This modelling is based on a range of data layers and provides a high-level strategic product for Catchment Management Authorities and government agencies to plan salinity actions.

North Coast basins

The hazard methodology identified relatively small areas of hazard in the North Coast basins. Most DIPNR staff at Kempsey and Grafton considered the implied hazard on these areas was associated with sodic soils considered to have no significance for salinity.

The greatest concentration of hazard identified for the North Coast was in the Richmond basin. There was a reasonably high correspondence with swampy areas in the Myrtle Creek / Bungawalbin Creek catchment and the Berlings Creek catchment north of Casino. The hazard methodology highlighted areas in the Shannon Brook catchment that have relatively poor water quality and a salt load of 69 $t.km^{-2}.y^{-1}$, and the upper Myrtle Creek catchment that produces 19 $t.km^{-2}.y^{-1}$ salt load. Salt outbreaks have been mapped in both of these catchments. The Richmond River at Casino carries a salt load of 24 $t.km^{-2}.y^{-1}$ with streams and tributaries higher in the catchment carrying from 26–54 $t.km^{-2}.y^{-1}$. This indicates that there was a considerable salt store mobilised in those catchments highlighted by the hazard methodology.

The highest hazard identified in the Clarence basin occurred in areas between Grafton and the coast but these areas are probably more appropriately classified as acid sulfate soil landscapes.

Negligible hazard was identified in the Bellinger and Hasting basins although salt loads are moderate to very high for all streams analysed. In the Macleay, high hazard areas were almost entirely associated with sodic soils on terrace formations adjacent to the river. These sodic soils are not considered to be implicated in salinity (G. Atkins pers. comm. 2002).

Hunter basins

The data density of mapped salinity outbreaks in the Hunter resulted in a generally good correlation between known outbreaks and hazard. The extent of extrapolation from the known outbreaks was considered precise and the area of hazard was generally not overstated. Areas identified in the Manning basin, where no salinity outbreak mapping was available, appear feasible. Identified areas of high hazard in the Karuah basin are likely to be confused with acid sulfate soils. Hazard was not identified for the Lake Macquarie and Tuggerah Lake basin but stream salt loads are high to very high.

Sydney South Coast basins

In the western Sydney area of both the Hawkesbury and Sydney basins, there was good general agreement between mapped outbreak areas and hazard. However, recent investigations have shown that the outbreak mapping exaggerated the extent of current outbreaks. As this data was used as the evidence layer, the identified hazard is also likely to be an overstatement. The Parramatta River above Parramatta and its tributary Toongabbie Creek drain the Sydney basin area and have extreme salt loads of 129 and 181 $t.km^{-2}.y^{-1}$ respectively.

Considerable areas of high hazard were identified in the mid Hawkesbury catchment, particularly around Lake Burragorang, the Colo River catchment and the Macdonald River Catchment. Almost all of this area is National Park, including the Colong Wilderness area, but may contain salinity hazards because of its geology. There is no stream salt load data available for these areas.

In the Capertee River valley in the headwaters of the Colo system, geology with high salinity groundwater contributes to high salt loads and poor water quality. The hazard methodology identified a high hazard in this catchment despite there being no previous mapping of outbreaks. Field checking by staff from the Penrith Office of DIPNR confirms the occurrence of high hazard in this catchment.

High hazard was identified in the lower Cox's Creek catchment corresponding with areas of forest. However, small areas of mapped salinity outbreaks higher in the catchment were missed. High salt loads from the upper catchment also suggest a high hazard in these areas.

Most of the salinity which occurs in the upper Hawkesbury and Shoalhaven basins was found in the areas covered by the Goulburn and Braidwood 1:100 000 map sheets. Salinity associated with gully erosion was not included in the evidence layer. The data density would almost double in these areas if these sites were included in the evidence layer. Due to the limitations in the evidence and predictive layers there appears to be a poor correspondence between existing salinity and hazard identification for some areas. For example, on the Goulburn sheet no hazard was identified in Jacqua Creek that corresponded with mapped areas of existing salinity.

Minor areas of incipient salinity located northwest of Goulburn and away from the river were not identified as a significant hazard. Generally, the few known sites in this area are associated with perched water tables on hill slopes rather than high water tables in valley floors and are less likely to be picked up by the FLAG wetness index. It was reported that salinity occurs in the Woodhouselee area east of Pejar Dam in low-lying areas adjacent to gullies but the hazard methodology did not indicate this. However, a high wetness/hazard index was identified in the Mulwaree Ponds area which corresponds to some mapped sites. This indicates potential for further salinity to develop in this area, particularly in the Gundary Plains where a medium hazard was identified.

Hazard areas identified in the northern part of the Braidwood sheet map generally appear reasonable. In the Lake Bathurst area there was good correspondence between areas identified as medium/high hazard and known salinity. For other areas the relationship was only average. Areas identified as medium/high salinity hazard but with no corresponding mapped salinity outbreaks occur in the southern section of the map (e.g. Reedy Creek, Mulloon Creek, and Manar Creek).

Small areas of hazard identified in the Bega, Towamba and upper Snowy River basins are considered feasible but hazard areas identified in the remainder of the Sydney South Coast basins, especially areas close to the coast, are considered incorrect.

Data issues

The weights-of-evidence mapping relies on two types of data:

- the evidence layer
- predictive land attribute layers.

The main advantage of using weights-of-evidence as a method of combining maps is that the method is objective and avoids subjective choice of weighting factors, as in the ranking of overlay maps. It can also provide a quick 'reconnaissance' approach. However, consistent data is required for both the predictive and response (or evidence) layers.

Major problems experienced with the evidence layer

The evidence layer used was the map coverage of known salinity outbreaks used in the National Land and Water Audit project. Saline soil profiles from the SALIS database were included as additional point source data. The major problems found with the data layer are described below:

Incomplete inclusion of available information

In the Goulburn district, only salinity associated with sheet and rill erosion was included in the evidence layer. Saline sites associated with gully erosion (as recorded in the multi-attribute mapping of the district) were not included in the evidence layer. These areas represent the most severely degraded and scalded sites and account for about 50% of the known sites.

Over-estimation of actual area salinised

In western Sydney, the mapped area of outbreak was considered by local staff in the Penrith office to be an over-estimate.

Missing data and unmapped salinity outbreaks

In the North Coast Region, salinity mapping has been confined to the eastern half along the coastal fringe zone (east of meridian 152º 30’ 00” E). In these areas when dryland salinity does occur, it is often closely associated with acid sulfate soil landscapes. The evidence layer, when combined with predictive layers, is likely to confuse the two processes, particularly where the resolution of the predictive layer is coarse. In contrast, some known areas of outbreak, for example around Walcha, have never been mapped. Data on dryland salinity was not necessarily recorded in soil landscape mapping reports or SALIS and was therefore not available to the evidence layer. An example is the Braidwood sheet where discharge areas make up only a very small proportion of the landscape units and soil landscapes cannot be used as a surrogate for salinity outbreak mapping (Jenkins pers. comm. 2002).

Inappropriate SALIS data

Most of the point data obtained from SALIS was associated with coastal dunes, swamps and acid sulfate soil landscapes and should have been excluded from the evidence layer. When combined with coarse geology from the predictive layers the process over-extrapolated these data points.

Data dominance

The hazard map is biased through data dominance, especially as the data is clustered in space (e.g. the Hunter basin and western Sydney).

Major problems experienced with the predictive attribute layers

Although it may be desirable to identify the location of all possible salinity outbreaks, this expectation is unrealistic. At best, hazard mapping aims to extend current knowledge of outbreaks by association with related attributes. The most significant attributes associated with dryland salinity hazard are geology, topography, soils and climate. Problems with scale and availability of these data layers are discussed below.

Geology

A uniform geology layer at a scale of 1:100 000 would be desirable, but was not available for the whole coast. A geology layer at 1:250 000 scale was available but this was not suitable for salinity hazard mapping due to data inconsistencies. This 1:250 000 scale map was a composite of all available geology maps at this scale. However, the individual maps were produced over a long period of time, during which mapping conventions changed and thus the degree of reliability varies. Many adjoining sheets were not properly edge matched, resulting in incorporation of false and artificial unit boundaries into the overall data layer. Importantly, naming conventions for units at this scale are based only on age and a specific local area name rather than an objective hierarchical grouping of lithology. Therefore, units that are similar in terms of geomorphology (i.e. very similar age, rock type and significance to salinity) and have a high degree of 'likeness', but are geographically isolated, cannot be logically grouped together. Lithology data was incomplete and therefore could not be used to group units. Approximately 30000 geology polygons were mapped for the coast but 12000 or 40% had no lithology data attached.

The NSW Atlas geology therefore had to be used despite the undesirably coarse resolution. This introduced a severe limitation in heterogeneity/resolution of geology boundaries, which led to unacceptably abrupt boundaries in the hazard mapping.

Soils

Uniform maps of 'soil type' were unavailable for the coast. Soil landscape maps were available at a scale of 1:100 000 for the majority of the coast and the remainder was covered by 1:250 000 CRA maps that essentially reproduced the soil landscape mapping process at a coarser scale. For the hazard mapping process a composite 'best' soils map was produced from both these sources. As with the geology layer the soil data layer shares a similar naming problem, where soil landscapes are named for some local feature where the landscape unit was first defined.

Soil landscapes themselves are composed of a catena of soil types on similar geology, landform and topographic position. Similar soil types (for example chromosols) may form on a number of different geologies and landform units resulting in a range of soil chemical properties. Simple grouping of soil types without further classification based on geology and landform can result in soils associated with salinity being lumped in with soils with no salinity association, and therefore inaccuracy. For the draft salinity hazard maps soil landscapes were grouped on whether or not they contained sodic soils. Sodic soils are often formed in association with salinisation processes (Fritsch and Fitzpatrick 1994) and are generally found in depositional lower landform positions. However, the inability to logically disaggregate on the basis of geology resulted in over-prediction of hazard, particularly the mid-Macleay, Richmond and Clarence basins.

Sodic soils on certain acid geologies, such as granite, form due to high natural sodium content independent of the salinisation and cation leaching processes described by Fritsch and Fitzpatrick (1994). However, salinity is often found at the margins of these geologies where sodic soils may overlap the contact zone between two geologies. This process was very difficult to delineate spatially without high resolution data. Likewise, a significant salinity process is associated with groundwater flow systems at the contact between basic volcanic basalt caps and lava flows, and underlying metasediments. Soil types overlying these contacts may have no particular salinity significance except at the contact. In these cases, it was the 'contact zone' which was the effective predictor, not the soil type. This was difficult to represent using the weights-of-evidence approach.

Topography

The effect of topography was primarily incorporated into the hazard map by merging the weights-of-evidence map with the FLAG wetness index. Elevation and landform were also incorporated as predictive attributes in the weights-of-evidence approach. Combining the evidence layer with the FLAG wetness index was designed to select those wet areas that are likely to be saline rather than just waterlogged. The FLAG wetness index maps of the basins are included in Appendices 1 to 20.

The FLAG wetness index was designed to find positions in the landscape where discharge was likely to be associated with break of slope. It does not identify the processes related to the contact zones previously outlined, which are often located well above the break of slope position.

An alternative wetness index called the compound topographic index (CTI) was also calculated for all the coastal catchments. Merging of the CTI with the weights-of-evidence layer may usefully delineate flow line discharge areas, although the FLAG wetness index will also do this and it captures the groundwater hillslope hydrology processes better than the CTI index. Therefore, the CTI index was not used especially as the problems associated with the weights-of-evidence layer were considered the more significant issue.

In salinity modelling using CATSALT (Tuteja et al. 2003; Vaze et al. in press), CTI was defined in bands according to the cumulative probability of the index. Landform units associated with soil catenae in soil landscapes were defined for the weights-of-evidence layer using the FLAG Upness index. This topographic analysis assumed sodic soils were usefully confined to lower landscape positions. Either of these index signatures may be useful in defining salinity associated with contact zone influences if sufficient resolution was available from a geology layer. In this respect airborne geophysical data, magnetics, and radiometrics in particular, may provide an answer to accurately defining contact zones in future as well as faults and other geological unconformities.

Groundwater flow systems

Groundwater flow systems (GFS) have an important bearing on salinity discharge processes and groundwater response times (Coram 1998). They are derived primarily from a consideration of geology and topography and their inclusion in the weights-of-evidence layer resulted in similar problems as outlined above. GFS data was available at a scale of At 1:5 000 000 and their inclusion in the weights-of-evidence layer did not enhance the predictive capacity of the draft hazard map.

Groundwater salinity

The process of assigning groundwater salinity data to geology is discussed in chapter three. The overall paucity of data meant that groundwater salinity could not be included in the analysis.

Depth to groundwater

Groundwater vulnerability mapping was available for a small proportion of the coastal basins. This data set contains information on depth to water tables. It was excluded from this analysis because of its incomplete coverage but its inclusion would be highly desirable, when the process for hazard mapping is refined, for selected target areas where the data are available.

Surface water salinity

The salt load and salinity analysis contained in this audit provides an objective means of ranking catchments in terms of salt sources. However, data constrained the number of catchments that could be analysed. Less than 25% of some basins was able to be covered by the analysis. The incomplete coverage meant this layer had to be excluded from the hazard mapping analysis.

Land-use

After initially including this layer it was excluded from the analysis to allow the methodology to predict hazard in forested areas. It was concluded that as mapped salt outbreak observations avoid forested areas (bias in the evidence layer) including landuse would bias the hazard prediction.