Australian Government

BIOREGIONAL ASSESSMENTS

PROVIDING SCIENTIFIC WATER RESOURCE INFORMATION ASSOCIATED WITH COAL SEAM GAS AND LARGE COAL MINES

Current water accounts and water quality for the Namoi subregion

Product 1.5 for the Namoi subregion from the Northern Inland Catchments Bioregional Assessment

8 February 2016

A scientific collaboration between the Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia

The Bioregional Assessment Programme

The Bioregional Assessment Programme is a transparent and accessible programme of baseline assessments that increase the available science for decision making associated with coal seam gas and large coal mines. A bioregional assessment is a scientific analysis of the ecology, hydrology, geology and hydrogeology of a bioregion with explicit assessment of the potential direct, indirect and cumulative impacts of coal seam gas and large coal mining development on water resources. This Programme draws on the best available scientific information and knowledge from many sources, including government, industry and regional communities, to produce bioregional assessments that are independent, scientifically robust, and relevant and meaningful at a regional scale.

The Programme is funded by the Australian Government Department of the Environment. The Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia are collaborating to undertake bioregional assessments. For more information, visit http://www.bioregionalassessments.gov.au.

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The Office of Water Science, within the Australian Government Department of the Environment, is strengthening the regulation of coal seam gas and large coal mining development by ensuring that future decisions are informed by substantially improved science and independent expert advice about the potential water related impacts of those developments. For more information, visit http://www.environment.gov.au/coal-seam-gas-mining/.

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Authorship is listed in relative order of contribution.

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Cover photograph

Gulligal Lagoon, which is located about halfway between Gunnedah and Boggabri on the western side of the Namoi River, NSW, 2005

Credit: Neal Foster

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Introduction

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) was established to provide advice to the federal Minister for the Environment on potential water-related impacts of coal seam gas (CSG) and large coal mining developments.

Bioregional assessments (BAs) are one of the key mechanisms to assist the IESC in developing this advice so that it is based on best available science and independent expert knowledge. Importantly, technical products from BAs are also expected to be made available to the public, providing the opportunity for all other interested parties, including government regulators, industry, community and the general public, to draw from a single set of accessible information. A BA is a scientific analysis, providing a baseline level of information on the ecology, hydrology, geology and hydrogeology of a bioregion with explicit assessment of the potential direct, indirect and cumulative impacts of CSG and coal mining development on water resources.

The IESC has been involved in the development of *Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources* (the BA methodology; Barrett et al., 2013) and has endorsed it. The BA methodology specifies how BAs should be undertaken. Broadly, a BA comprises five components of activity, as illustrated in Figure 1. Each BA will be different, due in part to regional differences, but also in response to the availability of data, information and fit-for-purpose models. Where differences occur, these are recorded, judgments exercised on what can be achieved, and an explicit record is made of the confidence in the scientific advice produced from the BA.

The Bioregional Assessment Programme

The Bioregional Assessment Programme is a collaboration between the Department of the Environment, the Bureau of Meteorology, CSIRO and Geoscience Australia. Other technical expertise, such as from state governments or universities, is also drawn on as required. For example, natural resource management groups and catchment management authorities identify assets that the community values by providing the list of water-dependent assets, a key input.

The Technical Programme, part of the Bioregional Assessment Programme, will undertake BAs for the following bioregions and subregions:

- the Galilee, Cooper, Pedirka and Arckaringa subregions, within the Lake Eyre Basin bioregion
- the Maranoa-Balonne-Condamine, Gwydir, Namoi and Central West subregions, within the Northern Inland Catchments bioregion
- the Clarence-Moreton bioregion
- the Hunter and Gloucester subregions, within the Northern Sydney Basin bioregion
- the Sydney Basin bioregion
- the Gippsland Basin bioregion.

Technical products (described in a later section) will progressively be delivered throughout the Programme.

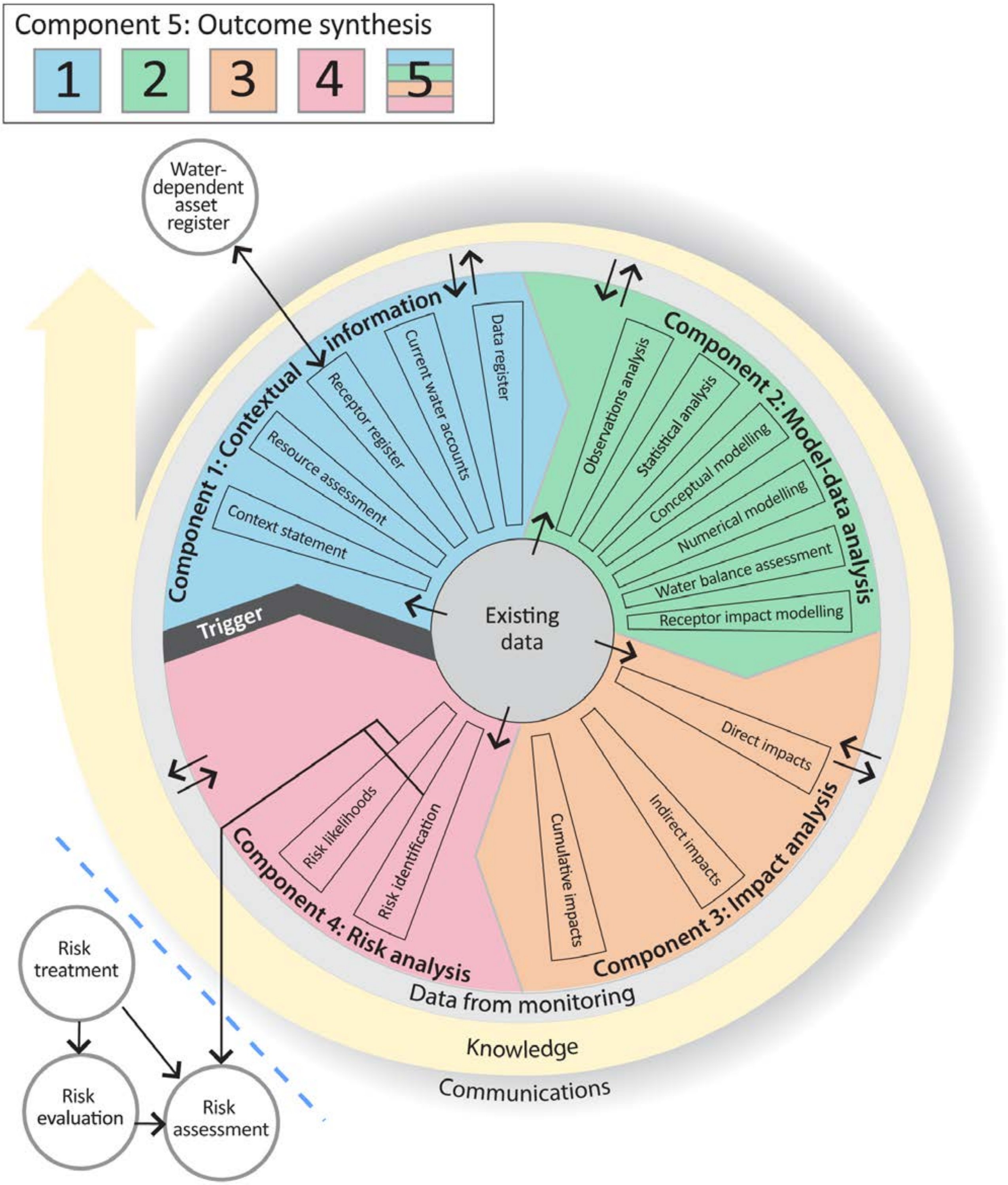

Figure 1 Schematic diagram of the bioregional assessment methodology

The methodology comprises five components, each delivering information into the bioregional assessment and building on prior components, thereby contributing to the accumulation of scientific knowledge. The small grey circles indicate activities external to the bioregional assessment. Risk identification and risk likelihoods are conducted within a bioregional assessment (as part of Component 4) and may contribute activities undertaken externally, such as risk evaluation, risk assessment and risk treatment. Source: Figure 1 in Barrett et al. (2013), © Commonwealth of Australia

Methodologies

For transparency and to ensure consistency across all BAs, submethodologies have been developed to supplement the key approaches outlined in the *Methodology for bioregional assessments of the impact of coal seam gas and coal mining development on water resources* (Barrett et al., 2013). This series of submethodologies aligns with technical products as presented in Table 1. The submethodologies are not intended to be 'recipe books' nor to provide step-by-step instructions; rather they provide an overview of the approach to be taken. In some instances, methods applied for a particular BA may need to differ from what is proposed in the submethodologies – in this case an explanation will be supplied. Overall, the submethodologies are intended to provide a rigorously defined foundation describing how BAs are undertaken.

Table 1 Methodologies and associated technical products listed in Table 2

Code	Proposed title	Summary of content	Associated technical product
M01	*Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources*	A high-level description of the scientific and intellectual basis for a consistent approach to all bioregional assessments	All
M02	*Compiling water-dependent assets*	Describes the approach for determining water-dependent assets	1.3 Description of the water-dependent asset register
M03	*Assigning receptors and impact variables to water-dependent assets*	Describes the approach for determining receptors associated with water-dependent assets	1.4 Description of the receptor register
M04	*Developing a coal resource development pathway*	Specifies the information that needs to be collected and reported in product 1.2 (i.e. known coal and coal seam gas resources as well as current and potential resource developments). Describes the process for determining the coal resource development pathway (reported in product 2.3)	1.2 Coal and coal seam gas resource assessment 2.3 Conceptual modelling
M05	*Developing the conceptual model for causal pathways*	Describes the development of the conceptual model for causal pathways, which summarises how the 'system' operates and articulates the links between coal resource developments and impacts on receptors	2.3 Conceptual modelling
M06	*Surface water modelling*	Describes the approach taken for surface water modelling across all of the bioregions and subregions. It covers the model(s) used, as well as whether modelling will be quantitative or qualitative.	2.6.1 Surface water numerical modelling
M07	*Groundwater modelling*	Describes the approach taken for groundwater modelling across all of the bioregions and subregions. It covers the model(s) used, as well as whether modelling will be quantitative or qualitative. It also considers surface water – groundwater interactions, as well as how the groundwater modelling is constrained by geology.	2.6.2 Groundwater numerical modelling

Code	Proposed title	Summary of content	Associated technical product
M08	*Receptor impact modelling*	Describes how to develop the receptor impact models that are required to assess the potential impacts from coal seam gas and large coal mining on receptors. Conceptual, semi-quantitative and quantitative numerical models are described.	2.7 Receptor impact modelling
M09	*Propagating uncertainty through models*	Describes the approach to sensitivity analysis and quantifying uncertainty in the modelled hydrological response to coal and coal seam gas development	2.3 Conceptual modelling 2.6.1 Surface water numerical modelling 2.6.2 Groundwater numerical modelling 2.7 Receptor impact modelling
M10	*Risk and cumulative impacts on receptors*	Describes the process to identify and analyse risk	3 Impact analysis 4 Risk analysis
M11	*Hazard identification*	Describes the process to identify potential water-related hazards from coal and coal seam gas development	2 Model-data analysis 3 Impact analysis 4 Risk analysis
M12	*Fracture propagation and chemical concentrations*	Describes the likely extent of both vertical and horizontal fractures due to hydraulic stimulation and the likely concentration of chemicals after production of coal seam gas	2 Model-data analysis 3 Impact analysis 4 Risk analysis

Each submethodology is available online at http://www.bioregionalassessments.gov.au. Submethodologies might be added in the future.

Technical products

The outputs of the BAs include a suite of technical products variously presenting information about the ecology, hydrology, hydrogeology and geology of a bioregion and the potential direct, indirect and cumulative impacts of CSG and coal mining developments on water resources, both above and below ground. Importantly, these technical products are available to the public, providing the opportunity for all interested parties, including community, industry and government regulators, to draw from a single set of accessible information when considering CSG and large coal mining developments in a particular area.

The information included in the technical products is specified in the BA methodology. Figure 2 shows the information flow within a BA. Table 2 lists the content provided in the technical products, with cross-references to the part of the BA methodology that specifies it. The red rectangles in both Figure 2 and Table 2 indicate the information included in this technical product.

This technical product is delivered as a report (PDF). Additional material is also provided, as specified by the BA methodology:

- all unencumbered data syntheses and databases
- unencumbered tools, model code, procedures, routines and algorithms
- unencumbered forcing, boundary condition, parameter and initial condition datasets
- the workflow, comprising a record of all decision points along the pathway towards completion of the BA, gaps in data and modelling capability, and provenance of data.

The PDF of this technical product, and the additional material, are available online at http://www.bioregionalassessments.gov.au.

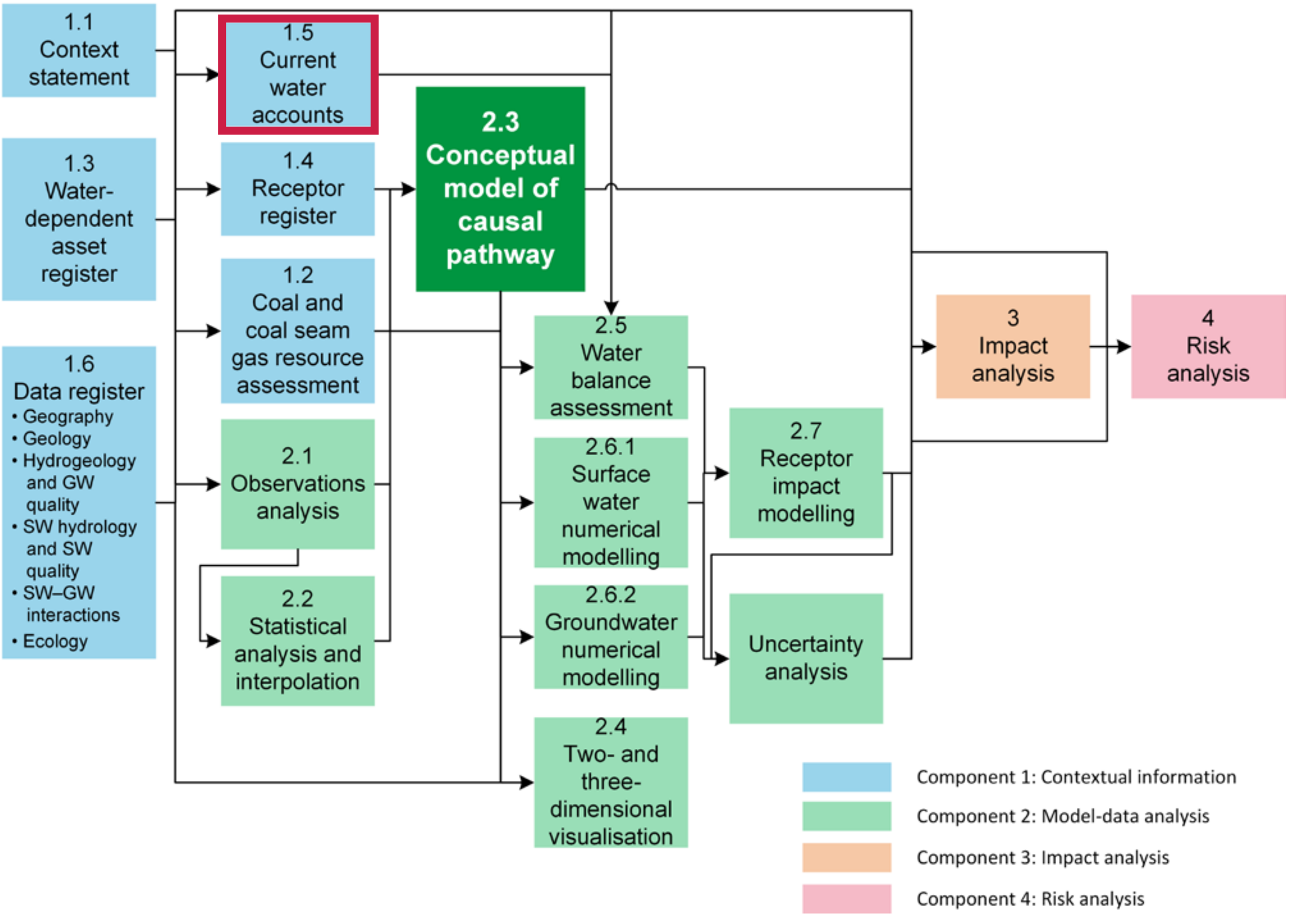

Figure 2 The simple decision tree indicates the flow of information through a bioregional assessment

The red rectangle indicates the information included in this technical product.

Table 2 Technical products delivered by the Northern Inland Catchments Bioregional Assessment

For each subregion in the Northern Inland Catchments Bioregional Assessment, technical products are delivered online at http://www.bioregionalassessments.gov.au, as indicated in the 'Type' column[a]. Other products – such as datasets, metadata, data visualisation and factsheets – are provided online.

Component	Product code	Title	Section in the BA methodology[b]	Type[a]
Component 1: Contextual information for the Namoi subregion	1.1	Context statement	2.5.1.1, 3.2	PDF, HTML
	1.2	Coal and coal seam gas resource assessment	2.5.1.2, 3.3	PDF, HTML
	1.3	Description of the water-dependent asset register	2.5.1.3, 3.4	PDF, HTML, register
	1.4	Description of the receptor register	2.5.1.4, 3.5	PDF, HTML, register
	1.5	Current water accounts and water quality	2.5.1.5	PDF, HTML
	1.6	Data register	2.5.1.6	Register
Component 2: Model-data analysis for the Namoi subregion	2.1-2.2	Observations analysis, statistical analysis and interpolation	2.5.2.1, 2.5.2.2	PDF, HTML
	2.3	Conceptual modelling	2.5.2.3, 4.3	PDF, HTML
	2.5	Water balance assessment	2.5.2.4	PDF, HTML
	2.6.1	Surface water numerical modelling	4.4	PDF, HTML
	2.6.2	Groundwater numerical modelling	4.4	PDF, HTML
	2.7	Receptor impact modelling	2.5.2.6, 4.5	PDF, HTML
Component 3: Impact analysis for the Namoi subregion	3-4	Impact analysis	5.2.1	PDF, HTML
Component 4: Risk analysis for the Namoi subregion		Risk analysis	2.5.4, 5.3	
Component 5: Outcome synthesis for the Northern Inland Catchments bioregion	5	Outcome synthesis	2.5.5	PDF, HTML

[a]The types of products are as follows:
- 'PDF' indicates a PDF document that is developed by the Northern Inland Catchments Bioregional Assessment using the structure, standards, and look and feel specified by the programme.
- 'HTML' indicates the same content as in the PDF document, but delivered as webpages.
- 'Register' indicates controlled lists that are delivered using a variety of formats as appropriate.
- 'Cross-reference' indicates material that does not use the same structure, standards, and look and feel specified by the programme. This material is typically developed externally or through aligned research projects funded by the Department of the Environment. A webpage links to this material and explain how it fits into the Assessment.
- 'Not produced' indicates that the product was not developed. A webpage explains why and points to relevant submethodologies (Table 1).

[b]Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources (Barrett et al., 2013)

About this technical product

The following notes are relevant only for this technical product.

- All reasonable efforts were made to provide all material under a Creative Commons Attribution 3.0 Australia Licence. The copyright owners of the following figure, however, did not grant permission to do so: Figure 14. It should be assumed that third parties are not entitled to use this material without permission from the copyright owner.
- All maps created as part of this BA for inclusion in this product used the Albers equal area projection with a central meridian of 151.0° East for the Northern Inland Catchments bioregion and two standard parallels of –18.0° and –36.0°.
- Contact bioregionalassessments@bom.gov.au to access metadata (including copyright, attribution and licensing information) for all datasets cited or used to make figures in this product. At a later date, this information, as well as all unencumbered datasets, will be published online.
- The citation details of datasets are correct to the best of the knowledge of the Bioregional Assessment Programme at the publication date of this product. Readers should use the hyperlinks provided to access the most up-to-date information about these data; where there are discrepancies, the information provided online should be considered correct. The dates used to identify Bioregional Assessment Source Datasets are the dataset's published date. Where the published date is not available, the last updated date or created date is used. For Bioregional Assessment Derived Datasets, the created date is used.

References

Barrett DJ, Couch CA, Metcalfe DJ, Lytton L, Adhikary DP and Schmidt RK (2013) Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment. Department of the Environment, Australia. Viewed 8 February 2016, http://www.iesc.environment.gov.au/publications/methodology-bioregional-assessments-impacts-coal-seam-gas-and-coal-mining-development-water

1.5 Current water accounts and water quality for the Namoi subregion

This product provides current water account and water quality information that will be used in subsequent products in the bioregional assessment.

The water accounts include information about water stores, flows, allocations and use that will be required in product 2.5 *Water balance assessment*, product 2.6.1 *Surface water numerical modelling*, and product 2.6.2 *Groundwater numerical modelling*.

This product also provides information about surface water and groundwater quality that will be required for product 3-4 *Impact and risk analysis*.

1.5.1 Current water accounts

Summary

This product summarises surface water accounts in the Namoi river basin for the period 2004–05 to 2011–12. It includes information about major water resources: water stores, flows, allocations, surface water permits and use. Streamflow and water use are the most complete estimates of water availability and use within the water balance and are thus used as the basis for the water account. The Namoi subregion is smaller than the Namoi river basin because the eastern part of the river basin does not overlie a coal-bearing geological basin. The surface water accounts are conducted for the Namoi river basin and not for the subregion because publicly available information on water use is summarised at the basin scale. The Namoi river basin includes the Namoi, Peel and Manilla rivers. Current coal and coal seam gas (CSG) development and exploration are primarily located in the central and eastern parts of the subregion.

There are three large dams (Keepit, Split Rock and Chaffey dams) and a few small dams in the Namoi river basin (but outside the subregion) that supply water to agricultural, domestic and municipal users. The combined storage volume in the large dams is 882 GL. The mean water volume stored for 2004–05 to 2011–12 was 233 GL (26%).

The main surface water resource of the Namoi subregion is the Namoi River. The long-term mean annual flow in the Namoi River at Gunnedah downstream of Keepit Dam is about 620 GL/year whereas at Goangra (46 km upstream of the end-of-system at Walgett) it is about 563 GL/year. The reduction in flow is due to the presence of weirs and surface water diversions mainly used for irrigation as well as instream evaporation and groundwater leakage. About 51% (714 km^2) of irrigation in the Namoi river basin is located between Gunnedah and Walgett. The Peel River contributes on average (1973–2011) 235 GL/year to the Namoi River.

The surface water baseline diversion limit was estimated at 508 GL/year whereas the mean annual cap target from 2005–06 to 2011–12 was 241 GL/year, highlighting the recent dry conditions. In the Namoi river basin, total surface water permits amount to 424 GL/year in the regulated sections of the river, of which 1.4 GL/year (less than 1%) are high security, 286 GL/year (68%) are general security, 2.2 GL/year (less than 1%) are for domestic and stock, 19 GL/year (4%) are for local water utilities and 115 GL/year (27%) are supplementary permits. Total surface water permits amount to 117 GL/year in the unregulated sections of the Namoi river basin. The mean annual surface water diverted from 2004–05 to 2011–12 was 278 GL, with 271 GL/year (97%) used in irrigation and 7 GL/year (3%) used for domestic and stock or local water utilities. On average, 84 GL/year of surface water is diverted to agriculture in unregulated rivers. These diversions are unmetered estimates and represent about 30% of mean annual surface water diversions across the basin. Further increase in surface water diversions is restricted under current water plans.

This product also summarises groundwater account data in the Namoi subregion for the period 2006–07 to 2013–14. There are approximately 10,300 licensed bores across the

subregion. Approximately 7600 are for stock and domestic water rights, 1401 are for monitoring and exploration of groundwater resources, 983 are for irrigation, 3 are for conservation, and the remaining 309 are for commercial or town water supply extraction.

The mean annual groundwater usage from 2006–07 to 2013–14 was 165 GL/year. The total licensed groundwater extraction volume in 2013–14 was 327 GL/year. However, this includes volumes relating to the entirety of some groundwater sources that only lie partly in the subregion. 252.5 GL/year (77%) was licensed under Aquifer class access licences, 57.7 GL/year (18%) was licensed under Supplementary Water class licences, 16.8 GL/year (5%) was licensed under Local Water Utility class licences and 0.025 GL/year (0.008%) was licensed under Aquifer (Town Water Supply) class licences. The most heavily utilised groundwater sources are the Lower Namoi and the Upper Namoi zones 3, 4, 5 and 8. Groundwater extraction for basic water rights does not require a water access licence, and consequently can only be estimated. Estimated take under stock and domestic rights is 46.4 GL/year.

1.5.1.1 Surface water

This product summarises water accounts in the Namoi river basin for the water years (year starting in July and ending in June) 2004–05 to 2011–12, for which all publicly available data used here overlapped. A water account provides a summary of resource availability for a defined area through quantifying storage volumes, inflows and outflows within a management framework. Surface water streamflow (either as inflows or outflows into a basin or subregion) is the result of numerous – natural and anthropogenic – interacting processes, and provides the most complete estimate of water availability. On the other hand, surface water diversions provide the most complete estimate of water use for productive activities (irrigation, mining, town water supply). Both are routinely monitored in the Namoi and may be impacted by current coal and coal seam gas (CSG) development and exploration; hence they form the basis of the water accounts. The accounts are specifically intended to estimate current water availability and use patterns. They rely on observed rather than modelled data wherever possible, as there would be uncertainty associated with modelled estimates and propagation of errors from model assumptions (Kirby et al., 2008). Publicly available information on water use is only available for the river basin, hence this product conducts the account for the entire basin. The time period 2004–05 to 2011–12 applies for all analyses conducted here, unless stated otherwise. The water accounts are thus indicative of recent climate conditions and water use practices.

The Namoi River, located in north-eastern NSW, drains an area of 42,000 km^2 from east to west from its headwaters in the Great Dividing Range (CSIRO, 2007). The Namoi subregion is smaller than the Namoi river basin because the eastern part of the river basin, which includes three large dams, does not overlie a coal-bearing geological basin (Welsh et al., 2014). Further details on the Namoi river basin and the Namoi subregion, including the proportion of the river within the subregion, are given in companion product 1.1 for the Namoi subregion (Welsh et al., 2014). Current coal and CSG development and exploration which may impact water resources are primarily located in the central and eastern parts of the subregion (Geoscience Australia, Dataset 1). Detailed information about coal and CSG development is provided in companion product 1.2 for the Namoi subregion (Northey et al., 2014). Figure 3 shows a detailed stream network, storages, gauging stations, major land uses and current and potential coal mines and CSG developments in the subregion. The major tributaries of the river upstream of Narrabri are the Peel, Manilla, McDonald and Mooki rivers and Coxs Creek. The tributaries downstream of Narrabri are Pian (anabranch), Gunidgera (anabranch), and Baradine and Bohena creeks (Green et al., 2011). There are numerous other minor tributaries.

Flows in the Namoi river basin are highly regulated. Long-term hydrometric records (see CSIRO, 2007) indicate that Split Rock Dam regulates 93% of all dam inflows and Keepit Dam regulates 77% of all dam inflows. Flows in the Peel River are less regulated with Chaffey Dam regulating 41% of all dam inflows (CSIRO, 2007). The long-term mean annual flow (1970–2011) in the Namoi River at Gunnedah downstream of Keepit Dam is about 620 GL/year whereas at Goangra (46 km upstream of the end-of-system at Walgett) it is about 563 GL/year (NSW Office of Water, Dataset 2). The reduction of flow is due to the presence of weirs and surface water diversions mainly used for irrigation and in-stream losses (evaporation and leakage to groundwater). About 51% (714 km^2) of irrigation in the Namoi river basin is located between Gunnedah and Walgett, about 10 km upstream of the junction of the Namoi and Barwon rivers (Department of Agriculture: Australian Bureau of Agricultural and Resource Economics and Sciences, Dataset 3) (Figure 3). The long-term mean annual flow (1973–2011) of the Peel River is 235 GL/year (NSW Office of Water, Dataset 2).

There are major unregulated tributaries upstream of Split Rock Dam including the Manilla and Upper Namoi rivers. The Mooki River (which joins the Namoi River at Gunnedah) and Bundella and Coxs creeks (which join the Namoi River at Boggabri) are also unregulated; as well as the lower section of Pian Creek and Lake Goran catchment (NSW Government, 2012) (Figure 3). Extensive irrigation (about 53 km^2) – much of it large scale – occurs in the Mooki River (and tributaries), Coxs Creek and Pian Creek catchments (Department of Agriculture: Australian Bureau of Agricultural and Resource Economics and Sciences, Dataset 3).

The baseline diversion limit was estimated at 508 GL/year but a reduction of 10 GL/year equated to a new sustainable diversion limit of 498 GL/year (the Commonwealth's *Basin Plan 2012*). The average annual cap target (which depends on climate conditions and water stored in dams) from 2005–06 to 2011–12 was 241 GL/year, highlighting the recent dry conditions (MDBC, 2006; MDBC, 2007; MDBC, 2008a; MDBA, 2009; MDBA, 2010; MDBA, 2011; MDBA, 2012).

The mean annual surface water diverted from 2005–06 to 2011–12 was 278 GL, with 271 GL/year (97%) used in irrigation and 7 GL/year (3%) used for domestic or other purposes. On average, 84 GL/year of surface water diverted to agriculture in unregulated rivers are unmetered estimates (MDBC, 2006; MDBC, 2007; MDBC, 2008a; MDBA, 2009; MDBA, 2010; MDBA, 2011; MDBA, 2012). These diversions in unregulated rivers represent about 30% of mean annual surface water diversions across the basin. Further increase in surface water diversions is restricted under current water plans.

The remainder of this product describes:

- water volumes held in surface water storages, inflows and outflows
- gauged inflows and outflows
- surface water permits and allocations
- surface water diversions

- data gaps.

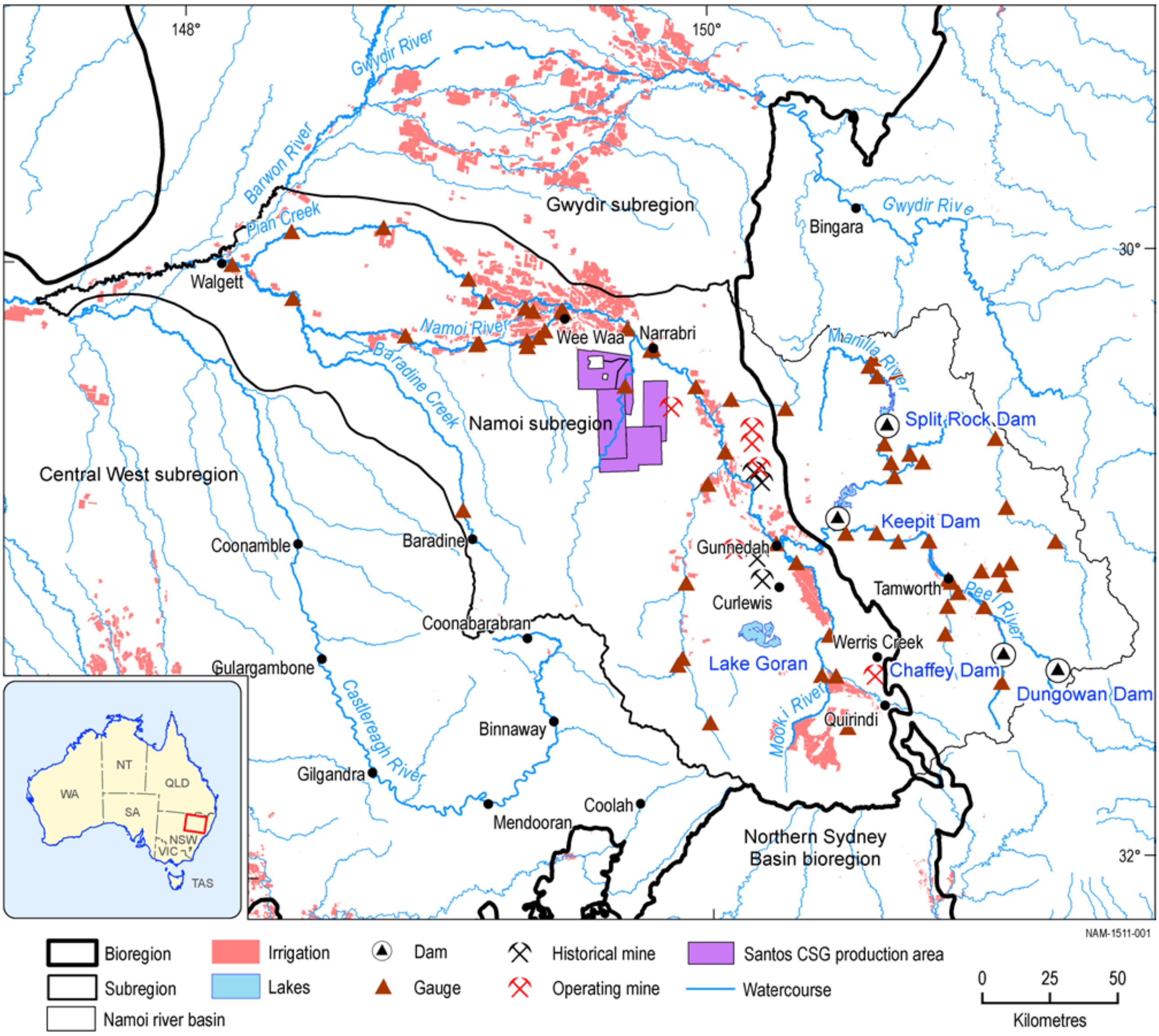

Figure 3 Tributaries of the Namoi River, streamflow stations, town centres, coal mines (historical and operating) and coal seam gas production areas

Data: Geoscience Australia (Dataset 1), information current as of December 2012; Department of Agriculture: Australian Bureau of Agricultural and Resource Economics and Sciences (Dataset 3); Bureau of Meteorology (Dataset 6); DTIRIS, Resources and Energy, Minerals Division Titles Branch (Dataset 7)

1.5.1.1.1 Water accounts in the Namoi river basin

There are three major dams in the Namoi river basin: Chaffey Dam (capacity of 62 GL), Keepit Dam (423 GL), and Split Rock Dam (397 GL) (MDBA, 2010). All three lie outside of the Namoi subregion (Figure 3). These dams supply water to irrigators, the main water users in the basin, although Keepit Dam was originally built for flood mitigation. A smaller dam (Dungowan Dam, 6 GL, on Dungowan Creek in the Peel River system) supplies water to the city of Tamworth – the largest urban centre in the basin. Additionally, there are about 32,000 farm dams spread across the Namoi river basin (MDBC, 2008b), which divert about 160 GL/year (the Commonwealth's *Basin Plan 2012*). Storage volumes for 2004–05 to 2011–12 are summarised in Table 3. The mean annual volume was 40.4 GL (range 17 to 62 GL) in Chaffey Dam, 144.3 GL (range 24 to 416 GL) in Keepit Dam and 55.3 GL (range 13 to 108 GL) in Split Rock Dam. The combined mean annual storage was 239.9 GL (range 54 to 561 GL).

Table 3 Storage volumes at the start (July) of the water year, inflows and outflows for dams in the Namoi river basin

	Chaffey Dam (Capacity: 62 GL)			Keepit Dam (Capacity: 423 GL)			Split Rock Dam (Capacity: 397 GL)		
	Volume (GL)	Inflows (GL/y)	Outflows (GL/y)	Volume (GL)	Inflows (GL/y)	Outflows (GL/y)	Volume (GL)	Inflows (GL/y)	Outflows (GL/y)
2004–05	30	1.3	1.5	159	5.8	7.8	99	2.5	1.3
2005–06	27	1.8	1.6	109	14.0	14.2	108	0.7	4.5
2006–07	24	1.0	1.2	76	6.7	10.0	79	0.1	5.5
2007–08	17	3.7	0.5	24	11.5	3.7	13	0.7	0.4
2008–09	48	3.0	2.5	95	14.1	5.3	25	0.6	0.6
2009–10	60	1.4	2.0	155	4.0	5.7	21	0.2	0.7
2010–11	55	8.5	9.6	120	47.9	16.7	14	2.8	0.4
2011–12	62	3.1	3.7	416	45.2	40.9	83	14.6	0.6

Data: MDBC (2006, 2007, 2008a); MDBA (2009, 2010, 2011, 2012); NSW Office of Water (Dataset 2)

Mean inflows and outflows for Chaffey Dam were 3.0 GL/year and 2.8 GL/year, respectively. For Keepit Dam, inflows and outflows were 18.6 GL/year and 13.0 GL/year, respectively; and inflows and outflows for Split Rock Dam were 2.8 GL/year and 1.7 GL/year, respectively. Inflows reported here correspond to gauged streamflow in a station or stations upstream of the dam. Other sources of inflows and outflows such as local runoff, rainfall on the reservoir surface and evapotranspiration from the reservoir surface also account for differences in yearly total storage.

Gauged inflows and outflows

Gauged inflows to the Namoi subregion include flows released from Keepit Dam and six contributing streams and creeks (Figure 4). Details and mean annual flows for stations in these tributaries are summarised in Table 4. There are numerous minor tributaries which are ungauged, were previously gauged and the corresponding gauging station has now closed, or where the streamflow records were of short duration and/or with gaps (see companion product 1.1 for the Namoi subregion (Welsh et al., 2014) for further details on gauging stations). Mean annual inflows for 2004–05 to 2011–12 were 72.5 GL/year (NSW Office of Water, Dataset 2).

Mean annual end-of-system flows (Table 4) for 2004–05 to 2011–12 were 483 GL/year (NSW Office of Water, Dataset 2). End-of-system flows are normally measured at station 419091 (Walgett) on the Namoi River (Figure 4). For 2010–11 and 2011–12 the end-of-system measurement was taken at station 419026 (Namoi River at Goangra, Figure 4) as the Walgett gauge was affected by backwater effects from the Barwon River for most of the year (State Water, 2011). Water may be also diverted to Pian Creek via Knights Weir. Mean annual outflows in station 419049 (Pian Creek at Waminda, Figure 4) were 68 GL/year (NSW Office of Water, Dataset 2) (Table 4). Mean total outflows for the period were 551 GL/year (Table 4).

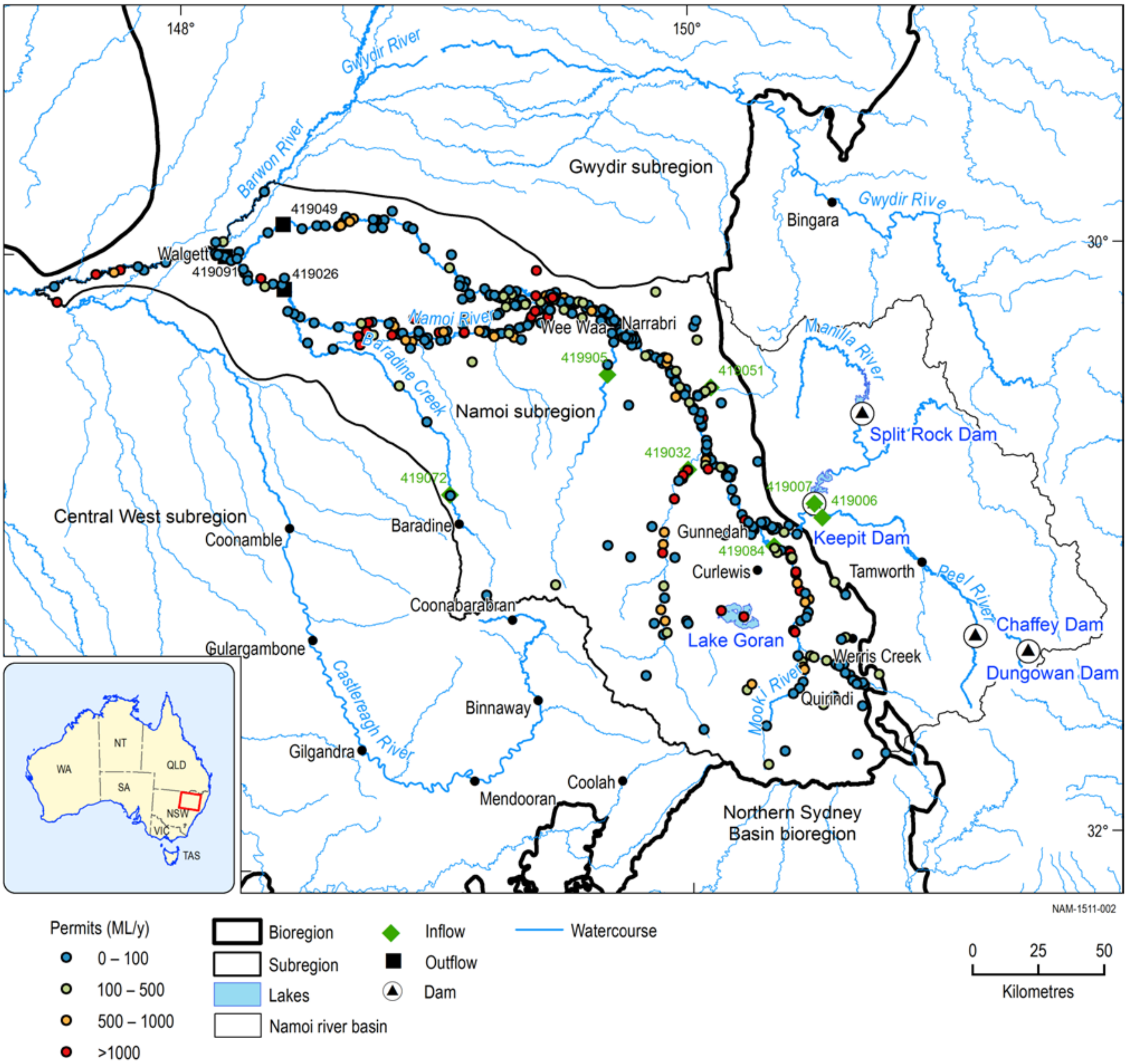

Figure 4 Location of surface water permits, inflow and outflow streamflow stations in the Namoi subregion

Data: Bioregional Assessment Programme (Dataset 4); Bureau of Meteorology (Dataset 6)

Table 4 illustrates large inter-annual variability for the water account period (2004–05 to 2011–12). During the 2001–2009 Millennium Drought (van Dijk et al., 2013), lower than average precipitation and inflows into reservoirs resulted in decreased streamflow in the Namoi river basin. Reservoir storage was at its lowest in 2007–08. The drought ended in 2010 with heavy rainfall caused by strong La Niña conditions (Webb, 2012).

Table 4 Mean annual streamflow for stations with inflows and outflows into the Namoi subregion

Station number and name	Mean annual streamflow (GL/y)							
	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12
Inflows								
419006 – Peel River at Carroll Gap	36.1	58.0	11.0	79.0	225.4	46.3	570.0	342.1
419007 – Namoi River downstream of Keepit Dam	94.0	170.6	119.8	44.4	63.3	67.8	201.0	491.3
419032 – Coxs Creek at Boggabri	43.5	18.8	8.7	10.1	6.3	78.2	250.6	60.5
419051 – Maules Creek at Avoca East	34.5	6.9	0.6	0.9	0.9	1.1	20.1	119.6
419072 – Baradine Creek at Kienbri no.2[a]	1.7	0.5	0.0	26.1	0.2	0.1	0.0	0.0
419084 – Mooki River at Ruvigne	62.4	1.5	15.8	35.3	92.8	11.2	264.6	103.9
419083 – Brigalow Creek at Tharlane	42.2	6.2	0.3	8.6	3.9	24.4	30.4	47.5
Outflows								
419091 – Namoi River at Walgett[b]	411.4	201.0	7.5	95.1	115.1	457.4	1186.4	1394.3
419049 – Pian Creek at Waminda	7.5	14.1	0.9	6.4	23.9	2.1	205.1	285.4

[a]Data missing from October 2011 onwards
[b]End-of-system flows for 2010–11 and 2011–12 was taken at station 419026 (Namoi River at Goangra) as Walgett gauge was affected by backwater from the Barwon River for most of the year (State Water, 2011)
Data: NSW Office of Water (Dataset 2)

Surface water permits and allocations

Total surface water permits in the regulated rivers of the Namoi river basin amount to approximately 424 GL/year of which 1.4 GL/year (less than 1%) are high security (i.e. water permit holders receive their full permit allocation in all but severe drought periods), 286 GL/year (68%) are general security (i.e. water permit holders receive their allocation based on water resource availability), 2.2 GL/year (less than 1%) are for domestic and stock, 19 GL/year (4%) are for local water utilities and 115 GL/year (27%) are supplementary permits (Green et al., 2011). Water permits in the unregulated rivers amount approximately to 117 GL/year, making a total of approximately 541 GL/year in both regulated and unregulated sections (NSW's *Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources 2012*; Burrell et al., 2013). In the Namoi subregion, water permits amount to approximately 467 GL/year (Bioregional Assessment Programme, Dataset 4). Table 5 summarises surface water permits (within the Namoi subregion) by purpose and Table 6 by type and water source.

Table 5 Surface water permits grouped by purpose[a] in the Namoi subregion

Purpose	Permits	Volume (GL/y)
Conservation of water, irrigation	11	2.12
Domestic	10	0.02
Domestic, farming, stock	3	0.03
Domestic, industrial	3	0.01
Domestic, irrigation	10	2.03
Domestic, irrigation, stock	569	271.64
Domestic, stock	44	0.44
Farming	2	0.01
Horticulture	5	0.68
Horticulture, irrigation	8	0.46
Industrial	3	1.11
Industrial - sand and gravel	5	0.09
Irrigation	551	133.05
Irrigation, mining (low security)	1	0.03
Irrigation, recreation (high security)	8	0.26
Irrigation, stock	135	43.79
Mining	2	3.00
Not determined	12	7.15
Recreation - low security	9	0.49
Stock	12	0.31
Total	**1403**	**466.7**

[a]There were twelve additional water permits of miscellaneous purpose with no share volume including augmentation, conveyancing, dewatering, industrial and pisciculture, and recirculation.
Data: Bioregional Assessment Programme (Dataset 4)

Table 6 Surface water permits[a,b] grouped by river or creek in the Namoi subregion

Name of river or creek	Permits	Volume (GL/y)
Baradine Creek	34	19.7
Barwon Darling Unregulated River	22	5
Bluevale	13	1.6
Bohena Creek	34	1.2
Brigalow Creek	7	1.3
Bundock Creek	22	2.3
Coghill Creek	2	0.6
Coxs Creek	56	16.1
Etoo And Talluba Creeks	9	0.8
Eulah Creek	21	2.5
Lake Goran	12	9.9
Lower Macquarie River	3	2
Lower Namoi	14	3.4
Lower Namoi Regulated River	966	353.7
Maules Creek	12	1.1
Mooki River	68	29.5
Phillips Creek	8	0.2
Pian Creek	32	13
Quirindi Creek	55	1.7
Spring And Bobbiwaa Creeks	2	0.4
Warrah Creek	13	0.2
Werris Creek	6	0.4
Total	**1411**	**466.7**

[a]There were four additional permits with no determined water source nor share volumes
[b]All surface water permits are water access right which refers to the right conferred by law to hold or take water from a water resource
Data: Bioregional Assessment Programme (Dataset 4)

Figure 5 summarises allocations to water permits for 2004–05 to 2011–12. Generally, basic rights, domestic and stock, local water utilities and high security licences received 100% of entitlements each water year (NSW Office of Water, Dataset 5). A continuous accounting allocation system is used for general security licences in the regulated section of the Namoi river basin. Each individual water permit can hold up to 200% licensed allocation volume, including credit for unused allocation in previous years. In any particular season, the volume of water that each water permit can use is limited to a maximum of 125% of licensed permit with a maximum of 300% over any 3 years. In every water year from 2004–05 to 2009–10 general security entitlements received less than 100% allocation due to drought conditions. This meant that the general security carryover (water credited from previous water years) in 2011–12 resulted in an allocation of 112%, the highest since the system began management under NSW's *Water Management Act 2000* (Burrell et al., 2013).

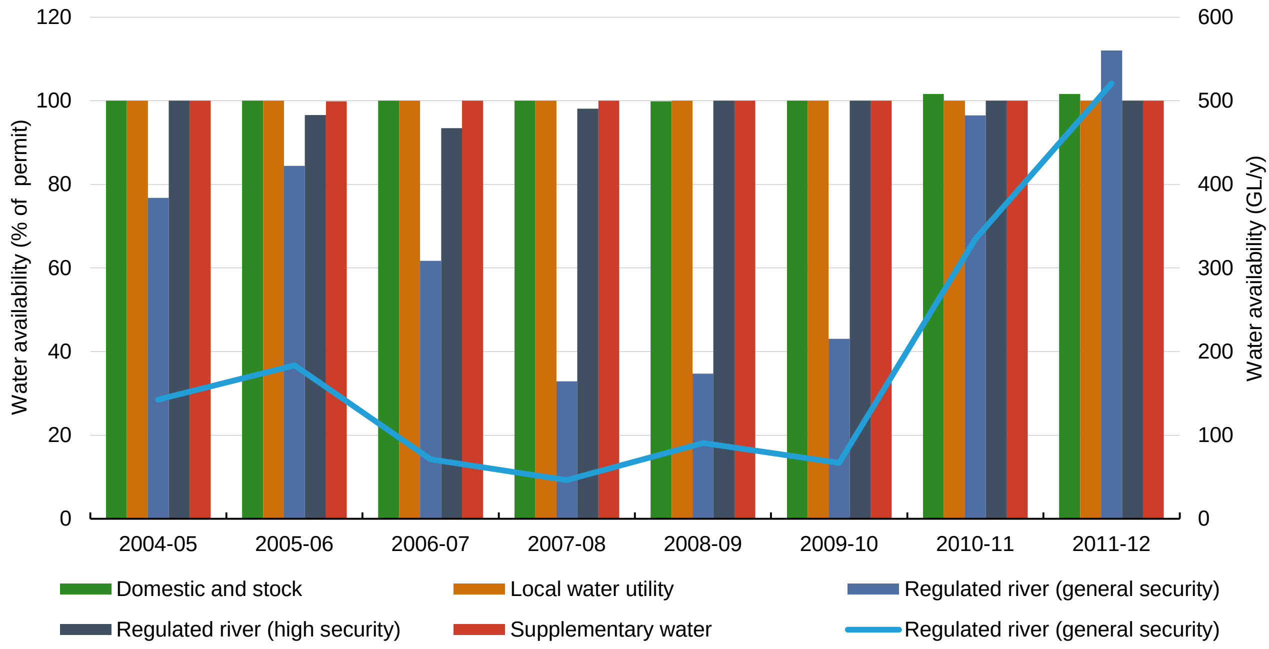

Figure 5 Namoi regulated river percentage water availability per water permit type (bars)

Blue line on secondary y-axis represents the total water availability for general security water permits, which is the volume credited including the allocation at the beginning of the water year plus unused water carried forward from previous years.
Data: NSW Office of Water (Dataset 5)

Surface water diversions

Diversions are monitored in the regulated part of the Namoi river basin whereas there is no monitoring in the unregulated part of the basin and diversions are estimated (MDBA, 2010). Every water year, a limit or cap to water diversions is determined based on water availability using the Namoi IQQM (Integrated Quantity Quality Model; Simons et al., 1996). Each water year, the cap is estimated as the amount of diversions that would have occurred under management rules and irrigation development at 1993–94 levels (MDBA, 2010). Figure 6 shows the basin annual diversions per sector for 2004–05 to 2011–12 as well as the annual cap targets. The mean annual surface water diverted from 2004–05 to 2011–12 was 278 GL, with 271 GL/year (97%) used in irrigation and 7 GL/year (3%) used for domestic or other purposes. On average, 84 GL/year (30%) of surface water diverted to agriculture in unregulated rivers are unmetered estimates (Figure 6). Diversions in most water years were lower than their corresponding cap targets, except for 2006–07 when the cap was exceeded and cap credits from previous years had to be used (MDBC, 2008a).

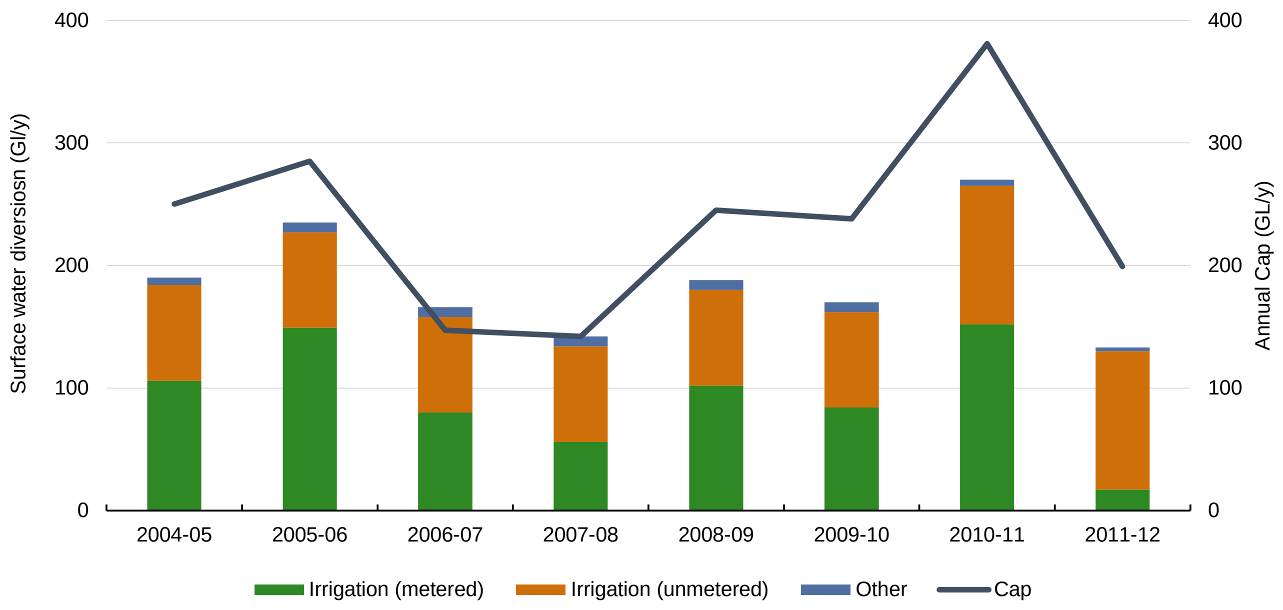

Figure 6 Namoi river basin diversions by purpose (bars)

'Other' diversions include domestic, stock, industry and town water supply. Dark blue line in secondary y-axis represents annual cap diversion target.

Data: MDBC (2006, 2007, 2008a); MDBA (2009, 2010, 2011, 2012). Data for 2011–2012 sourced from Burrell et al. (2013)

1.5.1.1.2 Gaps

There are several additional water sources and volumes that require additional calculations or models to be determined, including:

- mean river channel storage
- reservoir and river channel rainfall and evaporation
- ungauged tributary inflow
- ungauged runoff
- surface water – groundwater interactions.

Some of the sources not included here are implicitly considered; for example, reservoir rainfall and evaporation would be reflected in changes in the storage volume. Where possible, there is scope for estimating and reporting these volumes as part of surface water numerical modelling in companion product 2.6.1 for the Namoi subregion.

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1.5.1.2 Groundwater

This section summarises groundwater account data in the Namoi subregion for the available water years (year starting in July and ending in June) for the period 2006–07 to 2013–14. Several groundwater sources in the Namoi subregion have data for only a subset of this period, and in those cases the shorter record has been used.

Groundwater in the Namoi subregion is managed as 21 groundwater sources. The groundwater sources represent geological sequences that are hydrogeologically similar and grouped together for management purposes, groundwater management is discussed further in Section 1.5.1.2.2. Figure 7 shows the groundwater sources present across the Namoi subregion. It is important to note that several of the groundwater sources extend beyond the limits of the subregion (Figure 7 indicates the proportion of each groundwater source that lies within the Namoi subregion). However, water accounting information is generally only available for groundwater sources in their entirety and all of the water account data presented in this product relates to the whole of each groundwater source, not the proportion that lies within the subregion.

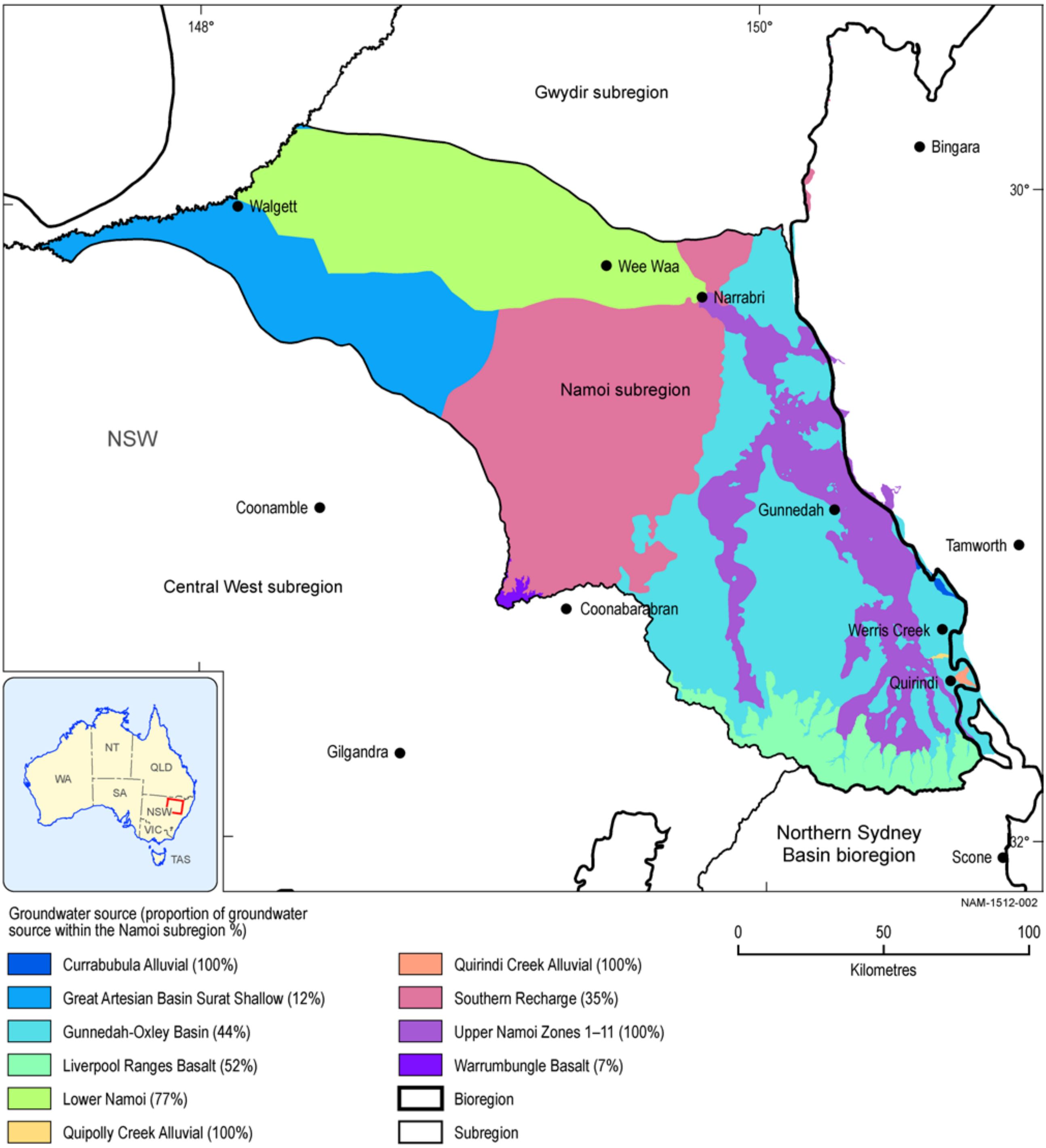

Figure 7 Groundwater sources in the Namoi subregion

Data: NSW Office of Water (Dataset 3)

1.5.1.2.1 Current water accounts

Groundwater inflows

Recharge from rainfall is the only inflow used for the groundwater sources when setting the sustainable diversion limits (calculated by the Murray–Darling Basin Authority for sustainable diversion limit (SDL) resource units) or long-term average extraction limits (LTAEL) (set by the NSW Office of Water) across the Namoi subregion. Table 7 and Table 8 present the recharge volumes used to determine LTAEL for each groundwater source, as set in the water sharing plans (NSW Government 2003; 2008; 2011a; 2011b; 2011c; 2012).

Table 7 Characteristics of groundwater sources in the Namoi subregion

These data relate to the entirety of each groundwater source, even where only a proportion of the area of the groundwater source lies within the Namoi subregion.

Groundwater source	Proportion of groundwater source within the Namoi subregion (%)	Recharge estimate[a] (ML/y)	Stock and domestic right estimate (ML/y)[d]	Long-term average sustainable diversion limit (ML/y)[e]	Licensed entitlement volume 2013–14 (ML)
Great Artesian Basin Surat Shallow	12%	584,009	978	15,500	5,712
Surat	12%	75,000[b]	28,100	75,000[f]	8,845
Southern Recharge	35%	42,400	3,000	29,680[f]	26,750
Gunnedah–Oxley Basin MDB	44%	414,559	5,778	114,500	24,029
Liverpool Ranges Basalt MDB	52%	80,349	1,828	2,160	422
Warrumbungle Basalt	7%	28,630	540	550	71
Currabubula Alluvial	100%	na[c]	17.8	60.1[g]	302
Quipolly Alluvial	100%	na[c]	3.9	475.6[g]	737
Quirindi Alluvial	100%	na[c]	14.1	1,231.4[g]	2,356
Lower Namoi	77%	86,000	3,304	88,300	106,752
Upper Namoi – Zones 1 to 11 (see Table 8 for detail)	100%	95,100	2,832	123,400[h]	153,454

[a]Recharge estimates were taken from the relevant water sharing plans or water sharing plan background documents.
[b]This value is not recharge. Rather, it is the volume of water required to maintain pressure levels experienced under the level of water extraction associated with the water entitlements, infrastructure and management rules in place at 1990.
[c]Recharge estimates were not available for these groundwater sources, as recharge was not used to determine the SDL/LTAEL. Estimated annual licensed extraction and estimated stock and domestic use, at the commencement of the plan, were used instead.
[d]Stock and domestic usage estimates for each groundwater source were taken from the relevant water sharing plans.
[e]SDL values were taken from Schedule 4 of the Commonwealth's Basin Plan 2012.
[f]LTAEL values for the Surat and Southern recharge groundwater systems are drawn from the relevant water sharing plans, as they are not considered part of the MDB.
[g]The LTAEL for the these groundwater sources are obtained from NSW's Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources 2012 as they are grouped together as part of a single groundwater SDL resource unit in the Commonwealth's Basin Plan 2012.
[h]The long-term SDL for the Upper Namoi is only available for the region as a whole, and not for each of the zones.
Data: NSW Office of Water (Dataset 2); Burrell et al (2014); NSW Government (2003); NSW Department of Water and Energy (2009); NSW Office of Water (2011; 2012a; 2012b; 2013)

The NSW Office of Water uses groundwater planning models for the Upper and Lower Namoi alluvial systems to produce detailed annual water budgets. The water budget presents modelled values for a range of inflows and outflows to the alluvial groundwater systems. It includes volumes of water that flow between the river and groundwater system, the lateral flow into and out of each layer, the flow between layers, recharge from rainfall and volumes of groundwater pumped from the model layers. This enables a change in water storage to be calculated for each layer. It is noted that modelled water budgets are only available for the Upper and Lower Namoi alluvial groundwater sources in the Namoi subregion.

Where planning models have not been developed, and there is insufficient monitoring bore data to estimate a complete budget, there is no information available regarding other (non-rain or groundwater extraction) elements of the water budget (e.g. flows between groundwater sources, changes to aquifer storage or flows to, or from, rivers). This is generally the case for the non-alluvial groundwater sources in the Namoi subregion. In these cases, the NSW Office of Water's soil water budget accounting method is applied to obtain an estimate of the potential annual recharge. This method is used to determine deviations in annual potential recharge as a deviation from the long-term mean potential recharge. To date, this data layer has only been presented for the 2011–12 and 2012–13 water years (Burrell et al., 2014).

Table 8 Characteristics of groundwater sources in the Upper Namoi Alluvium

These data relate to the entirety of each groundwater source, even where only a proportion of the area of the groundwater source lies within the Namoi subregion.

Groundwater source	Proportion of groundwater source within the Namoi subregion (%)	Recharge estimate[b] (ML/y)	Stock and domestic right estimate (ML/y)[c]	Licensed entitlement volume 2013–14 (ML)
Zone 1, Borambil Creek	<100%[a]	2,100	39	2,934
Zone 2, Coxs Creek (Mullaley to Boggabri)	100%	7,200	359	13,153
Zone 3, Mooki Valley (Breeza to Gunnedah)	100%	17,300	470	25,364
Zone 4, Namoi Valley (Keepit Dam to Gins Leap)	<100%[a]	25,700	667	39,303
Zone 5, Namoi Valley (Gins Leap to Narrabri)	100%	1,600	262	18,704
Zone 6, Tributaries of the Liverpool Range (south to Pine Ridge Road)	100%	1,400	274	11,448
Zone 7, Yarraman Creek (east of Lake Goran to Mooki River)	100%	3,700	89	3,704
Zone 8, Mooki Valley (Quirindi—Pine Ridge Road to Breeza)	100%	16,000	166	21,070
Zone 9, Coxs Creek (upstream Mullaley)	100%	11,400	187	11,342
Zone 10, Warrah Creek	100%	4,500	36	1,420
Zone 11, Maules Creek	<100%[a]	2,200	210	2,238
Zone 12, Kelvin Valley	0%	2,000	73	2,774

[a]A small proportion of the area of these zones lies outside the Namoi subregion, however, the exact proportion outside the subregion has not been quantified. See Figure 5 in companion product 1.3 Description of the water-dependent asset register for the Namoi Subregion (O'Grady et al., 2015) for a map of the zones.
[b]Recharge estimates were taken from the relevant water sharing plans or water sharing plan background documents
[c]Stock and domestic usage estimates for each groundwater source were taken from the relevant water sharing plans
Data: NSW Government (2003)

Groundwater outflows

Data on groundwater outflows are limited to data on extractions for consumptive use. Water licence data for the Namoi subregion were obtained from the NSW Office of Water (Dataset 2 and Dataset 3).

Figure 8 shows the distribution of licensed groundwater bores, and their associated water use category, simplified from the NSW Office of Water (Dataset 2). Table 9 shows the number of groundwater bores in these categories. There are approximately 10,300 licensed bores across the Namoi subregion. Most bores are licensed for stock and domestic use.

Groundwater extraction by coal mines and coal seam gas developments, both for use and for dewatering purposes, will occur from a number of groundwater sources and must be licenced. Further analysis and modelling of water use by mines and CSG developments will be presented in companion products 2.1, 2.3, 2.5 and 2.6.

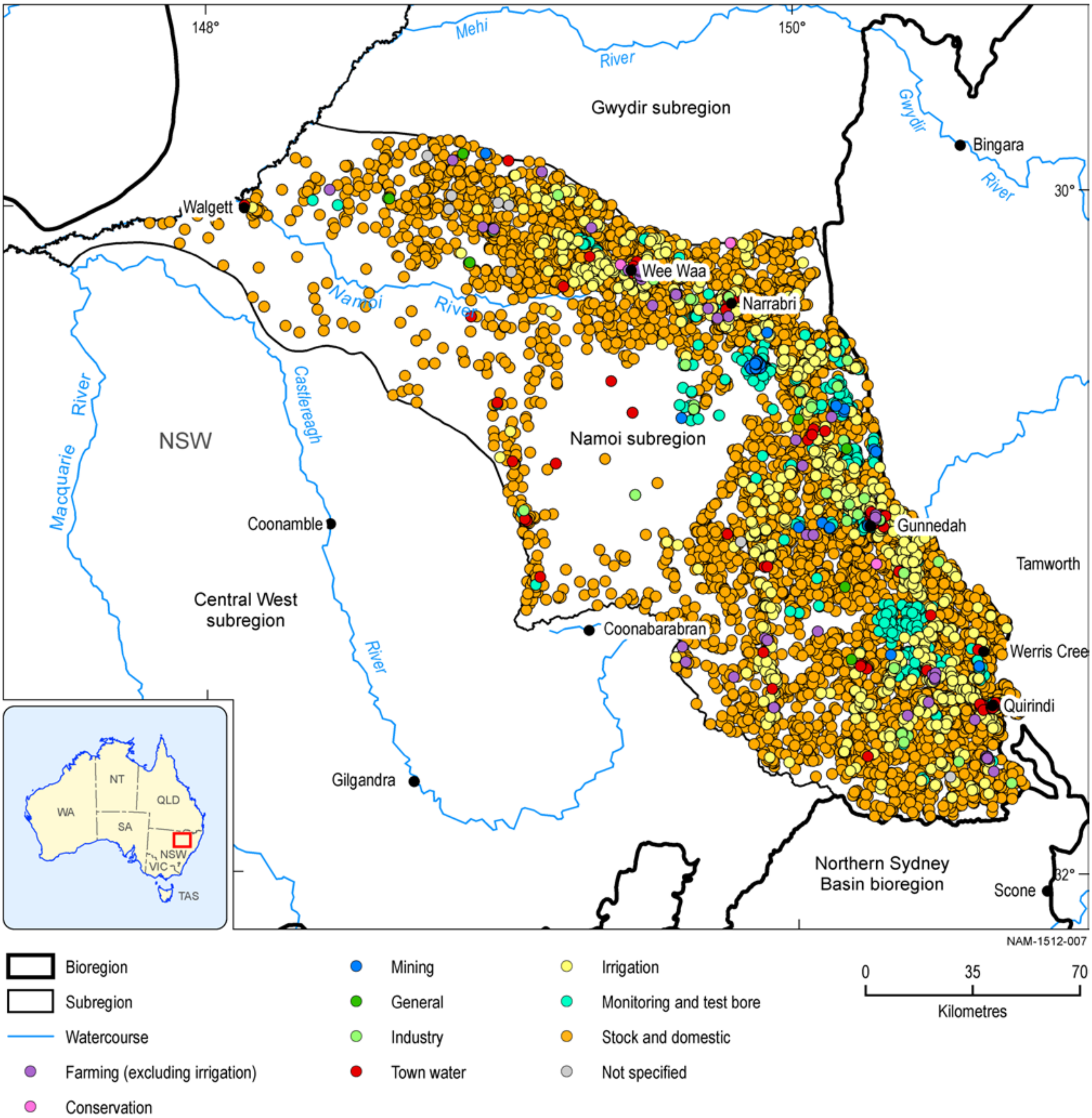

Figure 8 Distribution and use category of licensed bores in the Namoi subregion

Data: Bioregional Assessment Programme (Dataset 1)

Table 9 Licence categories of bores across the Namoi subregion

Grouped category	Total number	Percentage of bores in the Namoi subregion
Stock and domestic	7593	73.8%
Conservation	3	<0.1%
Farming (excl. irrigation)	56	0.5%
Irrigation	983	9.6%
Industry	44	0.4%
Mining	114	1.1%
Monitoring and test bores	1401	13.6%
Town water	87	0.8%
General	3	<0.1%
Not specified	5	<0.1%

Data: Bioregional Assessment Programme (Dataset 1)

An estimate of current groundwater usage

The groundwater use data presented in this product has been obtained from the NSW Water Register (NSW Office of Water, Dataset 2).

Groundwater use data comes from metering in some groundwater sources, however metering of groundwater extraction is not yet mandatory across all groundwater sources, and will be rolled out over time across NSW (NSW Office of Water, 2012b). All licensed bores in the Upper Namoi water sources (approximately 1100 bores) are metered and their usage is recorded at regular intervals (two to six readings per year) (Barrett, 2010). In contrast, basic water right volumes are estimated, as licencing and metering is not required for stock and domestic rights.

Table 10 presents the available time series usage data for all of the groundwater sources in the Namoi subregion. In summary, most of the groundwater used within the subregion is taken from five sources:

- Lower Namoi – average annual use 75,510 ML/year, licensed volume 106,752 ML in 2013–14
- Upper Namoi Zone 4 – average annual use 21,091 ML/year, licensed volume 39,303 ML in 2013–14
- Upper Namoi Zone 5 – average annual use 15,906 ML/year, licensed volume 18,704 ML in 2013–14
- Upper Namoi Zone 3 – average annual use 14,957 ML/year, licensed volume 25,364 ML in 2013–14
- Upper Namoi Zone 8 – average annual use 12,923 ML/year, licensed volume 21,070 ML in 2013–14.

Table 10 Annual groundwater usage data for all groundwater sources in the Namoi subregion (excludes stock and domestic usage estimates)

These data relate to the entirety of each groundwater source, even where only a proportion of the area of the groundwater source lies within the Namoi subregion.

Groundwater source	Volumes (ML)								
	2006–07	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14	Average annual use
Currabubula Alluvial	NA	NA	NA	NA	NA	NA	0	1.1	0.55
Great Artesian Basin Surat Shallow	NA	NA	NA	NA	NA	932	1,570	1,180	1,227
Gunnedah–Oxley Basin MDB	NA	NA	NA	NA	NA	2,570	3,808	6,123	4,167
Liverpool Ranges Basalt MDB	NA	NA	NA	NA	NA	0	0	18	6
Lower Namoi	124,108	102,409	72,824	82,615	30,495	32,858	57,792	100,983	75,510
Quipolly Alluvial	NA	NA	NA	NA	NA	NA	80	125	103
Quirindi Alluvial	NA	NA	NA	NA	NA	NA	284	220	252
Southern Recharge	NA	NA	2,564	2,748	2,162	2,118	2,760	2,870	2,537
Surat	NA	NA	1,774	1,601	1,603	1,525	2,171	2,503	1,863
Upper Namoi Zone 1	2,238	1,529	1,260	1,425	932	988	1,312	1,225	1,364
Upper Namoi Zone 2	12,218	10,635	10,314	6,560	3,741	4,287	6,617	10,679	8,131
Upper Namoi Zone 3	28,068	10,008	9,501	17,809	8,538	7,161	15,586	22,985	14,957
Upper Namoi Zone 4	30,654	23,455	20,291	19,278	15,664	9,521	23,329	26,539	21,091
Upper Namoi Zone 5	19,697	16,438	12,428	16,542	13,031	8,716	19,614	20,781	15,906
Upper Namoi Zone 6	1,952	1,023	676	1,132	528	560	1,338	1,558	1,096
Upper Namoi Zone 7	2,678	946	941	698	454	1,026	1,429	1,855	1,253
Upper Namoi Zone 8	19,028	11,495	9,043	11,628	8,909	8,704	15,123	19,455	12,923
Upper Namoi Zone 9	3,258	1,911	2,141	1,449	2,241	880	2,069	4,117	2,258
Upper Namoi Zone 10	0	0	17	0	0	0	0	0	2
Upper Namoi Zone 11	988	467	641	591	135	331	339	675	521
Warrumbungle Basalt	NA	NA	NA	NA	NA	0	0	0	0

NA indicates years for which no data are available for the groundwater source.
Data: NSW Office of Water (Dataset 2)

Figure 9 to Figure 13 show time series data for the numbers of licences within each licence class, and the licensed volume, allocation, and water use for each of the five groundwater sources listed above. The plots show that usage is consistently different to (and typically below) the licensed and allocated volumes. The groundwater access licences in the Namoi correspond to one of the following categories:

- Aquifer access licences
- Supplementary Water access licences
- Aquifer (Town Water Supply) access licences
- Local Water Utility access licences.

It should be noted that the available water determinations for Supplementary Water access licence class water in the Upper and Lower Namoi alluvial groundwater sources are being reduced incrementally in the water sharing plan, and will be reduced to zero ML per unit of share component at the start of the 2015–16 water year. This trend can be seen in the allocated water plots in Figure 9 to Figure 13. It can also be seen that the annual use exceeds the total allocation and licensed volume for 2013–14 in the Lower Namoi and Upper Namoi zones 3 and eight groundwater sources, and in 2012–13 and 2013–14 for the Upper Namoi zone 5. This has occurred due to licence holders making use of the carryover provisions available in these groundwater sources. Carryover provisions allow licence holders to accrue unused water allocation in their aquifer access licence accounts, and use up to two times their entitlement volume in any water year if the average of the preceding three year’s extraction does not exceed the extraction limit by 5% or greater, and providing the water is available in their water account.

The total licensed groundwater extraction volume in the Namoi subregion in 2013–14 was 327 GL/year. Extraction under Aquifer class access licences was 252.5 GL/year (77%), 57.7 GL/year (18%) under Supplementary Water class licences, 16.8 GL/year (5%) under Local Water Utility class licences and 0.025 GL/year (0.008%) under Aquifer (Town Water Supply) class licences. The mean annual groundwater usage from 2006–07 to 2013–14 was 165 GL/year.

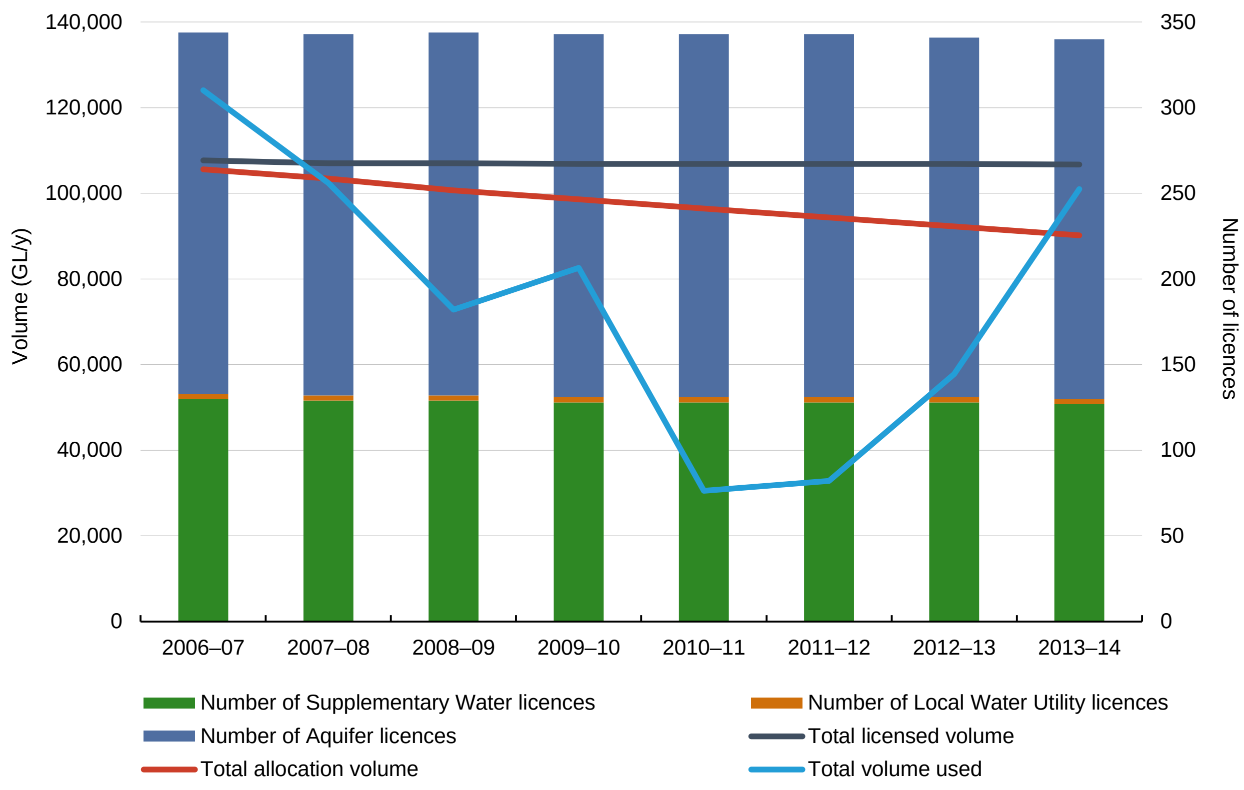

Figure 9 Entitlement and usage data for the Lower Namoi Groundwater Source

Data: NSW Office of Water (Dataset 2)

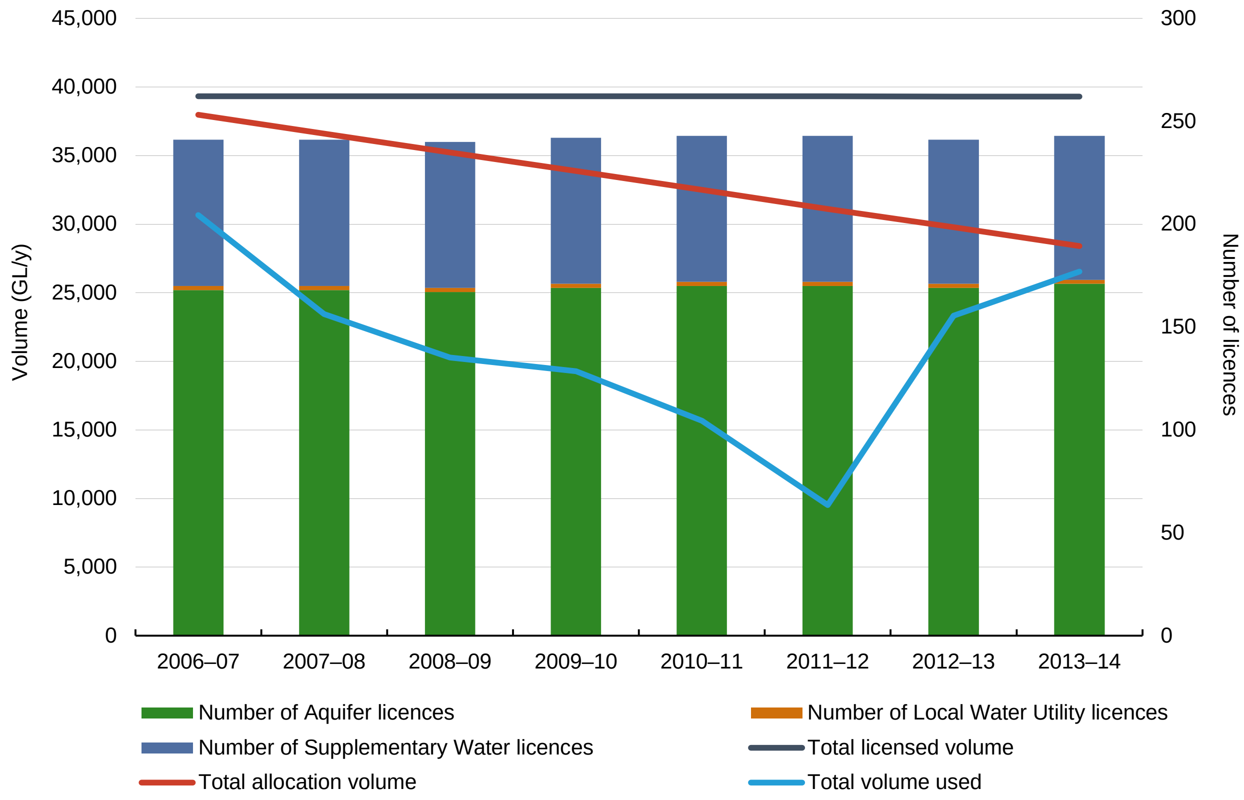

Figure 10 Entitlement and usage data for the Upper Namoi Zone 4 Namoi Valley (Keepit Dam to Gins Leap) Groundwater Source

Data: NSW Office of Water (Dataset 2)

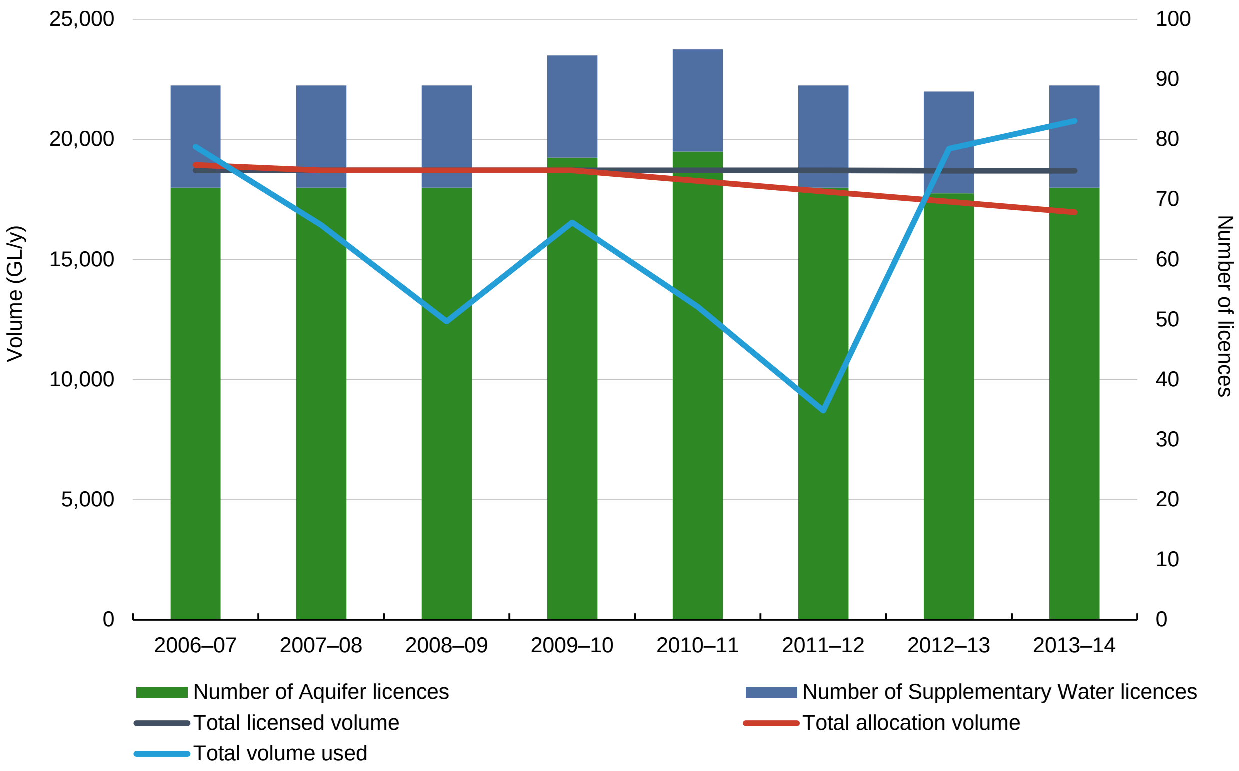

Figure 11 Entitlement and usage data for the Upper Namoi Zone 5 Namoi Valley (Gins Leap to Narrabri) Groundwater Source

Data: NSW Office of Water (Dataset 2)

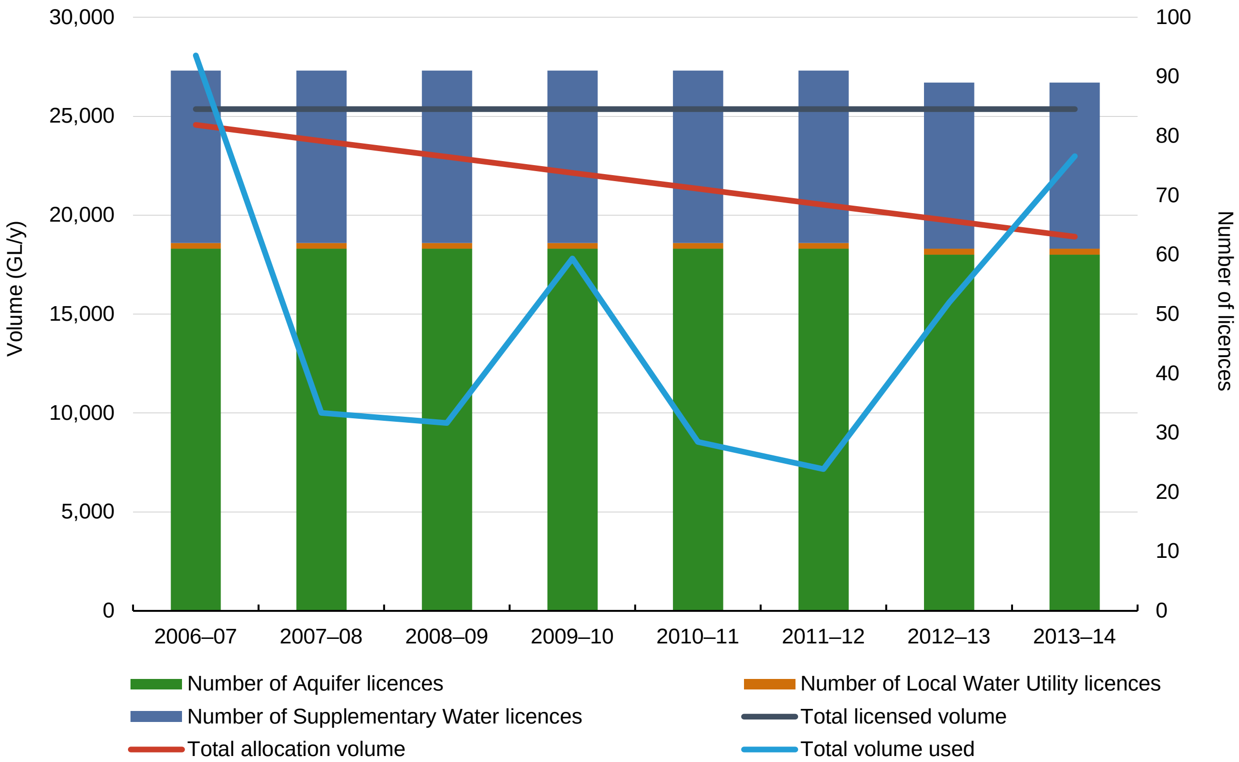

Figure 12 Entitlement and usage data for Upper Namoi Zone 3 Mooki Valley (Breeza to Gunnedah) Groundwater Source

Data: NSW Office of Water (Dataset 2)

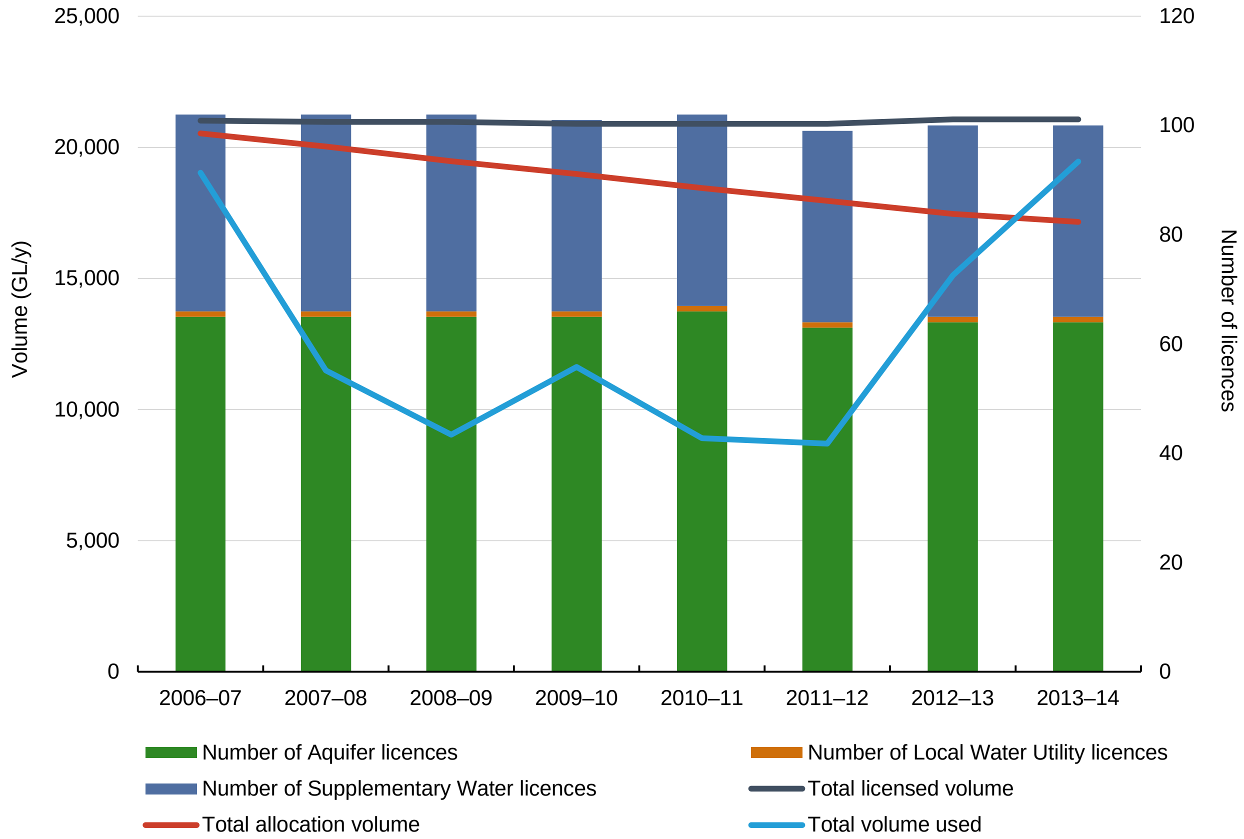

Figure 13 Entitlement and usage data for the Upper Namoi Zone 8 Mooki Valley (Quirindi–Pine Ridge Road to Breeza) Groundwater Source

Data: NSW Office of Water (Dataset 2)

1.5.1.2.2 Water management

Groundwater management across the Namoi subregion is undertaken through six water sharing plans prepared by the NSW government. The plans lie wholly or partially within the subregion: Figure 14 shows the extent and overlap of the areas governed by each water sharing plan. The plans cover the 22 groundwater sources defined by the NSW government in accordance with the Commonwealth’s *Basin Plan 2012* (the Basin Plan), noting that two of the groundwater sources (the Surat and Southern Recharge) are not considered to be part of the Murray–Darling Basin (MDB).

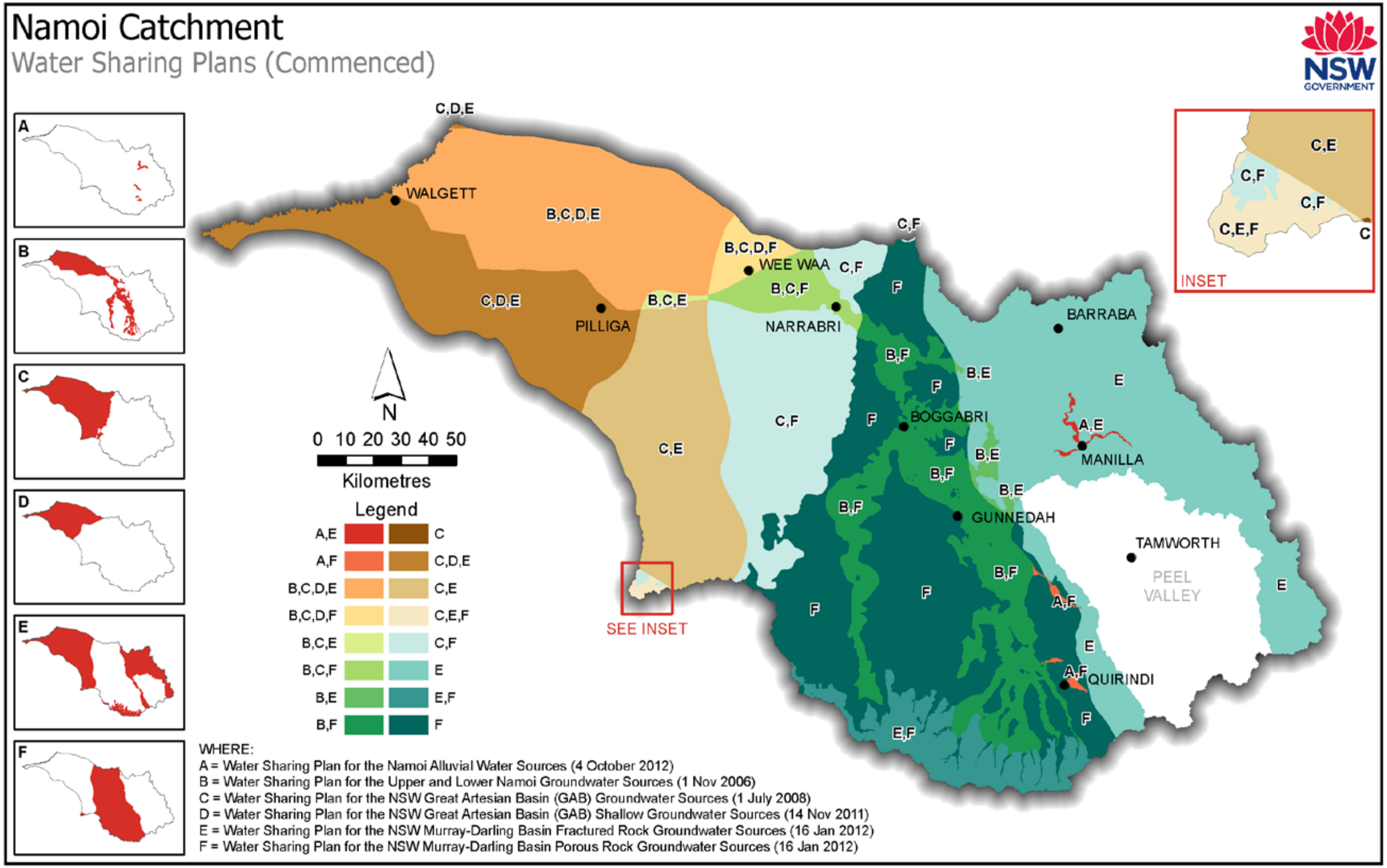

Figure 14 Map showing the areas of each of the six water sharing plans in effect across the Namoi subregion

The eastern edge of the subregion lies along the eastern boundary of the *Water Sharing Plan for the NSW Murray–Darling Basin Porous Rock Groundwater Sources*, indicated F. Inset maps indicate the extent of each of the water sharing plans, as indicated by the letters A to F. Areas marked with multiple letters indicate areas where more than one water sharing plan is in effect, covering groundwater in different geological formations.

Source: Figure 31 in Burrell et al. (2014). This figure is not covered by a Creative Commons licence. It has been reproduced with the permission of the NSW Department of Trade & Investment.

Table 11 and Table 12 link the water sharing plans, MDB water resource plan areas and MDB SDL areas that relate to each of the groundwater sources that are part of the MDB.

Sustainable diversion limits have been set for all of the groundwater sources in the Namoi subregion that lie within the MDB. The groundwater sources that are considered part of the Great Artesian Basin (Surat and Southern Recharge) are outside the MDB, and have long-term average extraction limits set within the relevant water sharing plans.

The water sharing plans establish rules for sharing water between the environmental needs of the aquifer and water users, and also between different types of water use such as town supply, rural domestic supply, stock watering, industry and irrigation (NSW Office of Water, 2015a). All groundwater sources in the Namoi subregion are covered by commenced water sharing plans. Water sharing rules set out in the plan address issues such as allocating water to the environment (environmental water), trading water between and within groundwater sources, and for using 'carryover' provisions to delay access to allocated water from one year to the next.

NSW requires that all bores have a work approval and are registered, regardless of the intended purpose. A water use approval, with associated water access licences, is also required to use water for all purposes except basic landholder rights (for example, for stock and domestic purposes).

A water access licence entitles the licence holder:

- to specified shares in the available water within a particular water management area
- to take water at specified times, rates or circumstances from specified areas or locations.

Bores licensed for extraction for commercial purposes generally require a meter to be installed and have an annual extraction limit (NSW Office of Water, 2015b).

Table 11 Groundwater management areas within the Namoi subregion

Groundwater source	Description of groundwater source[a]
Great Artesian Basin Surat Shallow	All groundwater above the Great Artesian Basin.
Surat	Includes water contained in all rocks of Cretaceous and Jurassic age at a depth of more than 60 m below ground level within the Surat Groundwater Source boundaries (as mapped)[b].
Southern Recharge	Includes: (a) all rocks of Cretaceous, Jurassic and Tertiary age; and (b) all alluvial sediments, except water covered by a different WSP[b].
Gunnedah–Oxley Basin MDB	Groundwater in: (a) all rocks of Permian, Triassic, Jurassic, Cretaceous and Tertiary age within the outcropped and buried areas; and (b) all alluvial sediments within the outcropped areas.
Liverpool Ranges Basalt MDB	Groundwater in: (a) all basalt and sediments of Tertiary age; and (b) all alluvial sediments; and all other groundwater, excluding groundwater in the Gunnedah–Oxley Basin and the Sydney Basin.
Warrumbungle Basalt	Groundwater in: (a) all basalt and sediments of Tertiary age; and (b) all alluvial sediments; and all other groundwater, excluding groundwater in the Gunnedah–Oxley Basin.
Currabubula Alluvial	All groundwater, excluding groundwater in the Gunnedah–Oxley Basin.
Quipolly Alluvial	All groundwater, excluding groundwater in the Gunnedah–Oxley Basin.
Quirindi Alluvial	All groundwater, excluding groundwater in the Gunnedah–Oxley Basin.
Lower Namoi	Groundwater in unconsolidated alluvium associated with the Namoi River and its tributaries including: (a) the Narrabri Formation; (b) the Gunnedah Formation; and (c) the Cubbaroo Formation; and all other groundwater, excluding groundwater in the Gunnedah–Oxley Basin.
Upper Namoi – Zones 1 to 11	Groundwater in unconsolidated alluvium associated with the Namoi River and its tributaries, including: (a) the Narrabri Formation; and (b) the Gunnedah Formation; and all other groundwater, excluding groundwater in the Gunnedah–Oxley Basin.

[a]Descriptions come from Schedule 4 of the Commonwealth's Basin Plan 2012 except for the Surat and Southern Recharge groundwater sources.
[b]Descriptions of the Surat and Southern Recharge groundwater sources come from the Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources (NSW Government, 2008).

Table 12 Groundwater sources and related water sharing plans

Groundwater source	Groundwater SDL[a] resource unit (SDL unit code)	Water sharing plan	MDB groundwater resource plan area (RPA Code)
Great Artesian Basin Surat Shallow	NSW GAB Surat Shallow (GS34)	Water Sharing Plan for the NSW Great Artesian Basin (GAB) Shallow Groundwater Sources (NSW Government, 2011a)	New South Wales Great Artesian Basin Shallow water resource plan area (GW13)
Surat	Not considered part of MDB	Water Sharing Plan for the NSW GAB Groundwater Sources (NSW Government, 2008). New South Wales Office of Water (NOW) intend to merge this plan with the NSW GAB Shallow Groundwater Sources Plan in 2018, during revision	Not within the MDB
Southern Recharge	Not considered part of MDB	Water Sharing Plan for the NSW GAB Groundwater Sources (NSW Government, 2008). NOW intend to merge this plan with the NSW GAB Shallow Groundwater Sources Plan in 2018, during revision	Not within the MDB
Gunnedah–Oxley Basin MDB	Gunnedah–Oxley Basin MDB (GS17)	Water Sharing Plan for the NSW Murray–Darling Basin Porous Rock Groundwater Sources (NSW Government, 2011c)	Eastern Porous Rock water resource plan area (GW16)
Liverpool Ranges Basalt MDB	Liverpool Ranges Basalt (GS22)	Water Sharing Plan for the NSW Murray–Darling Basin Fractured Rock Groundwater Sources (NSW Government, 2011b)	New England Fractured Rock and Northern Basalts water resource plan area (GW17)
Warrumbungle Basalt	Warrumbungle Basalt (GS49)	Water Sharing Plan for the NSW Murray–Darling Basin Fractured Rock Groundwater Sources (NSW Government, 2011b)	New England Fractured Rock and Northern Basalts water resource plan area (GW17)
Currabubula Alluvial	Upper Namoi Tributary Alluvium (GS48)	Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources (NSW Government, 2012)	Namoi Alluvium water resource plan area (GW14)
Quipolly Alluvial	Upper Namoi Tributary Alluvium (GS48)	Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources (NSW Government, 2012)	Namoi Alluvium water resource plan area (GW14)
Quirindi Alluvial	Upper Namoi Tributary Alluvium (GS48)	Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources (NSW Government, 2012)	Namoi Alluvium water resource plan area (GW14)
Lower Namoi	Lower Namoi Alluvium (GS29)	Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources (NSW Government, 2003)	Namoi Alluvium water resource plan area (GW14)
Upper Namoi – zones 1 to 11[b]	Upper Namoi Alluvium (GS47)	Water Sharing Plan for the Upper and Lower Namoi Groundwater Sources (NSW Government, 2003)	Namoi Alluvium water resource plan area (GW14)

[a]Sustainable diversion limit
[b]Zone 12, Kelvin Valley lies entirely outside the Namoi subregion

1.5.1.2.3 Gaps

There are several areas where additional monitoring or investigation would provide data that would help to improve the accuracy of the water accounting for each groundwater source, and consequently knowledge of the water budget elements for the water sources, including:

- updating estimates for basic rights (stock and domestic) water consumption to reflect current usage patterns and utilise best available estimation techniques
- investigating recharge to improve the accuracy of recharge estimates, for example the spatial variability of recharge
- investigating barriers and connections between adjacent groundwater sources
- undertake field monitoring to investigate individual elements of the modelled water balances to ensure all estimates of elements are realistic, for example measuring mine water inflows
- including surface water – groundwater interactions in water accounting.

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Datasets

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1.5.2 Water quality

Summary

This product summarises surface water quality information in the Namoi river basin. Surface water quality parameters which may be impacted by current and potential coal and coal seam gas (CSG) development include electrical conductivity, turbidity and temperature, suspended solids, pH, concentration of heavy metals and presence of hydrocarbons.

Electrical conductivity (proxy of salinity), turbidity and temperature data are available through the NSW Office of Water’s continuous monitoring network. Twelve gauging stations in the Namoi river basin are currently measuring some of these water quality parameters. Six are reported as measuring all parameters, and three of these have records covering less than three years. There is one gauge (Goangra), with long continuous records for electrical conductivity (EC) and temperature, located on the Namoi River below current and potential coal and CSG development.

A previous monitoring study, the Namoi Water Quality Project (NWQP), conducted from 2002 to 2007, suggested that the water quality in the Namoi River and its tributaries was generally acceptable for irrigation and other farming activities, although electrical conductivity and turbidity values exceeded the trigger set for the protection of aquatic ecosystems. Electrical conductivity values at Goangra during 2010–11 also exceeded the trigger values for most of the year but were similar to those reported in the NWQP study.

There is no routinely conducted surface water monitoring of heavy metals, trace elements and hydrocarbons. Groundwater is not routinely monitored for hydrocarbons and some trace elements.

Based on the salinity of groundwater in the Namoi subregion, groundwater is generally suitable for drinking and irrigation purposes, with small pockets of higher salinity groundwater.

1.5.2.1 Surface water

This product summarises surface water quality information in the Namoi river basin. Surface water quality may be directly impacted by runoff from areas altered by coal or coal seam gas (CSG) development (areas cleared of vegetation, service roads, and site processing facilities), discharge of mine or CSG waters and leaking of hydrocarbons. In addition, induced changes in streamflow as a result of large coal mining or CSG development may impact surface water quality as well. A number of physical and chemical hydrological parameters may be altered by current and potential coal and CSG development, including turbidity, suspended solids, pH, heavy metal concentrations, salinity, and the presence of hydrocarbons.

The NSW Office of Water conducts two types of monitoring: continuous monitoring at river gauging stations and targeted monitoring campaigns for a specific duration and purpose (NSW Office of Water, 2014a). Companion product 1.1 for the Namoi subregion (Welsh et al., 2014) summarised results of the Namoi Water Quality Project (NWQP) (Mawhinney, 2011), undertaken from 2002 to 2007. The NWQP focused on quality parameters related to agriculture (salinity, nutrient and pesticide concentrations, among others). It found that the water quality in the Namoi River and its tributaries was generally acceptable for irrigation and other farming activities, although several parameters (salinity, phosphorus and nitrogen) did not meet default trigger values for the protection of aquatic ecosystems in south-eastern Australia set out in guidelines for water quality by the Australian and New Zealand Environmental and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC and ARMCANZ, 2000). If trigger values are exceeded for a pollutant, a site-specific investigation is ‘triggered’ following the ANZECC and ARMCANZ guidelines. Future water quality assessments will be conducted using water quality targets set out in the Commonwealth’s *Basin Plan 2012*.

The remainder of this product includes:

- a description of the water quality parameters available from the NSW Office of Water’s continuous monitoring gauging station network (NSW Office of Water, 2014b)
- water quality parameters available in the Namoi river basin from the continuous monitoring gauging station network (NSW Office of Water, Dataset 1).

1.5.2.1.1 Water quality in the Namoi river basin

Water quality parameters available from the NSW Office of Water continuous monitoring network include long-term records of salinity, turbidity and water temperature (NSW Office of Water, 2014b).

Salinity is measured by the ability of soluble salts to transmit an electric current (electrical conductivity or EC) quantified in microSiemens per centimetre (µS/cm). The default trigger value in the Namoi uplands (from the top of the Great Dividing Range to the junction of the Peel and Namoi rivers immediately below Keepit Dam) is set at 350 µS/cm, whereas for the lowlands (from Gunnedah to the junction with the Barwon River at Walgett) it is set at 300 µS/cm (ANZECC and ARMCANZ, 2000).

Turbidity is a proxy for the amount of total suspended solids in water – the murkier or muddier it appears, the higher the measured turbidity. Turbidity is measured in Nephelometric Turbidity Units (NTU). The ANZECC and ARMCANZ (2000) default trigger value in the lowlands of the Namoi river basin is set at 50 NTU.

Temperature (°C) is monitored for instances of cold water pollution, which is an artificial decrease in the temperature of river water in a natural ecosystem. It occurs when stored cold water is released reducing the natural temperature of the river downstream (NSW Office of Water, 2014b), which may impact river ecosystems. This reduction in temperature mainly occurs when releases are made from large dams bound by walls higher than 15 m (Preece, 2004). Large coal mining operations generally do not have dams with walls higher than 15 m, thus are unlikely to cause cold water pollution, hence these data will not be analysed in the remainder of this product. Temperature is also used to assess surface water and groundwater interactions (e.g. Andersen and Acworth, 2009). Temperature maybe more stable in a gaining stream (i.e. a stream that gains water from local groundwater as it flows downstream), whereas it may fluctuate more with changes in atmospheric temperature in a losing stream (i.e. stream that loses water as it infiltrates from the river bed to the local groundwater, see Loheide and Gorelick, 2006).

Table 13 summarises the gauging stations and dates for which the above-described water quality parameters are available in the NSW Office of Water continuous monitoring network. Figure 15 shows the geographical location and parameters measured at each gauging station.

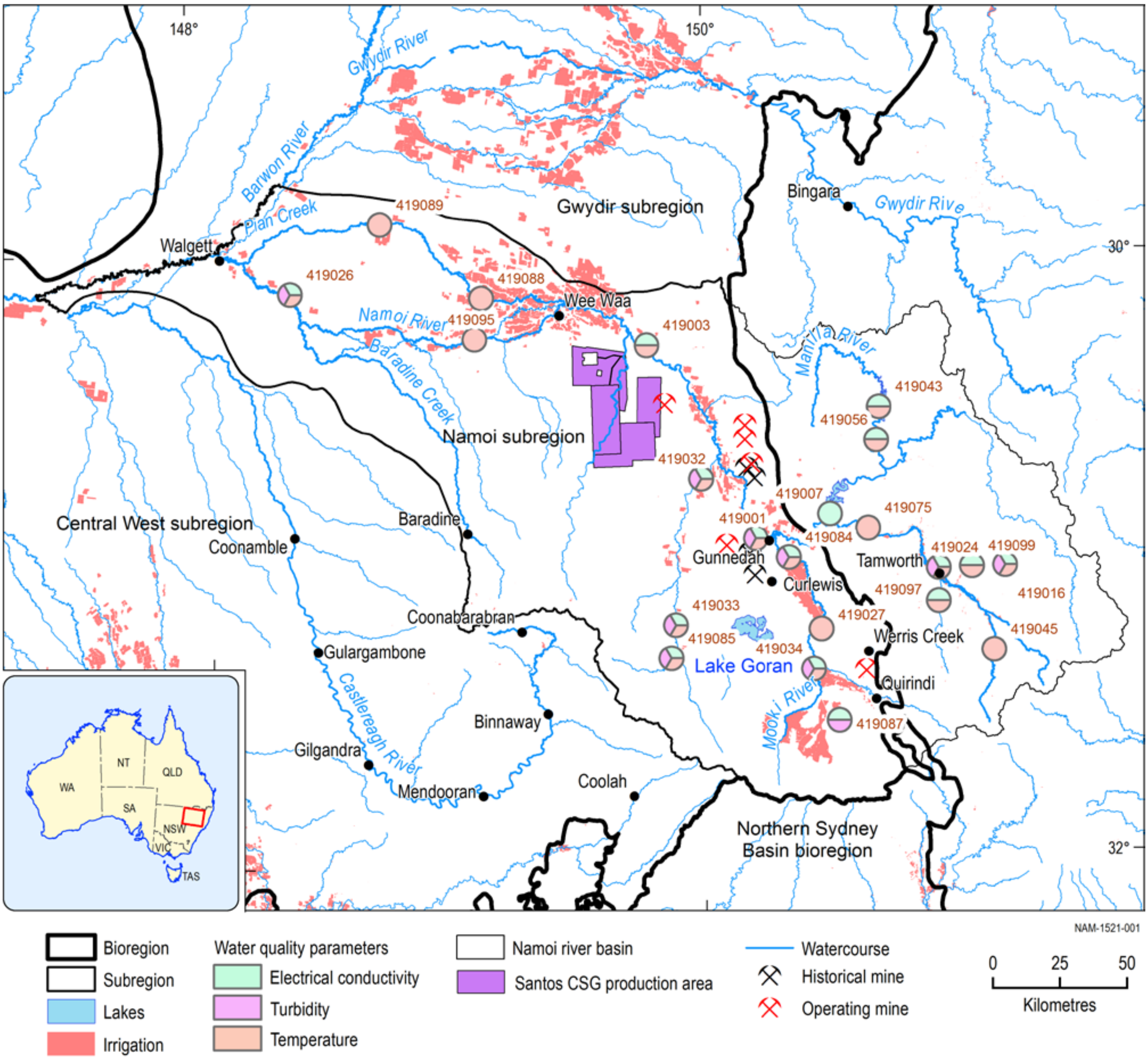

Figure 15 Tributaries of the Namoi River, streamflow gauging stations (showing water quality parameters measured), town centres, coal mines (historical and operating) and CSG production areas

Data: Geoscience Australia (Dataset 2), information current as of December 2012; Department of Agriculture: Australian Bureau of Agricultural and Resource Economics and Sciences (Dataset 3); Bioregional Assessments Programme (Dataset 4), DTIRIS, Resources and Energy, Minerals Division Titles Branch (Dataset 5)

There are 22 gauging stations with surface water quality data, 21 are reported as operational at the time of writing (NSW Office of Water, Dataset 1). Nine are reported as measuring EC, temperature and turbidity. There are five gauging stations with long (i.e. >10 years) records for EC and temperature (Table 13). Turbidity was measured at ten gauging stations, but measurements often lasted for less than three years (Table 13). It is noted that even if a gauging station is reported as operational, data may be missing or of poor quality for long periods.

Table 13 Gauging stations and dates of availability[a] for surface water quality parameters including electrical conductivity, turbidity and temperature

Gauging stations with more than ten years of data for electrical conductivity and temperature are indicated in bold type. Data years are calculated as the number of days with data divided by 365.25.

Gauging station	Electrical conductivity			Turbidity			Temperature		
	Start date	End date	Years	Start date	End date	Years	Start date	End date	Years
419001	09 Jun 1995	23 May 2010	14	09 Jun 1995	02 Feb 2000	1	09 Jun 1995	19 Dec 2011	16
419003	08 May 2002	11 Dec 2010	9	NA	NA	NA	08 May 2002	19 Dec 2011	10
419007	NA	NA	NA	NA	NA	NA	NA	NA	NA
419016	20 Dec 1995	23 Jun 2011	6	20 Dec 1995	13 Dec 1998	3	20 Dec 1995	03 Nov 2011	6
419024	21 Dec 1995	27 Jun 2011	12	21 Dec 1995	28 Jun 1999	3	21 Dec 1995	30 Nov 2011	13
419026	03 Jun 1995	10 Nov 2010	15	19 Apr 1996	20 Mar 1998	2	03 Jun 1995	05 Jan 2012	17
419027	NA	NA	NA	NA	NA	NA	15 Mar 1996	27 Jul 1998	2
419032	24 May 1995	04 Oct 2011	16	24 May 1995	14 May 1998	2	24 May 1995	04 Oct 2011	16
419033	05 Dec 1995	03 Sep 1998	3	13 Mar 1996	12 May 1998	1	05 Dec 1995	03 Sep 1998	3
419034	27 May 1995	03 Sep 1998	3	27 May 1995	13 May 1998	2	27 May 1995	03 Sep 1998	3
419043	24 Aug 2000	12 Jan 2003	1	NA	NA	NA	16 Aug 1975	09 Jan 2003	14
419045	NA	NA	NA	NA	NA	NA	27 Oct 1992	30 Nov 2011	19
419056	24 Aug 2000	10 Feb 2003	1	NA	NA	NA	20 Nov 1996	10 Feb 2003	3
419075	NA	NA	NA	NA	NA	NA	31 Oct 1996	19 Aug 1998	2
419084	04 Jul 1994	30 Mar 2010	11	03 May 1995	13 May 1998	2	03 Jul 1994	26 Oct 2011	13
419085	08 Jun 1995	03 Sep 1998	3	08 Jun 1995	12 May 1998	2	08 Jun 1995	03 Sep 1998	3
419087	08 Dec 1995	03 Feb 1999	2	08 Dec 1995	03 Feb 1999	2	NA	NA	NA
419088	NA	NA	NA	NA	NA	NA	08 Nov 1996	08 Nov 1999	3
419089	NA	NA	NA	NA	NA	NA	06 Nov 1996	16 Aug 2004	8
419095	NA	NA	NA	NA	NA	NA	19 Apr 2000	27 Nov 2007	8
419097	07 Aug 2002	25 Nov 2008	6	NA	NA	NA	07 Aug 2002	25 Nov 2008	6
419099	11 Apr 2008	23 Jun 2011	3	NA	NA	NA	11 Apr 2008	11 Sep 2011	3

[a]End dates are not always indicative of end of records, but of cut-off dates for inclusion in published datasets
NA denotes parameter not measured at the station
Data: NSW Office of Water (Dataset 1)

Figure 16 shows time series of daily mean EC and streamflow (Dataset 6) for the water year (year starting in July and ending in June) 2010–11, which was a year with rainfall higher than the mean (Ganter, 2011). EC values remain higher than the trigger value for the protection of aquatic ecosystems (300 µS/cm) for much of the year. Values drop below the trigger value only after salt in the landscape is mobilised by flows higher than 100 ML/day. The mean daily value for 2010–11 was about 390 µS/cm.

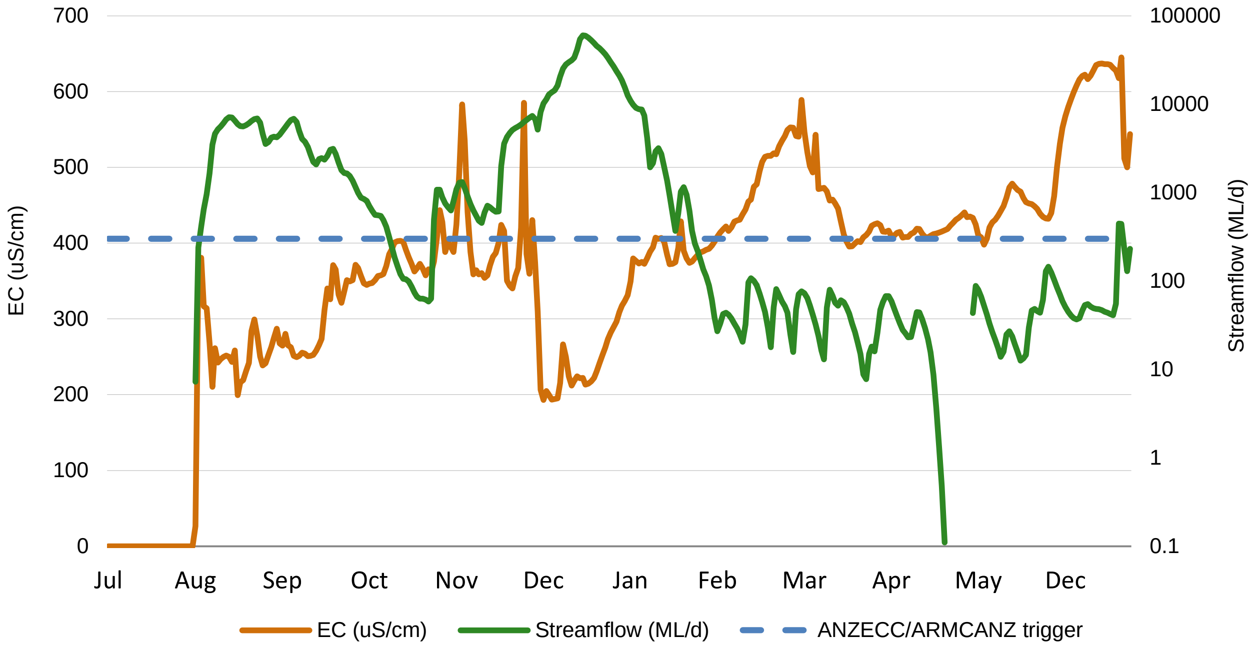

Figure 16 Time series of daily mean values of electrical conductivity and streamflow for water year 2010–11 at gauging station 419026 (Namoi River at Goangra)

Electrical conductivity (EC), shown by brown line, and streamflow (green line). The ANZECC/ARMCANZ default trigger value for the protection of aquatic ecosystems of 300 µS/cm is frequently exceeded. Note the secondary logarithmic y-axis for streamflow.
Data: NSW Office of Water (Dataset 6)

Data from the NSW Office of Water (Dataset 1) shows that turbidity at gauging station 419026 was measured only from April 1996 to March 1998; whereas NWQP measurements occurred from 2002 to 2007 (Mawhinney, 2011). The mean daily NTU according to NSW Office of Water (Dataset 1) was 141 (range zero to 443), which grossly exceeds the ANZECC and ARMCANZ (2000) trigger value of 50 NTU.

1.5.2.1.2 Gaps

There is a lack of data on the presence of heavy metals, trace elements and hydrocarbons which could result from coal mining and CSG operation and development. Other parameters not routinely monitored include: pH, alkalinity, dissolved oxygen, and major and minor ions.

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1.5.2.2 Groundwater

This product provides a baseline assessment of groundwater quality in the Namoi subregion with a focus on salinity and information on selected trace elements. Water quality is assessed against national guidelines provided by the National Health and Medical Research Council (NHMRC) and the Australian and New Zealand Environment and Conservation Council (ANZECC). Information about the major ion composition of groundwater in the Namoi subregion is reported in companion product 1.1 for the Namoi subregion (Welsh et al., 2014), together with a description of the hydrogeological units and conceptual understanding of hydrodynamics in the Namoi subregion.

Groundwater chemistry data were compiled from the NSW groundwater bore database (NSW Office of Water, Dataset 1). From this database, 1569 bores had data for salinity (electrical conductivity (EC)), but only a small subset of samples had trace element data. Some supplementary data (116 bores) from the National Collaborative Framework Hydrochemical Characterisation Project – Surat Basin hydrochemistry spreadsheets (Geoscience Australia, Dataset 2) were also used for the GAB portion of the Namoi subregion. Most bores in Dataset 1 cannot be attributed to specific hydrological units. However, the bores in Dataset 2 are specific to the GAB units in the Namoi subregion. Consequently, sample data have been assigned to either GAB units or non-GAB units, noting that non-GAB units will include a small proportion of bores in Gunnedah Basin sedimentary rocks. The databases contain data from bores drilled from the early 1900s through to the present. This time span has implications for data quality, given the significant changes over the decades in how data are collected and recorded.

To assess the potential hazards associated with using groundwater in the subregion, groundwater chemistry data were compared to national water quality guidelines in which a number of possible uses were considered: human drinking water, stock drinking water and long-term irrigation (defined as up to 100 years).

Trigger values were taken from the *Australian Drinking Water Guidelines* (ADWG) (NHMRC, 2011) and the *National Water Quality Management Strategy* (NWQMS) (ANZECC, 2000). Trigger values for EC were used rather than total dissolved solids (TDS) as EC values are more widely reported in the Namoi subregion.

1.5.2.2.1 Electrical conductivity

Electrical conductivity trigger values were determined using ADWG for human consumption (NHMRC, 2011) and the NWQMS for stock and irrigation water (ANZECC, 2000). The trigger values used for EC are given in Table 14 and are derived from the TDS concentrations in the guidelines, using an approximate conversion factor of 0.64, as recommended in the guidelines. The range of EC values in the data is shown in Table 14, together with the percentage of samples that exceed the different categories in the guidelines (human consumption, irrigation and stock watering).

Table 14 Electrical conductivity in Namoi subregion compared to water guidelines

Electrical conductivity (EC)	Number of analyses	Minimum value (µS/cm)	Maximum value (µS/cm)	ADWG trigger[a] (µS/cm)	Fraction in exceedance of guidelines (%)	Irrigation trigger[b] (µS/cm)	Fraction in exceedance of guidelines (%)	Stock trigger[c] (µS/cm)	Fraction in exceedance of guidelines (%)
Non-GAB[d] bores[e]	10,745	1.5	73,810	1,500	27%	8,000	6.7%	20,000	1.3%
GAB[d] bores[f]	638	144	28,600	1,500	31%	8,000	11%	20,000	3.0%

[a]Based on Australian Drinking Water Guidelines (NHMRC, 2011) and approximate conversion from total dissolved solids (TDS) to electrical conductivity (EC) using conversion factor 0.64. TDS greater than 900 mg/L (~1476 µS/cm) is considered poor quality drinking water.
[b]Based on Table 4.2.5 in the National Water Quality Management Strategy (ANZECC, 2000)
[c]Based on National Water Quality Management Strategy (ANZECC, 2000) and approximate conversion from TDS to EC. TDS greater than 13,000 mg/L (EC of ~20,000 µS/cm) is the maximum concentration when a decline in health of all stock would be expected (ANZECC, 2000, Table 4.3.1)
[d]Great Artesian Basin (GAB)
[e]Data: Bioregional Assessment Programme (Dataset 3)
[f]Data: Bioregional Assessment Programme (Dataset 4)

1.5.2.2.2 Electrical conductivity distribution

The EC data were used to generate maps showing EC for the non-GAB and GAB bores in the Namoi subregion. The most recent EC value was used to generate the map, so it does not represent a single snapshot of groundwater quality at a specific time; rather, the EC values provide an indication of variation in salinity across the subregion. Where multiple records of EC were available for a bore, it was noted that the EC of the groundwater predominantly fell within the same use category (drinking, irrigation, stock or >20,000µS/cm) over time, despite small changes in absolute EC values. Consequently, the distribution of EC across the sub-region is representative of average conditions in terms of categorising the bores based on their highest value water use. There is likely to be variation in the quality of the sample analyses used to create the maps due to the archival nature of the data. Factors affecting archival data can include use of different analysis methods, improvements in analysis technology over time, analysis accuracy and precision, variations in sample collection methodologies, and different bore construction techniques and quality. In an effort to reduce the effect of the archival nature of the data, only samples collected after 1970 have been included in Figure 17 and Figure 18.

Non-Great Artesian Basin groundwater

The EC data presented in Figure 17 show that groundwater in the Namoi subregion is generally suitable for drinking and irrigation purposes. Areas of higher salinity groundwater are in the Upper Namoi and the western half of the Lower Namoi alluvial systems.

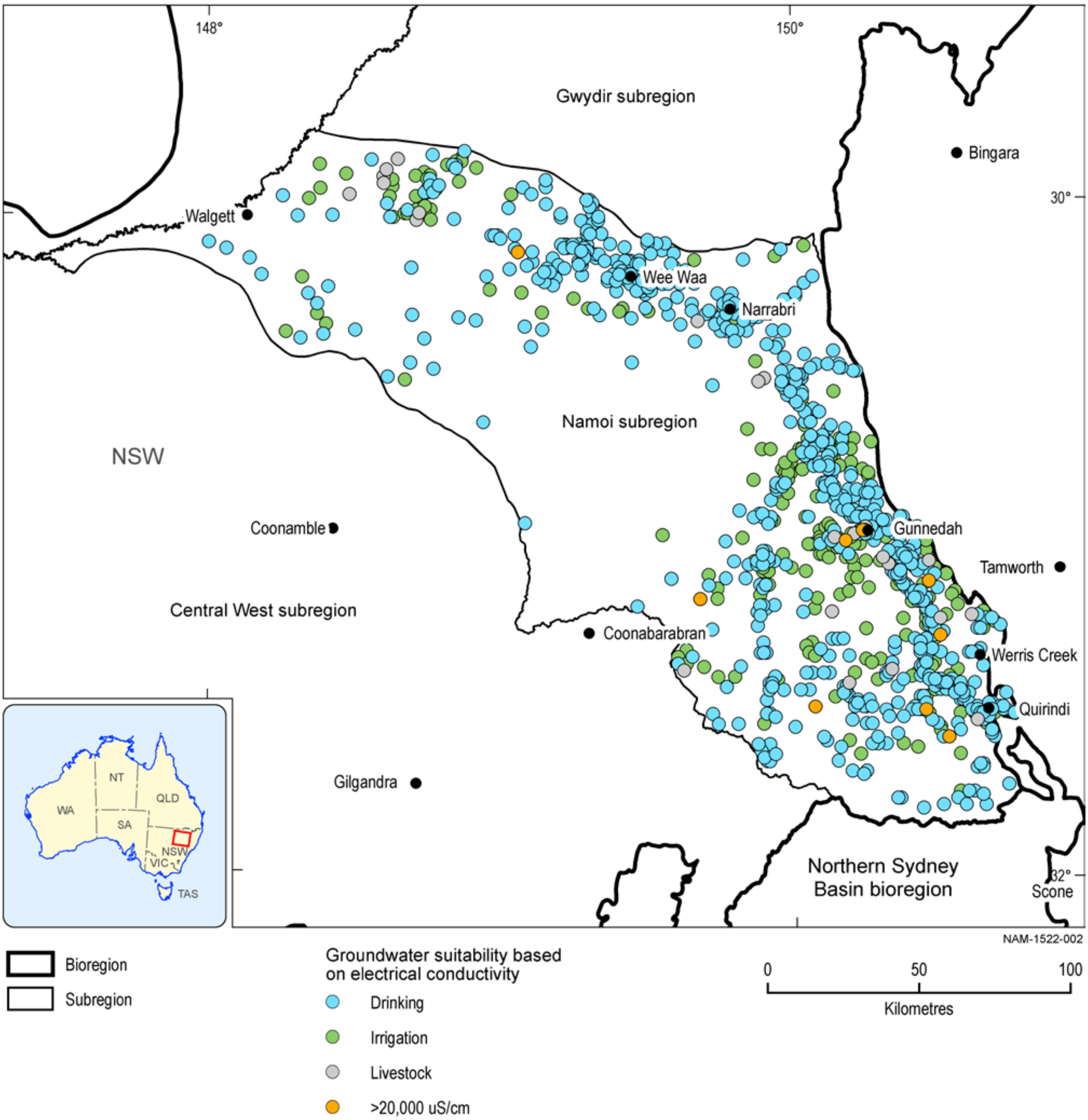

Figure 17 Distribution of electrical conductivity from non-Great Artesian Basin bores in the Namoi subregion (for bores sampled in 1970 and later)

Data: Bioregional Assessment Programme (Dataset 3)

Great Artesian Basin groundwater

Figure 18 shows that groundwater EC levels in bores screened in the GAB are also generally suitable for drinking and irrigation purposes, with small areas of higher salinity groundwater in the north-west of the subregion. Whilst some bores had a single EC reading greater than 20,000 µS/cm, when results were averaged across each bore, no bores averaged EC values in exceedance of the guidelines for livestock watering.

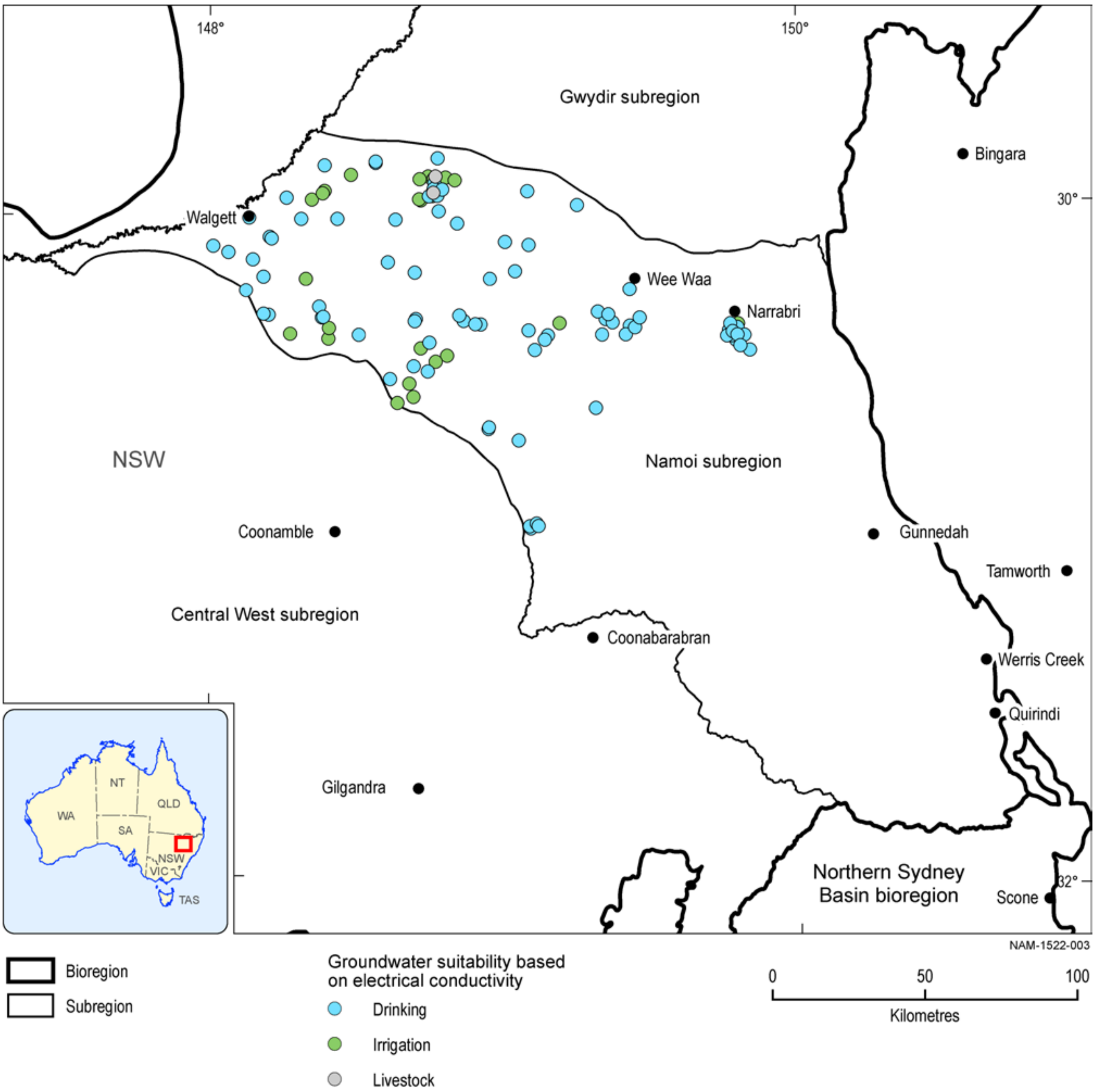

Figure 18 Distribution of electrical conductivity from Great Artesian Basin bores in the Namoi subregion

Date of sample analysis was not available for the majority of records
Data: Bioregional Assessment Programme (Dataset 4)

1.5.2.2.3 Trace elements

Exceedances for the trace elements available in the dataset were determined using the ADWG for human consumption (NHMRC, 2011) and NWQMS (ANZECC, 2000) for stock watering and irrigation water. Trace element trigger values and the percentage of analyses in exceedance of the guidelines in the non-GAB dataset are summarised in Table 15 and in Table 16 for the GAB dataset. Over 20% of samples from non-GAB bores show exceedances of drinking water guidelines for aluminium, iron, manganese, nickel and lead, however the groundwater is generally suitable for stock watering. The results from the GAB bores show exceedances of the drinking water guidelines primarily for iron, fluorine and manganese.

Table 15 Number of analyses and exceedances for trace elements in non-Great Artesian Basin groundwater of the Namoi subregion

	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	ADWG trigger[a] (mg/L)	Percentage in exceedance of guidelines (%)	Irrigation trigger[b] (mg/L)	Percentage in exceedance of guidelines (%)	Stock trigger[c] (mg/L)	Percentage in exceedance of guidelines (%)
Aluminium (Al)	527	0.05	20	0.2[e]	17%	5	3.0%	5	3.0%
Boron (B)	1290	bd[d]	8.4	4	0.62%	0.5	3.7%	5	0.62%
Cobalt (Co)	171	0.01	0.05	NA	NA	0.05	0%	1	0%
Chromium (Cr)	171	0.01	0.05	0.05	0%	1	0%	1	0%
Copper (Cu)	494	bd[d]	2	2	0%	1	1.0%	1	1.0%
Fluorine (F)	3368	bd[d]	247.93	1.5	6.4%	1	11.3%	2	3.5%
Iron (Fe)	2244	bd[d]	73.64	0.3[e]	30%	0.2	38%	NA	NA
Manganese (Mn)	504	bd[d]	3.7	0.1[e]	21%	0.2	14%	NA	NA
Molybdenum (Mo)	171	0.01	0.05	0.05	0%	0.01	91%	NA	NA
Nickel (Ni)	486	0.01	0.05	0.02	32%	0.2	0%	1	0%
Nitrate (NO_3)	977	bd[d]	110	50	0.2%	NA	NA	NA	NA
Lead (Pb)	489	0.01	0.1	0.01	100%	2	0%	0.1	0%
Uranium (U)[f]	20	0.42	3.6	0.017	0%	0.01	0%	20	0%
Zinc (Zn)	561	bd[d]	4.4	3[e]	0.18%	2	0.18%	2	0.18%

[a]Table 3.4.1 in *Australian Drinking Water Guidelines* (NHMRC, 2011)
[b]Table 4.2.10 in *National Water Quality Management Strategy* (ANZECC, 2000)
[c]Table 4.3.2 in *National Water Quality Management Strategy* (ANZECC, 2000)
[d]Below detection limit
[e]Aesthetic water quality trigger (not health related)
[f]Uranium values are in parts per billion
NA means 'data not available'
Data: Bioregional Assessment Programme (Dataset 5)

Table 16 Number of analyses and exceedances for trace elements in Great Artesian Basin groundwater of the Namoi subregion

	Number of analyses	Minimum value (mg/L)	Maximum value (mg/L)	ADWG trigger[a] (mg/L)	Percentage in exceedance of guidelines (%)	Irrigation trigger[b] (mg/L)	Percentage in exceedance of guidelines (%)	Stock trigger[c] (mg/L)	Percentage in exceedance of guidelines (%)
Aluminium (Al)	9	0.001	0.078	0.2[e]	0%	5	0%	5	0%
Boron (B)	198	0.03	8.4	4	4.6%	0.5	29%	5	4.6%
Copper (Cu)	9	0.003	0.817	2	0%	1	0%	1	0%
Fluorine (F)	307	0.02	5.13	1.5	14%	1	30%	2	6.5%
Iron (Fe)	64	0.01	28.6	0.3[e]	17%	0.2	27%	NA	100%
Manganese (Mn)	9	0.002	0.255	0.1[e]	11%	0.2	11%	NA	100%
Lead (Pb)	2	0.007	0.008	0.01	0%	2	0%	0.1	0%
Uranium (U)[f]	10	0.00006	0.001	0.02	0%	0.01	0%	20	0%
Vanadium (V)	12	bd[d]	3.47	NA	8.3%	0.5	8.3%	NA	8.3%
Zinc (Zn)	2	0.01	0.01	3[e]	100%	2	0%	2	100%

[a]Table 3.4.1 in Australian Drinking Water Guidelines (NHMRC, 2011)
[b]Table 4.2.10 in National Water Quality Management Strategy (ANZECC, 2000)
[c]Table 4.3.2 in National Water Quality Management Strategy (ANZECC, 2000)
[d]Below detection limit
[e]Aesthetic water quality trigger (not health related)
[f]Uranium values are in parts per billion
NA means 'data not available'
Data: Bioregional Assessment Programme (Dataset 4)

1.5.2.2.4 Gaps

The quality of the hydrochemistry data available for this assessment is difficult to determine, as analytical uncertainties are not reported in the dataset. The dataset includes chemical analyses of differing ages, sometimes decades apart, which will have differing levels of accuracy and precision. Additionally, bore screening interval data are unknown and stratigraphic unit information was not assigned in the database.

A number of potentially harmful trace elements have been omitted from this product due to scarcity or absence of data. Some elements have data available for only one or two sample points, while others have no data available at all. There is also a scarcity of the concentrations of a range of organic compounds in groundwater, such as polycyclic aromatic hydrocarbons, as hydrocarbons are not routinely measured in groundwater in the Namoi subregion.

Trace elements for which there was only limited data for groundwater outside the GAB are cobalt, chromium, molybdenum, and uranium. Trace elements for which there are no data for groundwater outside the GAB are arsenic, beryllium, cadmium, mercury, silver, vanadium and selenium.

Trace elements for which there was only limited data in the GAB are aluminium, copper, lead, manganese, uranium, vanadium and zinc. Trace elements for which there are no data in the GAB are arsenic, beryllium, cadmium, chromium, cobalt, mercury, molybdenum, nickel, nitrate, silver and selenium.

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