VOLUME 2 – THE INDICATORS

# 2016 Audit of the Sydney Drinking Water Catchment

June 2017

# Document history

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# Contents



## Figures

## Tables

## Abbreviations and terms

| | |
|---|---|
| Alluvium | Alluvium Consulting Australia Pty Ltd |
| AWD | Available water determination |
| BFRMP | Bush Fire Risk Management Plan |
| BFMC | Bush Fire Management Committee |
| BLR | basic landholder rights |
| BRIMS | Bushfire Risk Information Management System |
| Catchment | Sydney's Drinking Water Catchment |
| DEST | Commonwealth Department of Environment, Sport and Tourism |
| DO | Dissolved oxygen |
| DPI | NSW Department of Primary Industries |
| DWE | NSW Department of Water & Energy |
| EEC | Endangered Ecological Community |
| ELA | Eco Logical Australia Pty Ltd |
| EPL | Environment Protection Licence |
| FM Act | NSW *Fisheries Management Act* |
| GDE | Groundwater Dependent Ecosystem |
| HRNVE | Hybrid Riparian Native Vegetation Extent |
| LGA | Local Government Area |
| LTAAEL | Long-term average annual extraction limits |
| mg/L | Milligrams per litre |
| NTU | Nephelometric Turbidity Unit (a measure of turbidity) |
| PSAT | Pollution assessment source tool |
| RCI | NSW River Condition Index |
| RFS | NSW Rural Fire Service |
| RVE | Riparian Vegetation Extent |
| SCA | Sydney Catchment Authority |
| SoE | State of Environment |
| STP | Sewage treatment plant |
| TLGE | Total licensed groundwater entitlement |
| TN | Total nitrogen |
| TP | Total phosphorus |
| ug/L | Micrograms per litre |
| Water Sharing Plan | Water Sharing Plan for the Greater Metropolitan Region (2011) |
| WFP | Water Filtration Plant |
| WM Act | NSW *Water Management Act* |

# 1 Introduction

## 1.1 Report structure

The 2016 Audit of the Sydney Catchment area is structured in three volumes:

- Volume 1 – Catchment overview and concepts, audit method, key findings and recommendations
- Volume 2 – Detailed analysis of each indicator
- Volume 3 – Supporting technical data and detailed information.

This Volume 2 provides a detailed description of the methods adopted and results for each of the indicators assessed. The following chapters in this volume provide detailed analysis of each gazetted indicator for the period 1 July 2013 to 30 June 2016 in the context of longer term trends. The analysis has been undertaken by specialist auditors, listed in **Table 1**.

**Table 1. Independent audit specialists**

| Name (Organisation) | Role in audit |
|---|---|
| Ross Hardie (Alluvium) | Project director |
| Professor Barry Hart (Alluvium) | Expert review |
| Dr Neil Byron (Alluvium) | Expert review |
| Dr Richard Cresswell (ELA) | Expert review |
| Bruce Whitehill (Alluvium) | Lead auditor; Indicator specialist – Pollution and potential contamination |
| Beth Medway (ELA) | Lead auditor |
| Deanne Hickey (ELA) | GIS analysis and mapping |
| Brian Keogh (Cobalt[59]) | Stakeholder consultation |
| David Barratt (Alluvium) | Climate analysis |
| Dr Ross Sparks (CSIRO) | Water quality statistical analysis |
| Rohan Lucas (Alluvium) | Mining specialist |
| Mark Stacey (Alluvium) | Indicator specialist – Soil erosion |
| Mark Wainwright (Alluvium) | Indicator specialist – Land use; Population settlements and patterns; Community attitudes, aspirations and engagement |
| Ian Wright (University of Western Sydney) | Indicator specialist – Macroinvertebrates; Water quality |
| John Beattie (ELA) | Indigenous stakeholders consultation specialist |
| Dr Anna Greve (ELA) | Indicator specialist – Groundwater |
| Mark Southwell (ELA) | Indicator specialist – Environmental flows |
| Andrew Herron (ELA) | Indicator specialist – Surface water flow |
| Carly Waterhouse (ELA) | Indicator specialist – Surface water flow |
| Ian Dixon (ELA) | Indicator specialist – Fish; Riparian vegetation; Wetlands |
| Greg Steenbeeke (ELA) | Indicator specialist – Native vegetation |
| Danielle Meggos (ELA) | Indicator specialist - Fire |

## 1.2 Sub-catchment overview

As discussed in **Volume 1** of this 2016 Audit, the Sydney Catchment area ('the Catchment') is characterised by five major sub-catchments – Blue Mountains, Shoalhaven, Upper Nepean, Warragamba and Woronora. The Shoalhaven and Warragamba are the largest regions with 12 minor sub-catchments each, whereas the Blue Mountains, Upper Nepean and Woronora have one minor sub-catchment each (**Table 2**). The major and minor sub-catchments are mapped in **Figures 1** to **5** using aerial photographic imagery.

**Table 2. Sub-catchments, raw water storages and sewage treatment plants (STPs) in the Catchment**

| ID* | Minor sub-catchment | Major sub-catchment | Storages | Major STPs |
|---|---|---|---|---|
| 1 | Back & Round Mountain Creeks | Shoalhaven | | |
| 2 | Boro Creek | Shoalhaven | | |
| 3 | Braidwood | Shoalhaven | | Braidwood |
| 4 | Bungonia Creek | Shoalhaven | Lake Yarrunga | |
| 5 | Endrick River | Shoalhaven | | |
| 6 | Grose River | Blue Mountains | | |
| 7 | Jerrabattagulla Creek | Shoalhaven | | |
| 8 | Kangaroo River | Shoalhaven | Fitzroy Falls Dam, Lake Yarrunga | Kangaroo Valley |
| 9 | Kowmung River | Warragamba | | |
| 10 | Lake Burragorang | Warragamba | Lake Burragorang | |
| 11 | Little River | Warragamba | Lake Burragorang | |
| 12 | Lower Coxs River | Warragamba | Lake Burragorang | |
| 13 | Mid Coxs River | Warragamba | | Mt Victoria |
| 14 | Mid Shoalhaven River | Shoalhaven | | |
| 15 | Mongarlowe River | Shoalhaven | | |
| 16 | Mulwaree River | Warragamba | | |
| 17 | Nattai River | Warragamba | | Mittagong |
| 18 | Nerrimunga River | Shoalhaven | | |
| 19 | Reedy Creek | Shoalhaven | | |
| 20 | Upper Coxs River | Warragamba | | Lithgow |
| 21 | Upper Nepean River | Upper Nepean | Avon Dam, Cataract Dam, Cordeaux Dam, Nepean Dam, Upper Cordeaux Dam, Wingecarribee Dam | |
| 22 | Upper Shoalhaven River | Shoalhaven | | |
| 23 | Upper Wollondilly River | Warragamba | | |
| 24 | Werri Berri Creek | Warragamba | Lake Burragorang | |
| 25 | Wingecarribee River | Warragamba | Wingecarribee Dam | Berrima, Robertson |
| 26 | Wollondilly River | Warragamba | Lake Burragorang | Bundanoon |
| 27 | Woronora River | Woronora (also referred to as Metropolitan) | Woronora Dam | |

*Identification system for minor sub-catchments used in maps throughout the audit report

WaterNSW collects data from water quality and surface water flow monitoring stations in storages and streams in the Catchment. The main storages are listed in **Table 2** and mapped in **Figures 1** to **5**. Each monitoring station has a unique code which is referred to in the text and maps in this Audit. For example, water quality monitoring station 'DGC1' is located in the Grose River sub-catchment, shown in **Figure 1**. **Table 2** also lists the sewage treatment plants that discharge effluent (treated sewage) within the Catchment.

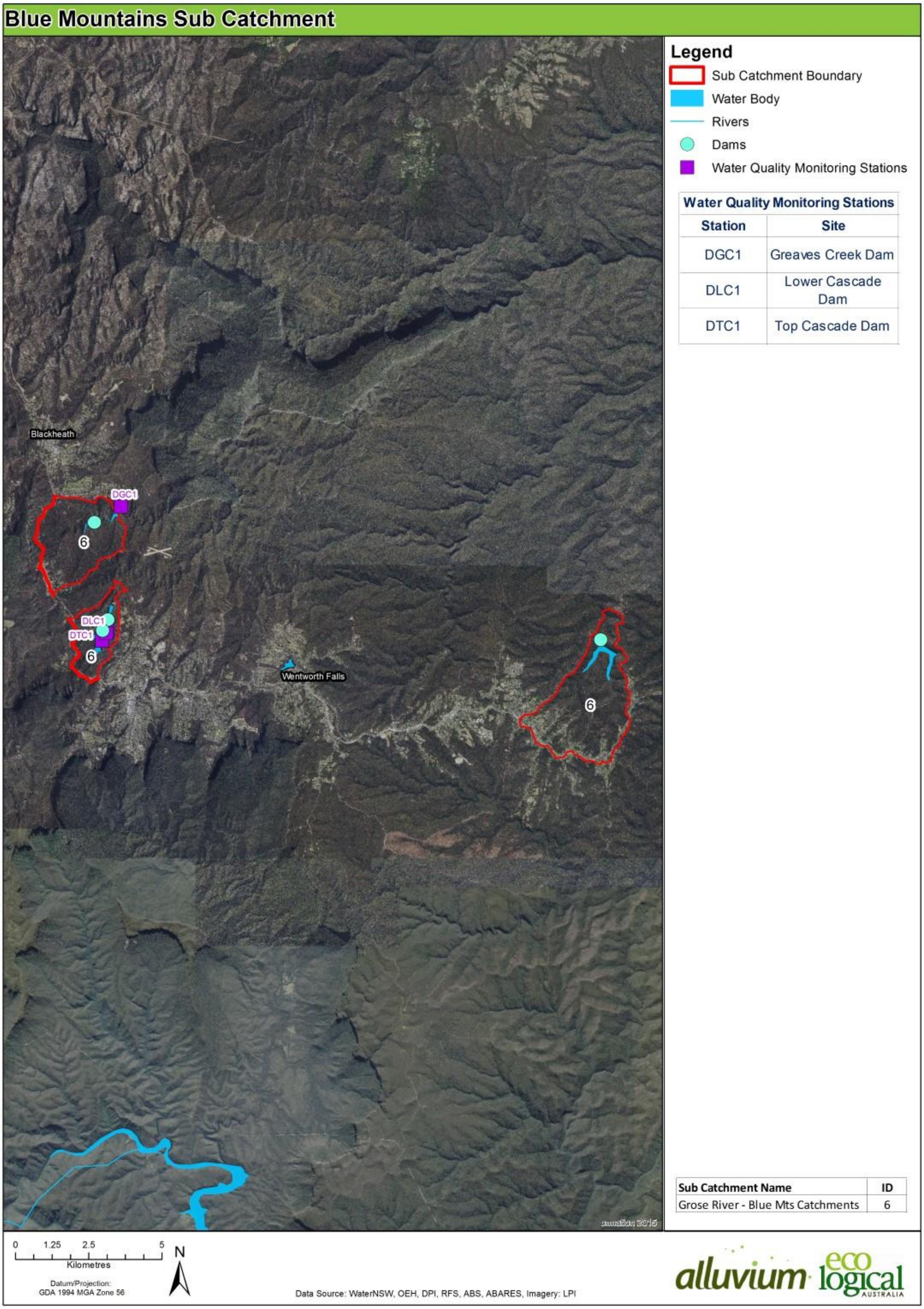
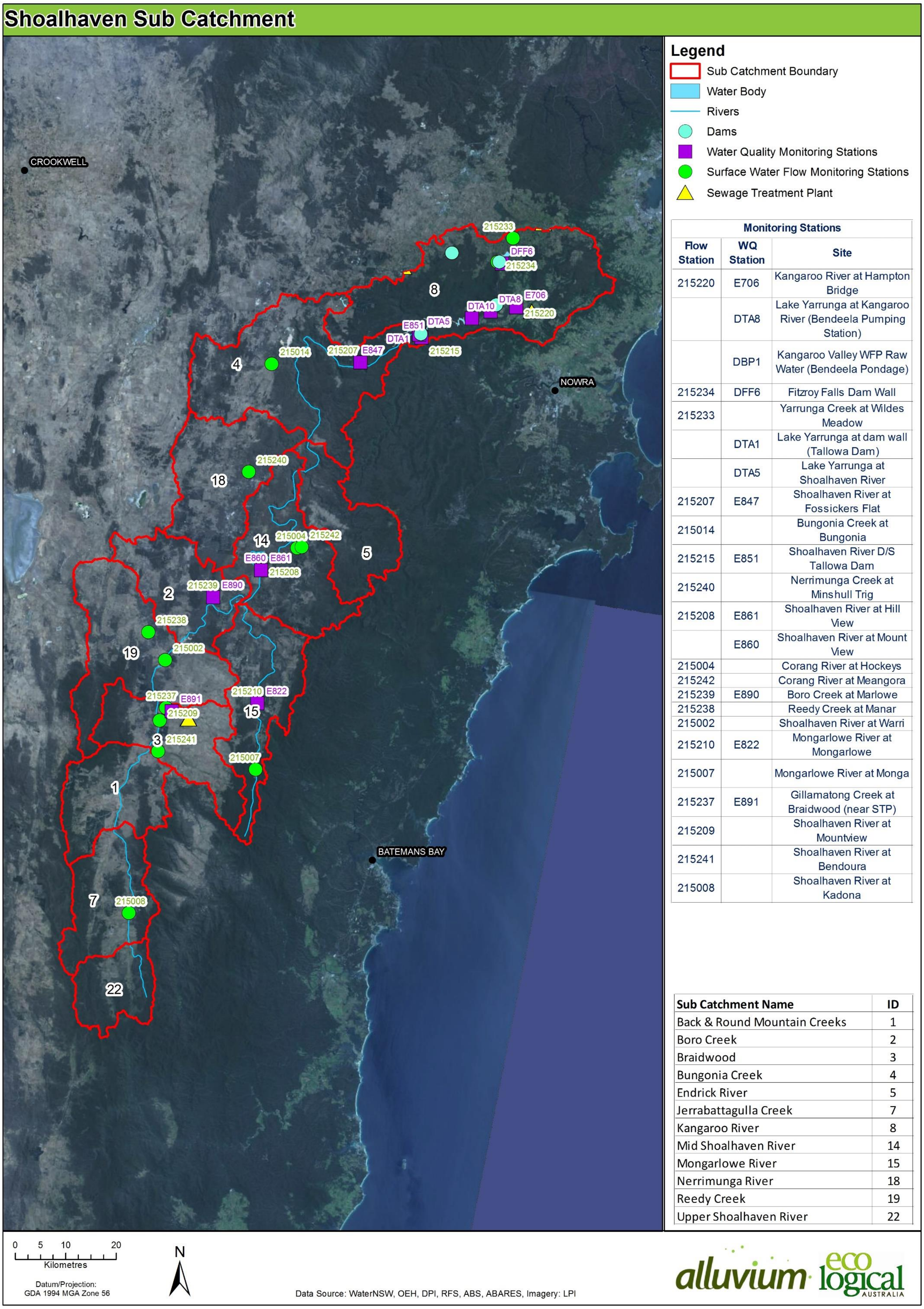



**Figure 1. WaterNSW monitoring locations in the Blue Mountains sub-catchment**




Monitoring Stations

| Flow Station | WQ Station | Site |
|---|---|---|
| 215220 | E706 | Kangaroo River at Hampton Bridge |
| | DTA8 | Lake Yarrunga at Kangaroo River (Bendeela Pumping Station) |
| | DBP1 | Kangaroo Valley WFP Raw Water (Bendeela Pondage) |
| 215234 | DFF6 | Fitzroy Falls Dam Wall |
| 215233 | | Yarrunga Creek at Wildes Meadow |
| | DTA1 | Lake Yarrunga at dam wall (Tallowa Dam) |
| | DTA5 | Lake Yarrunga at Shoalhaven River |
| 215207 | E847 | Shoalhaven River at Fossickers Flat |
| 215014 | | Bungonia Creek at Bungonia |
| 215215 | E851 | Shoalhaven River D/S Tallowa Dam |
| 215240 | | Nerrimunga Creek at Minshull Trig |
| 215208 | E861 | Shoalhaven River at Hill View |
| | E860 | Shoalhaven River at Mount View |
| 215004 | | Corang River at Hockeys |
| 215242 | | Corang River at Meangora |
| 215239 | E890 | Boro Creek at Marlowe |
| 215238 | | Reedy Creek at Manar |
| 215002 | | Shoalhaven River at Warri |
| 215210 | E822 | Mongarlowe River at Mongarlowe |
| 215007 | | Mongarlowe River at Monga |
| 215237 | E891 | Gillamatong Creek at Braidwood (near STP) |
| 215209 | | Shoalhaven River at Mountview |
| 215241 | | Shoalhaven River at Bendoura |
| 215008 | | Shoalhaven River at Kadona |

| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Shoalhaven River | 22 |

**Figure 2. WaterNSW monitoring locations in the Shoalhaven sub-catchment**

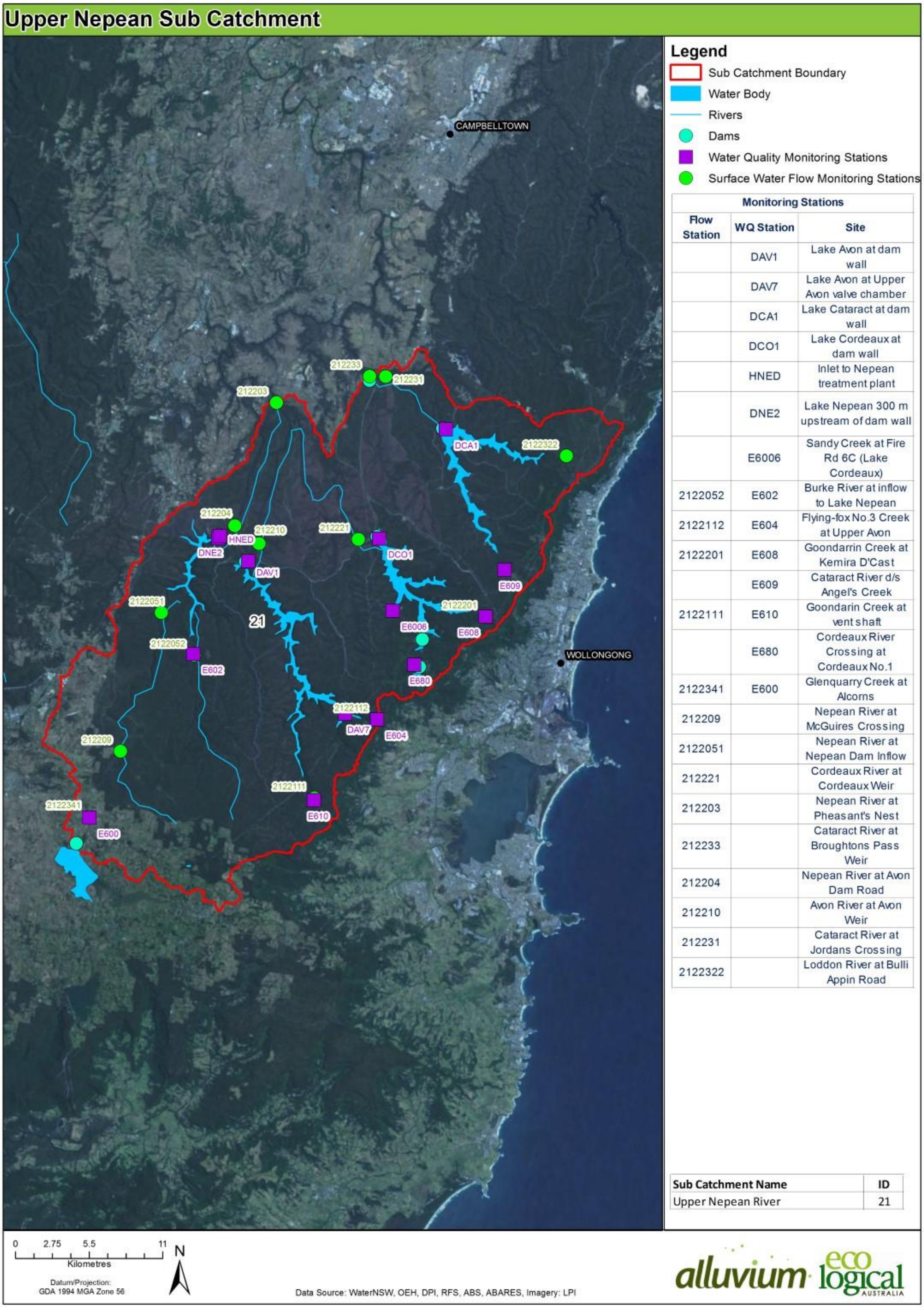
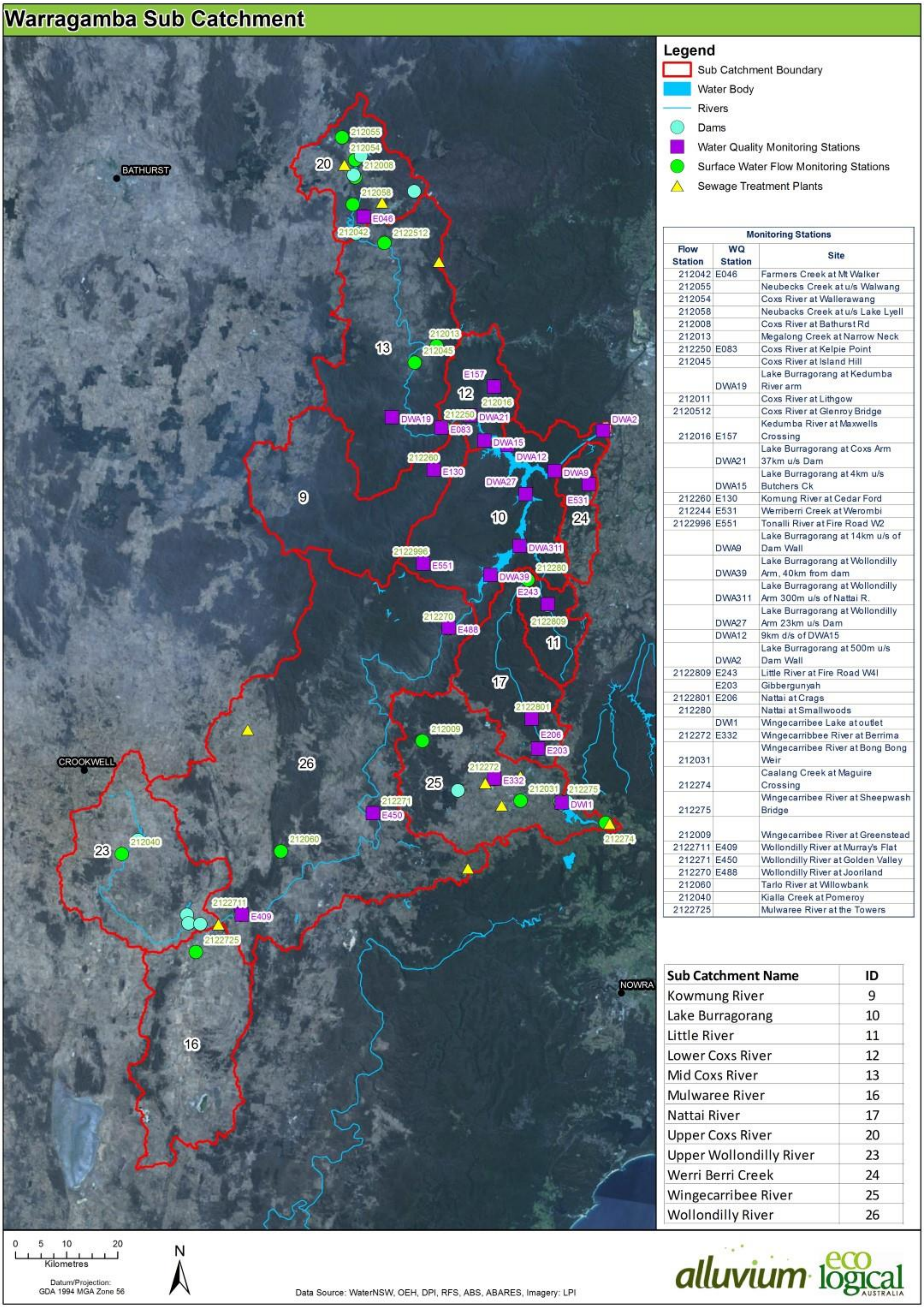



**Figure 3. WaterNSW monitoring locations in the Upper Nepean sub-catchment**




| Monitoring Stations | | |
|---|---|---|
| Flow Station | WQ Station | Site |
| 212042 | E046 | Farmers Creek at Mt Walker |
| 212055 | | Neubecks Creek at u/s Walwang |
| 212054 | | Coxs River at Wallerawang |
| 212058 | | Neubacks Creek at u/s Lake Lyell |
| 212008 | | Coxs River at Bathurst Rd |
| 212013 | | Megalong Creek at Narrow Neck |
| 212250 | E083 | Coxs River at Kelpie Point |
| 212045 | | Coxs River at Island Hill |
| | DWA19 | Lake Burragorang at Kedumba River arm |
| 212011 | | Coxs River at Lithgow |
| 2120512 | | Coxs River at Glenroy Bridge |
| 212016 | E157 | Kedumba River at Maxwells Crossing |
| | DWA21 | Lake Burragorang at Coxs Arm 37km u/s Dam |
| | DWA15 | Lake Burragorang at 4km u/s Butchers Ck |
| 212260 | E130 | Komung River at Cedar Ford |
| 212244 | E531 | Werriberri Creek at Werombi |
| 2122996 | E551 | Tonalli River at Fire Road W2 |
| | DWA9 | Lake Burragorang at 14km u/s of Dam Wall |
| | DWA39 | Lake Burragorang at Wollondilly Arm, 40km from dam |
| | DWA311 | Lake Burragorang at Wollondilly Arm 300m u/s of Nattai R. |
| | DWA27 | Lake Burragorang at Wollondilly Arm 23km u/s Dam |
| | DWA12 | 9km d/s of DWA15 |
| | DWA2 | Lake Burragorang at 500m u/s Dam Wall |
| 2122809 | E243 | Little River at Fire Road W4I |
| | E203 | Gibbergunyah |
| 2122801 | E206 | Nattai at Crags |
| 212280 | | Nattai at Smallwoods |
| | DWI1 | Wingecarribee Lake at outlet |
| 212272 | E332 | Wingecarribbee River at Berrima |
| 212031 | | Wingecarribee River at Bong Bong Weir |
| 212274 | | Caalang Creek at Maguire Crossing |
| 212275 | | Wingecarribee River at Sheepwash Bridge |
| 212009 | | Wingecarribee River at Greenstead |
| 2122711 | E409 | Wollondilly River at Murray's Flat |
| 212271 | E450 | Wollondilly River at Golden Valley |
| 212270 | E488 | Wollondilly River at Jooriland |
| 212060 | | Tarlo River at Willowbank |
| 212040 | | Kialla Creek at Pomeroy |
| 2122725 | | Mulwaree River at the Towers |

| Sub Catchment Name | ID |
|---|---|
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Upper Coxs River | 20 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |

**Figure 4. WaterNSW monitoring locations in the Warragamba sub-catchment**

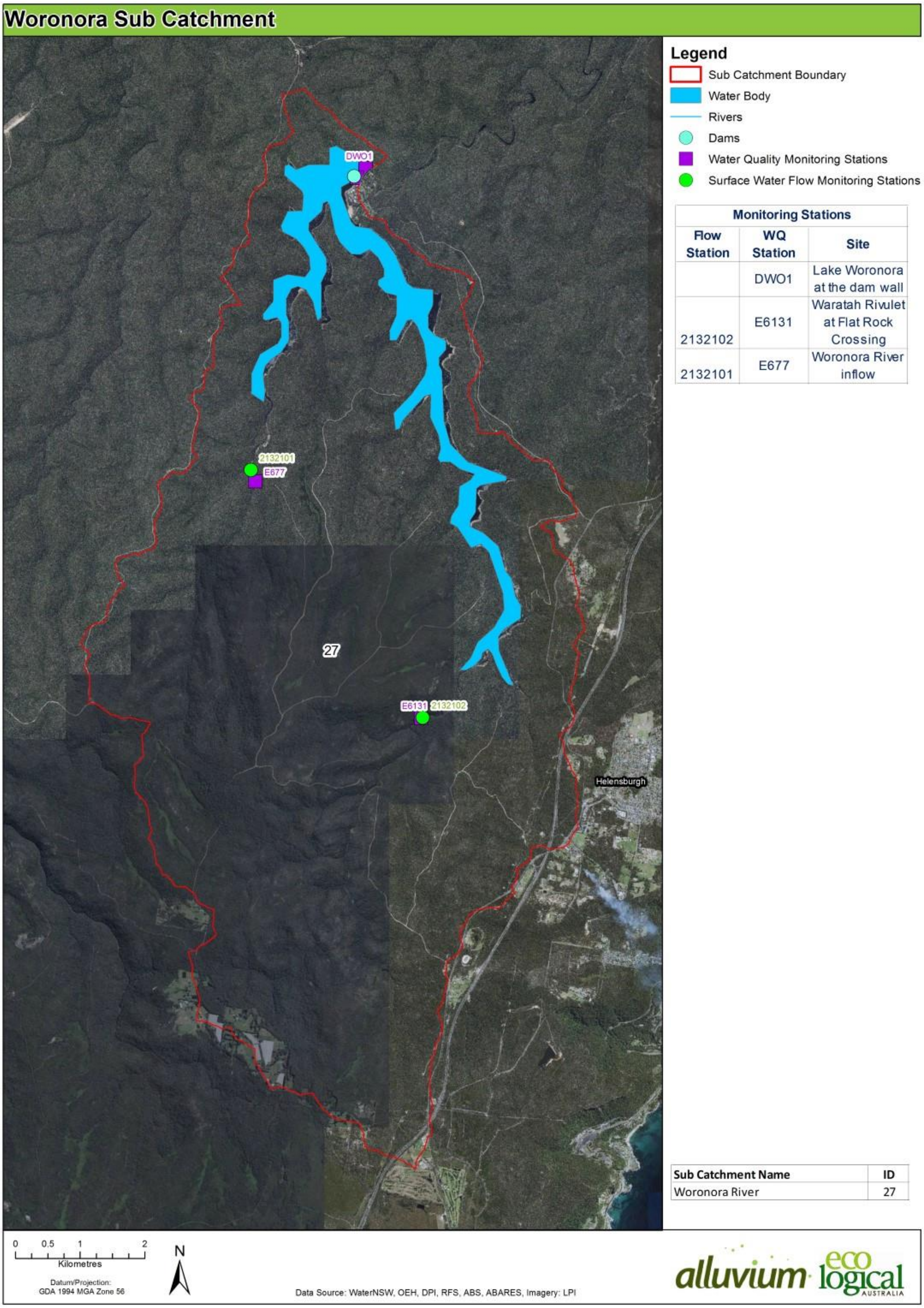



**Figure 5. WaterNSW monitoring locations and mining extent in the Woronora sub-catchment**

# 2 Primary indicators - water quality

## 2.1 Ecosystem and raw water quality

**Definition and context**
Data from WaterNSW monitoring sites in the streams and storage reservoirs were assessed with reference to relevant guidelines to determine if the 'ecosystem and raw water quality' was:

- **Good** – defined as when the median value complied with the relevant guideline for that analyte
- **Poor** - defined as when the median value complied with the guideline for that analyte, but when compared to the interquartile range it often failed to comply with the guideline
- **Very poor** - defined as when the median value for that indicator was outside the recommended values for that analyte

The auditors also reviewed the trends in the data for each analyte ie. to determine if the data showed an **improving**, **stable** or **worsening** trend.

**Method**
Water quality was assessed by comparing data collected from WaterNSW monitoring sites with appropriate water quality guidelines. Water quality data was extracted from WaterNSW's database for this Audit. A total of 12 water quality analytes (**Table 3**) were examined, consistent with previous audits.

Guidelines used in this audit are based on ANZECC (2000) Ecosystem Water Quality guidelines, using a similar approach to previous audits. The auditors determined guidelines considered to be appropriate if ANZECC guidelines were not available. Guidelines relevant to each analyte are identified in **Table 3**.

It is important to note that the criteria applied to this analysis refer to the quality of untreated or 'raw' water in 'natural' environments using generalised guidelines for healthy freshwater aquatic ecosystems, specifically for lowland rivers and freshwater lakes and reservoirs across south-east Australia. Use of ecosystem water quality guidelines are designed to trigger further investigation and the development of site-specific guidelines. Raw water from the Catchment is subject to treatment prior to its supply to drinking water customers. Annual Water Quality Monitoring reports (WaterNSW 2016) provide details of WaterNSW's management of water quality.

While the main focus of this water quality assessment was the current audit period (July 2013 to June 2016), historic data was also included to assess trends over time. Statistical analysis of water quality data was assessed over the audit period and the median values for each water quality indicator were compared to the relevant guideline for freshwater rivers or lake storages. Median values represent the midpoint of all values collected for each indicator at that site over the audit period. If the median value at a site was higher than the guideline, then it was considered that that site was non-compliant for that guideline more often than it was not.

The statistical analysis also calculated the interquartile range for each water quality variable for each sampling site. The interquartile ranges provide information about the distribution of results for each site over the audit period. The interquartile range is sometimes called the 'midspread' or middle 50% of the data between the $25^{th}$ and $75^{th}$ percentile. Half of the interquartile range was added and subtracted to the median value to investigate how frequently guidelines values were exceeded during the three year audit period.

The statistical analysis also accounted for variablility in water quality monitoring conditions by use of a linear regression model fitted with explanatory variables to take these conditions into account. These included using time, harmonics (for seasonal influences), day-of-the-week and depth.

Refer to **Volume 3** for further details of the statistical analysis including the number of observations upon which the median and interquartile values have been calculated.

**Water quality in storages**

**Table 4** summarises the results of water quality monitoring at each storage in the Catchment. Non-compliances are highlighted as having a **poor** level of compliance or **very poor** level of compliance (as explained in the 'Definition and context' section above). Other results in the table have a **good** level of compliance with guidelines. Storages that were found to have the overall best and worst water quality during the audit period based on multiple analytes are discussed below. Locations of monitoring sites are mapped in **Figures 1** to **5**.

***Storages with best water quality over the audit period***

- Lake Avon (Upper Nepean) has two sampling sites (DAV1 and DAV2), with only low pH results in the poor category. Both sites recorded a median pH of 6.7 over the review period.
- Lower Cascade (Blue Mountains) has the equal best water quality over the review period - Lower Cascade has one sampling site (DLC1), with only low dissolved oxygen in the very poor category. The site recorded a median dissolved oxygen of 87.2 % over the review period.
- Lake Cordeaux (Upper Nepean) has the third best water quality over the review period - Lower Cordeaux has one sampling site (DCO1), with only low dissolved oxygen (median 99%) and high aluminium (median 0.04 mg/L) in the very poor categories.
- Top Cascade (Blue Mountains) has the fourth best water quality over the review period - Top Cascade has one sampling site (DCO1) with low dissolved oxygen (median 84.9%) and high chlorophyll-a (median 3.8 ug/L) in the poor or very poor categories.
- Lake Woronora (Woronora) has the fifth best water quality over the review period - Lake Woronora has one sampling site (DCO1) with low pH (median 6.6), high ammonia (median 0.01 mg/L) and high aluminium (median 0.12 mg/L) in the poor or very poor categories.

***Storages with the worst water quality over the audit period***

*Lake Yarrunga*

Lake Yarrunga (Shoalhaven River) demonstrated the poorest water quality for a storage in this Audit. It has three sampling sites, all of which demonstrated problematic water quality in the current review period. At the site DTA1 on Lake Yarrunga, the majority (9 of 12) of water quality analytes were rated poor or very poor for the audit period. This included high chlorophyll-a (median 3.9 µg/L); low dissolved oxygen (median 86.3 %); high turbidity (median 4.2 NTU); high ammonia (median 0.0155 mg/L); high oxidised nitrogen (median 0.07 mg/L); high total nitrogen (median 0.37); high soluble reactive phosphorus (median 0.005 mg/L); high total phosphorus (median 0.02 mg/L); and high aluminium (median 0.19 mg/L). Four of the analytes rated poor, or very poor, have worsening 20 year trends (chlorophyll-a, total phosphorus, total nitrogen and aluminium) with dissolved oxygen having a worsening 20-year trend. Two of the indicators (turbidity and ammonia) rated poor or very poor, and have worsening 3 year trends.

At the site DTA5 on Lake Yarrunga, the majority (8 of 12) of water quality analytes were rated poor or very poor for the audit period. This included high chlorophyll-a (median 3.5 µg/L); low dissolved oxygen (median 89.5 %); high turbidity (median 5.4 NTU); high ammonia (median 0.025 mg/L); high total nitrogen (median 0.34); high soluble reactive phosphorus (median 0.004); high total phosphorus (median 0.023 mg/L); and high aluminium (median 0.19 mg/L). Four of the indicators rated poor or very poor, and have worsening 20 year trends (turbidity, soluble reactive phosphorus, total phosphorus and aluminium), with dissolved oxygen also having a worsening 20-year trend.

At the site DTA8 on Lake Yarrunga, the majority (9 of 12) of water quality indicators were rated poor or very poor for the audit period. This included high chlorophyll-a (median 7.6 µg/L); low dissolved oxygen (median 92 %); high turbidity (median 5.3 NTU); high ammonia (median 0.0175 mg/L); high total nitrogen (median 0.31); high soluble reactive phosphorus (median 0.004); high total phosphorus (median 0.0275 mg/L); and high aluminium (median 0.14 mg/L). Five of the indicators rated poor or very poor, and have worsening 20 year trends (turbidity, oxidised nitrogen, total phosphorus, aluminium and dissolved oxygen). Three indicators rated poor or very poor, had worsening 3 year trends (turbidity, ammonia and total nitrogen).

*Lake Nepean*

Lake Nepean also had problematic water quality over the review period. At the site DNE1 on Lake Nepean, the majority (7 of 12) of water quality indicators were rated poor or very poor for the audit period. This included low dissolved oxygen (median 92.3 %); high turbidity (median 12.6 NTU); high ammonia (median 0.0225 mg/L); high oxidised nitrogen (median 0.20 mg/L); high total nitrogen (median 0.41 mg/L); high total phosphorus (median 0.018 mg/L) and high aluminium (median 0.57 mg/L). Five of the analytes rated poor or very poor have worsening 20 year trends (turbidity, total phosphorus, total nitrogen, aluminium and dissolved oxygen). Four of the indicators rated poor or very poor, have worsening 3 year trends (turbidity, ammonia, total phosphorus and aluminium).

At this second site, DNE2, on Lake Nepean, 6 of 12 of water quality indicators were rated poor or very poor for the audit period. This included low pH (median 6.7); high ammonia (median 0.016 mg/L); high oxidised nitrogen (median 0.18 mg/L); high total nitrogen (median 0.36 mg/L); high total phosphorus (median 0.012 mg/L) and high aluminium (median 0.14 mg/L).

Five of the indicators rated poor or very poor had worsening 20 year trends (oxidised nitrogen, total nitrogen, total phosphorus and aluminium). Ammonia had a worsening 3 year trend.

*Wingecarribee Dam*

The Wingecarribee Dam storage reservoir has only one site 'DWI1'. 6 of 12 water quality indicators were rated poor or very poor for the audit period. This included high chlorophyll-a (median 12.5); high turbidity (median 10.9 NTU); high ammonia (median 0.01 mg/L); high total nitrogen (median 0.36 mg/L); high total phosphorus (median 0.021 mg/L) and high aluminium (median 0.24 mg/L). Four of the indicators rated poor or very poor had worsening 20 year trends (chlorophyll-a, turbidity, total phosphorus and aluminium). Four indicators rated poor or very poor had worsening 3 year trends (turbidity, total nitrogen, ammonia and aluminium).

*Lake Burragorang*

The Lake Burragorang storage (Warragamba Dam) has nine sampling sites with many sites commonly recording poor or very poor results over the audit period for the following four water quality analytes.

- All Lake Burragorang sites had high EC (median from 0.184 to 0.204 mg/L) and the EC trend was worsening over 3 years and 20 years at all sites.
- 8 of 9 Lake Burragorang sites had high total nitrogen (median from 0.32 to 0.40 mg/L) and for 7 sites the total nitrogen trend was worsening over 20 years.
- All sites had low dissolved oxygen (median 89.3 to 94.9 %) and the dissolved oxygen trend was worsening over 20 years.
- 4 sites had high chlorophyll-a (median 4.5 to 6.6 ug/L) with the trend worsening over 20 years at DWA39, stable at two sites (DWA19 and DWA21) and improving at one site (DWA15).

Sampling sites on Lake Burragorang also recorded some poor or very poor results for pH, aluminium, oxidised nitrogen and total phosphorus.

**Stream water quality**

**Table 5** summarises the results of water quality monitoring by WaterNSW for each stream or river. Non-compliances are highlighted as **poor** or **very poor**. Other results in the table have a **good** level of compliance with guidelines.

***Streams with the best water quality over the audit period***

- E610 (Goondarin Creek: Upper Nepean catchment) had the equal best water quality over the review period with only high aluminium in the poor category (median = 0.125 mg/L).
- E680 (Cordeaux River: Upper Nepean catchment) has the equal best water quality over the review period with only high total phosphorus (median 0.017) in the poor category. This displayed a worsening 20 year trend.

- E243 Little River (Warragamba catchment) had the equal second best water quality over the review period, with only low dissolved oxygen (median 93.8 %) and high aluminium (median 0.055 mg/L) in the very poor categories. Dissolved oxygen had a worsening 3 year trend and an improving 20 year trend. Aluminium also had a worsening 20 year trend.
- E602 Burke River (Upper Nepean catchment) had the equal second best water quality over the review period, with low pH (median 6.45) and high aluminium (median 0.055 mg/L) in the poor categories. pH and aluminium had a worsening 20 year trend.
- E604 Flying Fox (Upper Nepean catchment) has the equal second best water quality over the review period with only high total nitrogen (median 0.33 mg/L) and high total phosphorus (median 0.015 mg/L) in the poor categories. Total nitrogen had an improving 20 year trend and total phosphorus had a worsening 20 year trend.
- E551 Tonalli River (Warragamba catchment) has the equal second best water quality over the review period with only high EC (median 0.562 mS/cm) and low dissolved oxygen (median 60.85 %) in the poor categories, with dissolved oxygen showing a worsening 20 year trend.

***Streams with the worst water quality over the audit period***
*E203 (Gibbergunyah Creek: Warragamba catchment) had the most problematic water quality*

At the site E203 (Gibbergunyah Creek), the majority (10 of 12) of water quality analytes were rated poor or very poor for the audit period. These included high pH (median 7.56); high chlorophyll-a (median 2.8 µg/L); high EC (median 0.276 mS/cm), high turbidity (median 4.23 NTU); high ammonia (median 0.018 mg/L); high oxidised nitrogen (median 0.526 mg/L); high total nitrogen (median 0.99 mg/L); high soluble reactive phosphorus (median 0.011 mg/L); high total phosphorus (median 0.0815 mg/L); and high aluminium (median 0.49 mg/L). Most analytes had worsening trends over 20 and/or 3 years.

The auditors note that this site is located downstream of Mittagong STP for the purpose of monitoring the effectiveness of the plant.

*E891 (Gillamatong Creek: Shoalhaven catchment) had the equal second most problematic water quality*

The site E891 (Gillamatong Creek) had the equal second most number of indicators (8 of 12) rated poor or very poor for the audit period. This included high chlorophyll (median 12.15); high iron (median 3.04 mg/L); high EC (median 0.4635 mS/cm); high turbidity (median 5.05 NTU); low dissolved oxygen (median 88.4 %), high total nitrogen (median 0.90 mg/L) and high total phosphorus (median 0.126 mg/L.

Five water quality analytes that rated poor or very poor at this site displayed worsening trends. They were chlorophyll-a (3 years and 20 years), EC (20 years); iron (20 years) and total phosphorus (3 years and 20 years). Of the other problematic indicators, only one had an improving trend (turbidity 20 years).

*E332 (Wingecarribee River at Berrima: Warragamba catchment) had the equal second most problematic water quality*

The site E332 (Wingecarribee River at Berrima) has the equal second largest number of indicators (8 of 12) rated poor or very poor for the audit period. This included high chlorophyll-a (median 17.9 µg/L); low dissolved oxygen (median 78.25 %), high turbidity (median 11.6 NTU); high ammonia (median 0.044 mg/L); high oxidised nitrogen (median 0.115 mg/L); high total nitrogen (median 0.88 mg/L); high total phosphorus (median 0.0755 mg/L); high aluminium (median 0.308 mg/L).

Only one water quality indicator that rated poor, or very poor, had an increasing trend. This was aluminium with a worsening 20-year trend. Of the other 7 problematic indicators, three had improving trends over 20 years (turbidity and oxidised nitrogen) or were improving over 3 years (ammonia).

*E409 (Wollondilly River at Murrays: Warragamba catchment) had the equal third most problematic water quality*

The site E409 (Wingecarribee River at Berrima) has the third most indicators (8 of 12) rated poor or very poor for the audit period. These included high pH (median 7.7), high chlorophyll-a (median 9.15 µg/L); high EC (median 0.789 mS/cm) low dissolved oxygen (median 80.8 %), high total nitrogen (median 0.78 mg/L); high soluble reactive phosphorus (median 0.0115 mg/L); high total phosphorus (median 0.084 mg/L); and high aluminium (median 0.065 mg/L).

Aluminium and EC displayed a 20-year worsening trend. Dissolved oxygen had a worsening 3-year trend. Of the other problematic indicators, three had improving trends over 20 years (total nitrogen, soluble reactive phosphorus and total phosphorus). pH at this site had an improving trend detected over 3 and 20 years.

*E609 (Cataract River: Upper Nepean catchment) had the equal third most problematic water quality over the review period*

The site E609 (Cordeaux River) had the equal third most number of indicators (7 of 12) rated poor or very poor for the audit period. This included low pH (median 6.2); high turbidity (median 4.7 NTU); low dissolved oxygen (median 90.9 %), high total nitrogen (median 0.235 mg/L); high total phosphorus (median 0.022 mg/L); high ammonia (median 0.012 mg/L) and high aluminium (median 0.06 mg/L).

Three water quality indicators that rated poor or very poor had a worsening 20 year trend. They were total phosphorus, aluminium and pH. Of the other problematic indicators, three had improving trends over 20 years (total nitrogen, ammonia and dissolved oxygen).

*E890 (Boro Creek at Marlo: Shoalhaven catchment) had the fourth most problematic water quality*

The site E890 (Boro Creek at Marlo) had the equal third most numerous number of indicators (7 of 12) rated poor or very poor for the audit period. This included high chlorophyll (median 4.1); low pH (median 6.3); high turbidity (median 7.9 NTU); low dissolved oxygen (median 66.5 %), high total nitrogen (median 0.30 mg/L); high total phosphorus (median 0.033 mg/L); and high aluminium (median 0.1825 mg/L).

Chlorophyll-a, aluminium and total phosphorus had worsening 20 year trends. Of the other problematic indicators (turbidity had an improving 20 year trend).

**Conclusion**

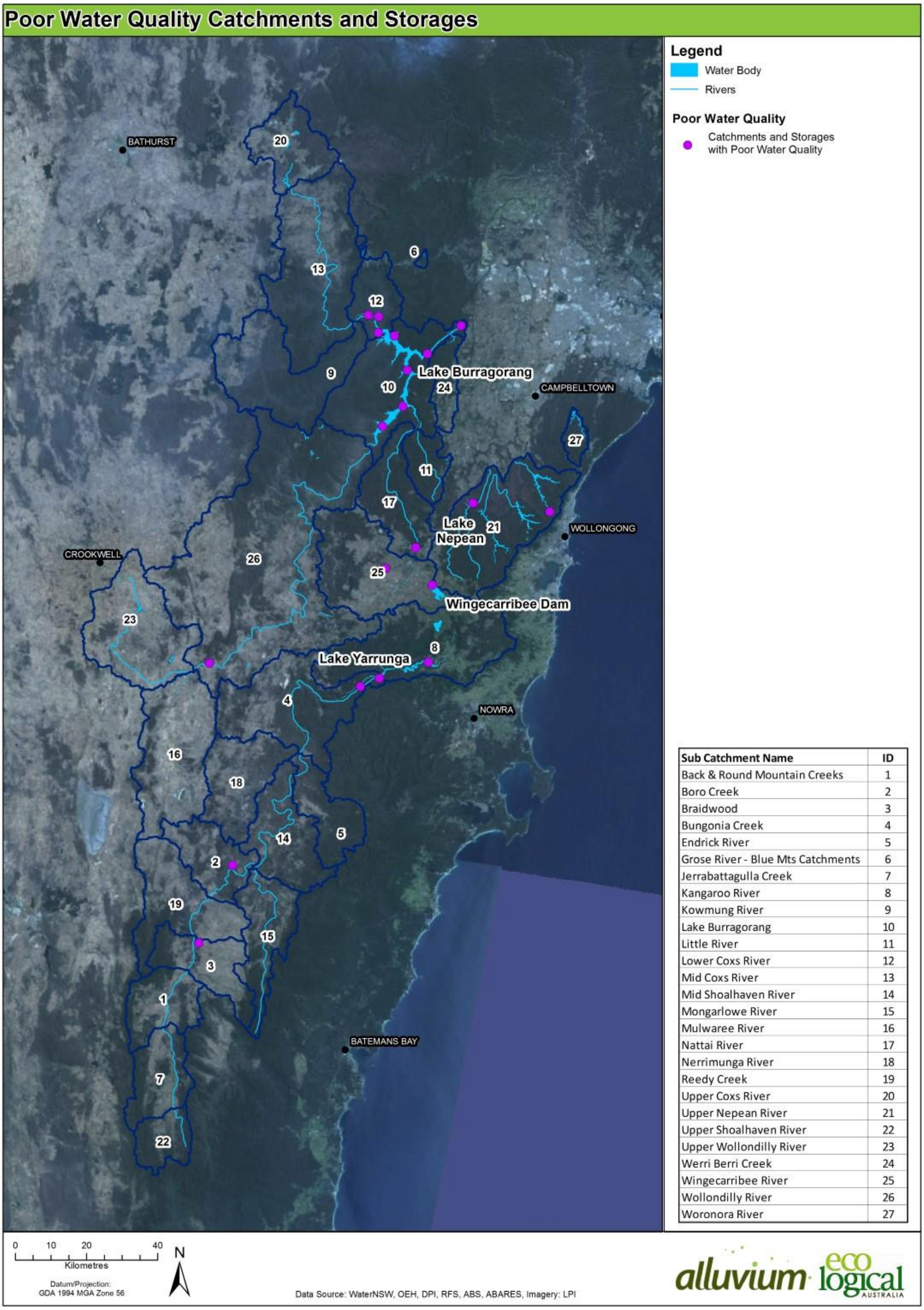
The majority of sites that were monitored by WaterNSW had good levels of compliance with water quality guidelines for ecosystem health. Storages and streams that were found to have the poorest water quality during the audit period are mapped in **Figure 6** and include:

- Lower Coxs River and Lake Burragorang
- Wingecarribee River flowing to Wingecarribee Dam
- Kangaroo River and Bungonia Creek flowing to Lake Yarrunga
- Upper Nepean River flowing to Lake Nepean

The audit revealed higher levels of salinity (measured as electrical conductivity) in Lake Burragorang. There is no directly relevant storage guideline readily available in ANZECC (2000) as the default value is based on Tasmanian lakes, and this was assessed by the auditors to be unrealistically low to apply to the Sydney Catchment. However, in terms of relativity, salinity of Lake Burragorang was higher than any other storages; nearly twice as high as the other WaterNSW storages in the Catchment with a long term rising trend. The auditors recommend that the sources and implications of the increased salinity levels in Lake Burragorang be investigated.

The water quality guidelines used in this audit were mainly from default values for south-eastern Australia in ANZECC (2000) guidelines. The auditors recommend that WaterNSW determines feasibility and benefits of developing their own locality-specific guidelines for the streams and storages, rather than using default values for south-eastern Australia. In order to develop specific guidelines, WaterNSW should establish suitable ‘reference sites’ which are in naturally vegetated sub-catchments in areas free of disturbance from human activity.

Future audits would be also enhanced by the inclusion of flow as a variable in water quality statistical analyses at least for major inflow sites.




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 6. Storages and streams with poor ecosystem water quality results 2013-16 (WaterNSW)**

**Table 3. Water quality guidelines for storages and catchments**

| Water Quality Variable | Storages | | Catchments | |
|---|---|---|---|---|
| | Guideline* | Justification | Guideline* | Justification |
| Chlorophyl--*a* | 5.0 µg/L | In ANZECC guidelines for south-eastern Australia lakes and reservoirs | 5.0 µg/L | In ANZECC guidelines for lowland rivers. ANZECC does not provide any guideline for upland rivers |
| pH | 6.5 – 8.0 pH units | In ANZECC guidelines for south-eastern Australia lakes and reservoirs | 6.5 – 7.5 pH units | Guideline range was given in ANZECC for upland rivers |
| Electrical Conductivity | 0.15 mS/cm | Selected by the auditor. The guideline value in ANZECC (2000) guideline for south-eastern Australia lakes and reservoirs was 0.02-0.03 mS/cm, from Tasmanian lakes, and was not considered to be realistic or representative for freshwater lakes of the Sydney region. | 0.35 mS/cm | Given as the maximum default value in ANZECC for upland rivers |
| Dissolved Oxygen | 90 - 110% Saturation | In ANZECC guidelines for south-eastern Australia lakes and reservoirs | 90 - 110% Saturation | In ANZECC guidelines for upland rivers |
| Turbidity | 5.0 NTU | Selected from lower end of range (1-20 NTU) given in the ANZECC guidelines for freshwater lakes and reservoirs | 5.0 NTU | Selected from lower end of ANZECC upland stream range 2 to 25 NTU |
| Ammonium-Nitrogen | 0.01 mg/L | In ANZECC guidelines for south-eastern Australia lakes and reservoirs | 0.013 mg/L | In ANZECC guidelines for upland streams |
| Oxidised Nitrogen (NOx) | 0.01 mg/L | In ANZECC guidelines for south-eastern Australia lakes and reservoirs | 0.015 mg/L | In ANZECC guidelines for upland streams |
| Total Nitrogen | 0.35 mg/L | In ANZECC guidelines for south-eastern Australia lakes and reservoirs | 0.250 mg/L | In ANZECC guidelines for upland streams |
| Soluble Reactive Phospohrus (SRP) | 0.005 mg/L | In ANZECC guidelines for south-eastern Australia lakes and reservoirs | 0.015 mg/L | In ANZECC guidelines for upland streams |
| Total Phosphorus | 0.01 mg/L | In ANZECC guidelines for south-eastern Australia lakes and reservoirs | 0.050 mg/L | In ANZECC guidelines for upland streams |
| Total Aluminium | 0.055 (if pH>6.5) mg/L | In ANZECC for protection of 95% of freshwater species. | 0.055 (if pH>6.5) mg/L | In ANZECC for protection of 95% of freshwater species |
| Total Iron | 3.5 mg/L | Based on water quality delivery to water filtrations plants | 3.5 mg/L | Based on water quality delivery to water filtrations plants |

*Units applied in this table (e.g. mg/L) are consistent with those used in the data provided by WaterNSW and with those used in previous audits

**Table 4. Summary of water quality non-compliances for storage reservoirs 2013-16 (median values) (WaterNSW)**

| Subcatchment | Ref | Storage | Chl-a | pH | EC | DO | Tur | Amm-N | NOx | TN | FRP | TP | Al | Iron |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Warragamba | DWA12 | Warragamba | 2.9 | 7.77 | 0.186 | 93.5 | 0.99 | 0.0025 | 0.09 | 0.37 | 0.002 | 0.006 | 0.02 | 0.05 |
| Warragamba | DWA15 | Warragamba | 4.5 | 7.91 | 0.184 | 94.9 | 1.06 | 0.0025 | 0.05 | 0.35 | 0.002 | 0.007 | 0.025 | 0.08 |
| Warragamba | DWA19 | Warragamba | 6.6 | 7.71 | 0.178 | 89.3 | 1.86 | 0.0025 | 0.01 | 0.32 | 0.00075 | 0.0095 | 0.03 | 0.14 |
| Warragamba | DWA2 | Warragamba | 3.4 | 7.66 | 0.186 | 91.6 | 0.78 | 0.0025 | 0.11 | 0.40 | 0.002 | 0.006 | 0.03 | 0.05 |
| Warragamba | DWA21 | Warragamba | 5.8 | 7.74 | 0.180 | 91.6 | 1.43 | 0.0025 | 0.01 | 0.32 | 0.001 | 0.009 | 0.03 | 0.1 |
| Warragamba | DWA27 | Warragamba | 2.9 | 7.73 | 0.191 | 92 | 1.04 | 0.0025 | 0.09 | 0.37 | 0.001 | 0.006 | 0.03 | 0.06 |
| Warragamba | DWA311 | Warragamba | 4 | 7.66 | 0.197 | 90.2 | 1.67 | 0.0025 | 0.05 | 0.38 | 0.002 | 0.006 | 0.04 | 0.08 |
| Warragamba | DWA39 | Warragamba | 6.2 | 7.67 | 0.204 | 90.5 | 2.90 | 0.0025 | 0.03 | 0.39 | 0.002 | 0.0105 | 0.055 | 0.16 |
| Warragamba | DWA9 | Warragamba | 3 | 7.69 | 0.187 | 91 | 0.81 | 0.0025 | 0.11 | 0.38 | 0.002 | 0.006 | 0.03 | 0.05 |
| Warragamba | DWI1 | Wingecarribee | 12.5 | 7.20 | 0.072 | 96.1 | 10.90 | 0.01 | 0.03 | 0.33 | 0.001 | 0.021 | 0.27 | 0.55 |
| Upper Nepean | DAV1 | Avon | 1.85 | 6.70 | 0.070 | 101 | 0.50 | 0.0025 | 0.01 | 0.15 | 0.001 | 0.0025 | 0.02 | 0.05 |
| Upper Nepean | DAV7 | Avon | 3.8 | 6.70 | 0.070 | 99.2 | 1.00 | 0.0025 | 0.00 | 0.16 | 0.001 | 0.005 | 0.03 | 0.12 |
| Upper Nepean | DCA1 | Cataract | 2.4 | 6.40 | 0.076 | 100 | 0.60 | 0.0055 | 0.01 | 0.16 | 0.0005 | 0.0025 | 0.08 | 0.23 |
| Upper Nepean | DCO1 | Cordeaux | 3.8 | 7.00 | 0.086 | 99 | 1.70 | 0.0025 | 0.00 | 0.22 | 0.002 | 0.007 | 0.04 | 0.18 |
| Upper Nepean | DNE1 | Nepean | 1.4 | 6.70 | 0.068 | 92.3 | 12.60 | 0.0225 | 0.20 | 0.41 | 0.002 | 0.018 | 0.57 | 0.58 |
| Upper Nepean | DNE2 | Nepean | 2.1 | 6.70 | 0.079 | 98.9 | 2.10 | 0.016 | 0.18 | 0.36 | 0.002 | 0.012 | 0.14 | 0.42 |
| Upper Nepean | DWO1 | Woronora | 1.3 | 6.60 | 0.106 | 98.8 | 1.50 | 0.01 | 0.07 | 0.20 | 0.002 | 0.0025 | 0.12 | 0.245 |
| Blue Mountains | DGC1 | Greaves Ck | 2.5 | 5.73 | 0.028 | 84.8 | 1.58 | 0.0155 | 0.03 | 0.16 | 0.003 | 0.009 | 0.18 | 0.565 |
| Blue Mountains | DLC1 | Lower Cascade | 2.3 | 7.41 | 0.087 | 87.2 | 0.74 | 0.0025 | 0.06 | 0.20 | 0.002 | 0.005 | 0.02 | 0.16 |
| Blue Mountains | DTC1 | Top Cascade | 3.8 | 7.26 | 0.071 | 84.9 | 0.50 | 0.0025 | 0.03 | 0.25 | 0.002 | 0.006 | 0.03 | 0.085 |
| Shoalhaven | DBP1 | Kangaroo Valley | 11.5 | 6.90 | 0.093 | 94 | 5.70 | 0.013 | 0.03 | 0.33 | 0.003 | 0.023 | 0.17 | 0.57 |
| Shoalhaven | DFF6 | Fitzroy Falls | 9.8 | 7.30 | 0.073 | 98 | 5.30 | 0.0025 | 0.00 | 0.33 | 0.001 | 0.015 | 0.17 | 0.26 |
| Shoalhaven | DTA1 | Yarrunga | 3.9 | 6.90 | 0.102 | 86.3 | 4.20 | 0.0155 | 0.07 | 0.37 | 0.005 | 0.02 | 0.19 | 0.61 |
| Shoalhaven | DTA5 | Yarrunga | 3.5 | 7.00 | 0.104 | 89.5 | 5.40 | 0.025 | 0.04 | 0.34 | 0.004 | 0.023 | 0.19 | 0.62 |
| Shoalhaven | DTA8 | Yarrunga | 7.6 | 6.80 | 0.103 | 92 | 5.30 | 0.0175 | 0.05 | 0.31 | 0.004 | 0.0275 | 0.14 | 0.62 |
| Prospect | RPR1 | Prospect | 3.7 | 7.70 | 0.192 | 98.2 | 1.20 | 0.0025 | 0.02 | 0.24 | 0.002 | 0.006 | 0.04 | 0.06 |
| Prospect | RPR6 | Prospect | 4.3 | 7.70 | 0.190 | 98.2 | 1.70 | 0.0025 | 0.02 | 0.26 | 0.001 | 0.0025 | 0.07 | 0.09 |

**Table 5. Summary of water quality non-compliances for streams 2013-16 (median values) (WaterNSW)**

| Subcatchment | Ref | Stream | Chl-a | pH | EC | DO | Tur | Amm-N | NOx | TN | FRP | TP | Al | Iron |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Warragamba | E083 | Coxs R Kelpie Point | 2.75 | 7.84 | 0.239 | 96.5 | 2.96 | 0.0025 | 0.006 | 0.235 | 0.005 | 0.235 | 0.085 | 0.21 |
| Warragamba | E130 | Kowmung River | 0.8 | 7.52 | 0.087 | 97.6 | 1.69 | 0.0025 | 0.0205 | 0.225 | 0.004 | 0.225 | 0.023 | 0.17 |
| Warragamba | E157 | Kedumba R Maxwells | 0.9 | 7.19 | 0.074 | 91.1 | 2.25 | 0.0025 | 0.1975 | 0.355 | 0.003 | 0.355 | 0.046 | 0.66 |
| Warragamba | E203 | Gibbergunyah Ck | 2.8 | 7.56 | 0.276 | 93 | 4.23 | 0.018 | 0.5265 | 0.99 | 0.011 | 0.99 | 0.49 | 0.54 |
| Warragamba | E206 | Nattai R @ Crags | 2.75 | 7.69 | 0.299 | 98 | 2.60 | 0.0025 | 0.5015 | 0.89 | 0.0085 | 0.89 | 0.076 | 0.9 |
| Warragamba | E210 | Nattai R @ Smallwoods | 2.5 | 7.34 | 0.269 | 90.6 | 3.60 | 0.008 | 0.0705 | 0.285 | 0.002 | 0.285 | 0.142 | 0.71 |
| Warragamba | E243 | Little River | 0.4 | 6.86 | 0.12 | 93.8 | 0.80 | 0.0025 | 0.0055 | 0.06 | 0.003 | 0.06 | 0.055 | 0.31 |
| Warragamba | E332 | Wingecarribee R Berrima | 17.9 | 7.255 | 0.2185 | 78.25 | 11.60 | 0.044 | 0.115 | 0.88 | 0.004 | 0.88 | 0.308 | 0.94 |
| Warragamba | E409 | Wollondilly @ Murrays | 9.15 | 7.705 | 0.789 | 80.8 | 2.25 | 0.0025 | 0.0045 | 0.78 | 0.0115 | 0.78 | 0.065 | 0.62 |
| Warragamba | E450 | Wollondilly @ Golden Valley | 2.8 | 7.685 | 0.423 | 88.7 | 1.90 | 0.0025 | 0.019 | 0.66 | 0.003 | 0.66 | 0.03 | 1.385 |
| Warragamba | E488 | Wollondilly @ Jooriland | 3.1 | 7.99 | 0.355 | 103 | 3.03 | 0.0025 | 0.007 | 0.63 | 0.002 | 0.63 | 0.2 | 0.76 |
| Warragamba | E531 | Werri Berri Ck @ Werombi | 1.8 | 7.025 | 0.3445 | 72.5 | 3.91 | 0.009 | 0.0345 | 0.28 | 0.003 | 0.28 | 0.2 | 1.17 |
| Warragamba | E551 | Tonalli River | 1 | 6.875 | 0.562 | 60.85 | 0.67 | 0.0025 | 0.006 | 0.135 | 0.0035 | 0.135 | 0.0075 | 0.195 |
| Upper Nepean | E6006 | Sandy Creek | 0.2 | 5.7 | 0.087 | 93.7 | Insufficient data | 0.0025 | 0.001 | 0.105 | 0.002 | 0.105 | 0.07 | 0.625 |
| Upper Nepean | E602 | Burke R (Nepean inflow) | 0.4 | 6.45 | 0.075 | 104 | 2.30 | 0.0025 | 0.003 | 0.11 | 0.002 | 0.11 | 0.055 | 0.9 |
| Upper Nepean | E604 | Flying Fox (Avon) | 0.3 | 6.8 | 0.14 | 98.8 | 0.50 | 0.0025 | 0.093 | 0.33 | 0.003 | 0.33 | 0.035 | 0.42 |
| Upper Nepean | E608 | Avon River | 0.3 | 7 | 0.142 | 96.85 | Insufficient data | 0.0025 | 0.081 | 0.2 | 0.004 | 0.2 | 0.05 | 0.4 |
| Upper Nepean | E609 | Cordeaux River | 0.5 | 6.2 | 0.112 | 90.9 | 4.70 | 0.012 | 0.0305 | 0.235 | 0.003 | 0.235 | 0.06 | 1.06 |
| Upper Nepean | E610 | Goondarin Creek | 0.3 | 6.9 | 0.1 | 96.4 | 1.80 | 0.0025 | 0.002 | 0.08 | 0.003 | 0.08 | 0.125 | 0.32 |
| Upper Nepean | E680 | Cataract River | 2.1 | 6.9 | 0.0965 | 100.35 | 2.30 | 0.006 | 0.019 | 0.16 | 0.003 | 0.16 | 0.02 | 0.75 |
| Upper Nepean | E6131 | Waratah River | 0.3 | 7.1 | 0.2005 | 92.8 | 4.40 | 0.0025 | 0.002 | 0.245 | 0.003 | 0.245 | 0.5 | 0.91 |
| Upper Nepean | E677 | Woronora River | 0.7 | 5.8 | 0.174 | 86.7 | 1.70 | 0.0025 | 0.001 | 0.12 | 0.002 | 0.12 | 0.145 | 0.67 |
| Shoalhaven | E706 | Kangaroo River @ Hampdon | 2.2 | 7.035 | 0.115 | 104.1 | 4.40 | 0.0175 | 0.109 | 0.45 | 0.009 | 0.45 | 0.35 | 0.89 |
| Shoalhaven | E822 | Mongarlow River | 0.8 | 7 | 0.056 | 94.5 | 1.90 | 0.0025 | 0.01 | 0.355 | 0.005 | 0.355 | 0.0815 | 0.62 |
| Shoalhaven | E847 | Shoalhaven R @ Fossickers | 1.7 | 7.4 | 0.11 | 104.4 | 3.50 | 0.0025 | 0.009 | 0.47 | 0.006 | 0.47 | 0.263 | 1.89 |
| Shoalhaven | E860 | Shoalhaven R @ Mount View | 1.5 | 7.5 | 0.082 | 101.3 | 3.40 | 0.0025 | 0.003 | 0.64 | 0.007 | 0.64 | 0.14 | 1.15 |
| Shoalhaven | E861 | Shoalhaven R @ Hillview | 3 | 7.5 | 0.1055 | 101.85 | 3.60 | 0.0025 | 0.001 | 0.47 | 0.005 | 0.47 | 0.183 | 0.92 |
| Shoalhaven | E890 | Boro Creek @ Marlow | 4.1 | 6.3 | 0.113 | 66.5 | 7.90 | 0.0025 | 0.002 | 0.3 | 0.006 | 0.3 | 0.1825 | 1.43 |
| Shoalhaven | E891 | Gillamatong Creek | 12.15 | 7.35 | 0.4635 | 88.4 | 5.05 | 0.0025 | 0.003 | 0.9 | 0.0135 | 0.9 | 0.005 | 3.04 |

## 2.2 Nutrient loads

**Definition and context**

Excessive plant nutrients in streams and storages are key pollutants in the Catchment. They can comprise different forms of nitrogen and phosphorus, and elevated levels of both are associated with degradation of water quality due to their influence on growth and development of phytoplankton algae. As discussed in **Section 2.3**, cyanobacteria (blue-green algae) is a chronic long-term problem in many streams and storages, and its presence and abundance are linked to elevated concentrations of nitrogen and phosphorus.

Nutrients in waters, particularly impounded waters of lakes and reservoirs, can accumulate over time in the water column and sediment. A lake or reservoir with high nutrient levels, which is often linked to higher levels of plant and algae growth, is termed 'eutrophic'. At the other end of the scale, lakes with very low levels of nutrients, and plant and algae growth, are classed as 'oligotrophic'. A major objective of water management is to promote low nutrient levels and maintain 'oligotrophic' lakes and reservoirs.

The source and magnitude (load) of nutrients in waterbodies is strongly influenced by human activities in that catchment, in combination with natural factors such as geology and soils. There are two broad classes of human activities that tend to generate pollutants (such as nutrients) from catchment land use activities and these are 'point sources' and 'diffuse sources'. 'Point-sources' are waste discharges, including large facilities such as from sewage treatment plants (STPs) that are regulated by the EPA under the *Protection of the Environment Operations Act 1997*. 'Diffuse-sources' are from the full spectrum of human activities, such as agriculture, urban development, intensive agriculture, forestry, soil erosion etc.

The concentration of nutrients in water is one important form of measurement for these pollutants. The other form of measurement is 'loads'. These are calculated by combining the concentration of nutrients in water (generally as mg/L) with water volumes to enable comparison of nutrient levels over extended periods of time. Previous audits have measured and compared different aspects of loads of nutrients discharged to, or estimated, in waterways. The units of measurement are often in mass (kilograms or tonnes per year), but can also be expressed in area terms (e.g. as kg per $km^2$).

Increasing loads of nutrients entering streams and storages is considered to be a **worsening** trend, whereas decreasing loads represents an **improving** trend.

**Data and method**

Information for this catchment indicator (nutrient loads) was supplied to the auditors from WaterNSW based on their 'Pollution Source Assessment Tool' (PSAT) (refer to **Section 5.2** for further details about PSAT). The second source of information was from the EPA who provided annual nitrogen and phosphorus loads for STPs that discharge treated waste to the Catchment.

Major STPs that treat and dispose of sewage wastes to catchment waterways, or to areas of land adjacent to catchment waterways, are listed in **Table 2** and mapped in **Figures 1** to **5**. The STPs are managed by local councils and have justifiably attracted considerable attention by WaterNSW, the EPA and from previous audits. Unlike many other sources of catchment contamination, STP waste discharges are monitored in accordance with individual Environment Protection Licences (EPL) regulated by the EPA as they are a major source of nutrients, pathogens and other contaminants that potentially have many adverse implications for water quality in the Catchment.

Unlike many sources of contaminants in the Catchment, the volume and water quality of effluent discharged from STPs is closely monitored in accordance with their individual 'Environment Protection Licence' (EPL) that is regulated by the EPA. Each STP EPL specifies acceptable concentrations of pollutants and stipulates compliance monitoring that each STP is required to undertake, and report to the EPA. The EPA provided data to the auditors to calculate and compare annual nutrient loads for the STPs that discharge waste into catchment waterways. Annual nitrogen and phosphorus loads (in kg/year) for each major STP that discharges its effluent directly into catchment waterways are provided in the following sections.

**Phosphorus loads from STPs**

Annual phosphorus loads were available for the STPs that discharge effluent into the catchment waterways (**Figure 7**). Loads were not available for this audit for the two STPs (Robertson and Berrima in the Wingecarribee sub-catchment) that discharge their wastes to land rather than to waterways.

An improving trend was identified in the current audit period (2013-16) for the combined phosphorus loads discharged from the STPs (**Figure 8** and **Table 6**). A total of 25 tonnes of phosphorus was discharged from the STPs during the current audit period. This represented a 32% reduction in loads compared to the previous audit period, when 36 tonnes of phosphorus was discharged (**Figure 8**).

The largest reduction in phosphorus loads in the current audit period (compared to the previous 2010-13 audit period) for an individual STP was recorded at Wallerawang STP (a 94% decrease) and Lithgow STP (an 82% decrease) (**Table 6**). As noted in **Table 6**, since no phosphorus load data was provided for Wallerawang STP for 2007/8 the real reduction in phosphorus loads was even larger than this. Lithgow and Wallerawang STPs both discharge wastes to tributaries of the Coxs River with downstream waterways suffering major cyanobacteria blooms in Farmers Creek, Lake Wallace and Lake Lyell.

Large decreases in phosphorus loads were also recorded from Bundanoon STP (29 % decrease), Goulburn STP (16 % decrease) and Bowral STP (13 % decrease) for this audit period compared to the previous audit (**Table 6**). The exception was for Moss Vale STP which recorded a 139% increase in phosphorus loads (from 380 kg/year in 2010-13, to 910 kg/year in 2013-16) due to population growth in the area and limited capacity of the STP.

**Table 6. Total phosphorus loads (kg) from each STP**

| STP Name | 2007-10 | 2010-13 | 2013-16 |
|---|---|---|---|
| Moss Vale | 436 | 380 | 907 |
| Bowral | 693 | 1073 | 939 |
| Lithgow | 10076 | 7884 | 1387 |
| Wallerawang* | 2296 | 1781 | 101 |
| Goulburn | 22768 | 24535 | 20619 |
| Mittagong | 510 | 608 | 592 |
| Bundanoon | 270 | 109 | 78 |
| **Total** | **37048** | **36370** | **24622** |

*No phosphorus load data was available for Wallerawang STP for 2007/8
Data source: EPA

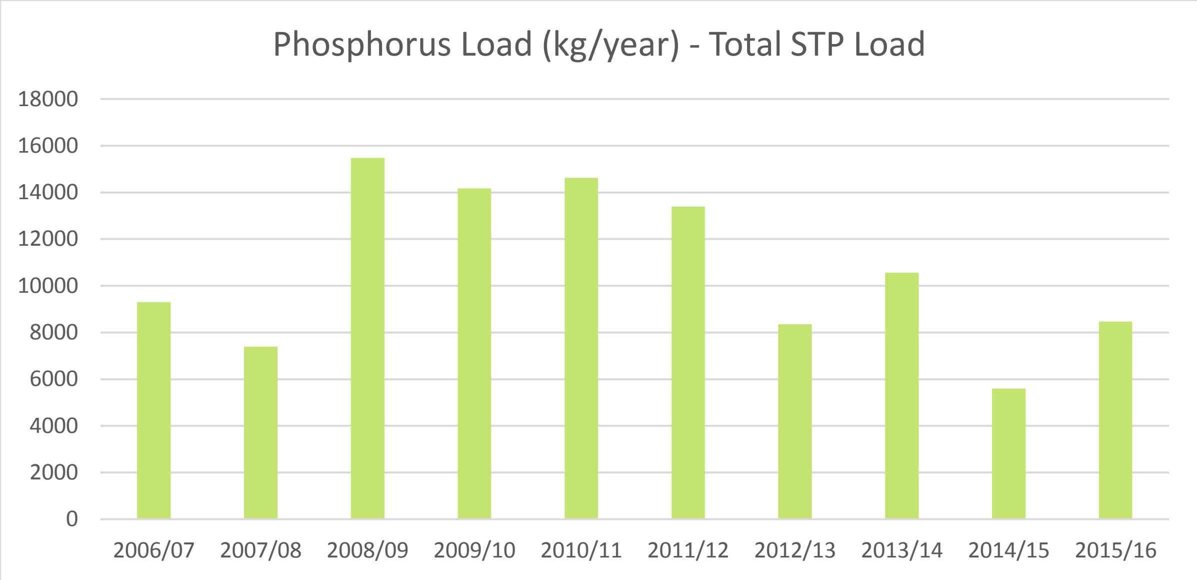



**Figure 7. Annual phosphorus loads from STPs 2006 - 2016 (EPA)**

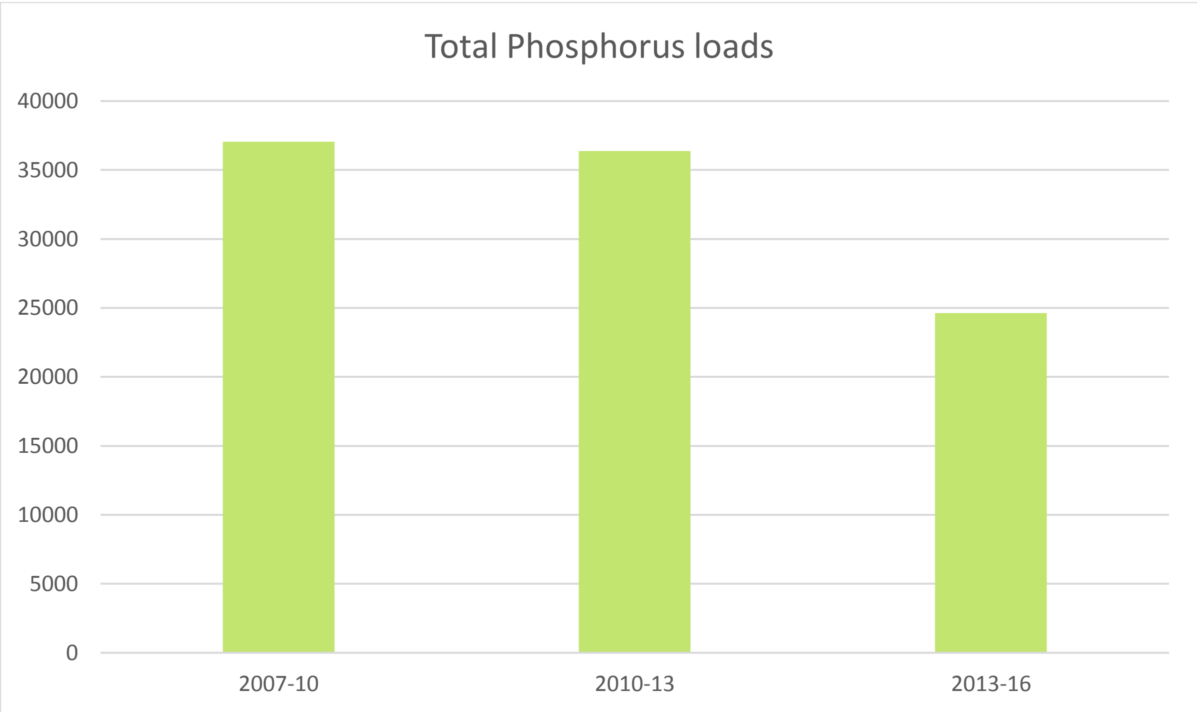



**Figure 8. Phosphorus loads (kg/3 year period) from STPs for recent audit periods (EPA)**

**Nitrogen loads from STPs**

Nitrogen loads from catchment STPs have demonstrated an improving trend over previous audit periods. In the current 2013-16 audit period a combined total of 181 tonnes of nitrogen was discharged from the major STPs into catchment waterways (**Figure 10** and **Figure 10**). This represents a 22% reduction in the combined nitrogen loads, compared to previous (2010-13) audit period when 234 tonnes of nitrogen was discharged. This reduction in nitrogen loads builds upon a modest reduction recorded from the 2007/10 to 2010/13 audit period. Over that time a decrease of (10%) in nitrogen loads from catchment STPs was recorded (259 tonnes compared to 234 tonnes).

About 30% less annual nitrogen load was discharged from the two STPs in the upper Coxs River catchment in this audit period compared to those from the previous audit period. The largest reductions were recorded in wastes discharged from Lithgow STP (**Table 7**). During the current audit period, it discharged a total of 27 tonnes of nitrogen, compared to 56 tonnes in the previous (2010-13) audit period, providing a 52% reduction.

The Wallerawang STP, near Lithgow in the upper Coxs catchment, discharged a total of 4 tonnes of nitrogen, a reduction of 40% compared to the previous audit period. This figure is an underestimate of the real reduction as no load data was available from Wallerawang STP for 2007/8.

Not all STPs in the catchment recorded reductions in nitrogen loads compared to previous audit periods. For example, the Mittagong STP discharged 22 tonnes of nitrogen in the current audit period. While this was marginally less than the 2010-13 audit period (25 tonnes) it was 2% more than the 19 tonnes that Mittagong STP discharged in the 2007-2010 audit period. In addition, the annual nitrogen load discharged from Mittagong STP of 7 tonnes in 2015-16 was more than the annual loads discharges from 2006/7 to 2009/10.

**Table 7. Total nitrogen from STPs**

| STP Name | 2007-10 | 2010-3 | 2013-16 |
|---|---|---|---|
| Moss Vale | 20912 | 22024 | 18100 |
| Bowral | 24011 | 28016 | 25247 |
| Lithgow | 50592 | 55569 | 26675 |
| Wallerawang | 6022* | 6010 | 3620 |
| Goulburn | 133938 | 92356 | 82396 |
| Mittagong | 18545 | 25297 | 21983 |
| Bundanoon | 5141 | 4195 | 3341 |
| **Total** | **259161** | **233466** | **181360** |

*No nitrogen load data was available for Wallerawang STP for 2007/8
Data source: EPA

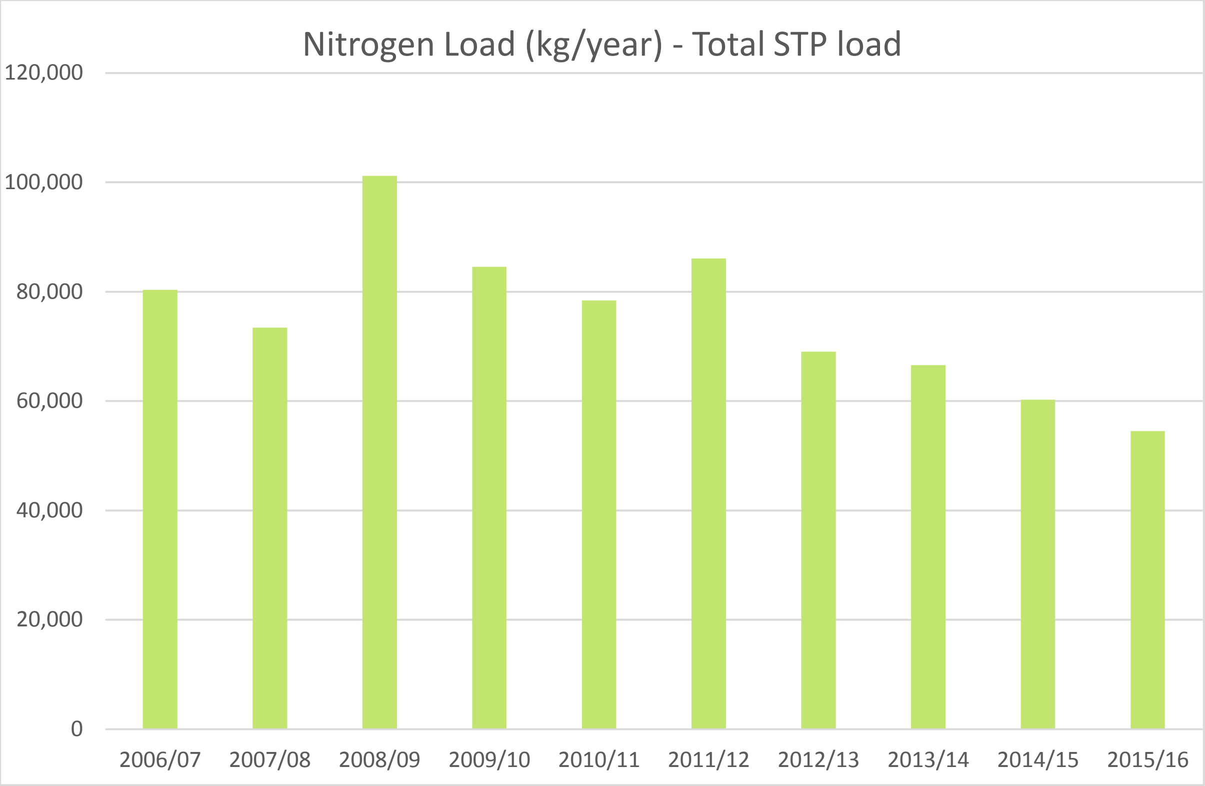



**Figure 9. Annual nitrogen loads from STPs in the Catchment (EPA)**

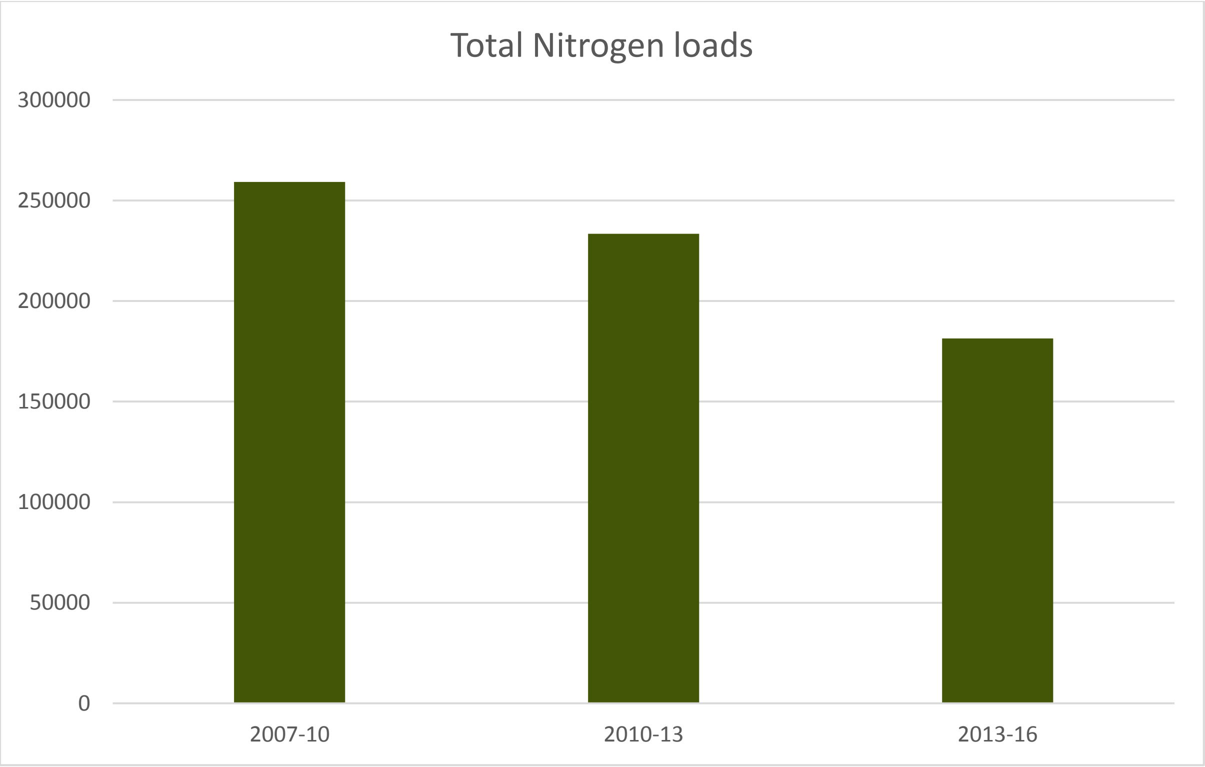



**Figure 10. Annual Nitrogen loads (kg/3 year periods) from STPs for recent audit periods (EPA)**

**Modelling diffuse-source nutrient loads**

WaterNSW has developed and refined a spatial 'Pollution Source Assessment Tool (PSAT)' to quantify the risk of nutrients and other pollutants being generated from the catchments and transported into waterways. The modelling uses a combination of science and catchment knowledge based on land-uses and other physical attributes. The 2010 audit report (for the 2007-10 audit period) recommended that future audits include estimates of nutrient loads within individual sub-catchments. The previous 2013 audit recommended actions to improve the methodology for identification and assessment of diffuse sources of nutrients.

In 2016 WaterNSW ran the PSAT for the third time over a period of eight years. They concluded that conditions in the Drinking Water Catchments have not changed dramatically since the initial run in 2007, but a number of incremental changes have occurred (refer to **Section 5.2** for further information). The PSAT has identified the priority landuse modules for risk of nutrient generation (**Table 8**). For each year that it was run (2008, 2012 and 2016) it found that grazing landuses represent the greatest risk of nutrients. Intensive animal production was the second or third priority and gully erosion was identified as the second top priority in 2016.

**Table 8. Priorities identified by PSAT model in 2008, 2012 and 2016**

| Priority | PSAT 2008 | PSAT 2012 | PSAT 2016 |
|---|---|---|---|
| 1 | Grazing | Grazing | Grazing |
| 2 | Intensive animal production | Intensive animal production | Gully erosion |
| 3 | Urban stormwater | Onsite wastewater management | Intensive animal production |
| 4 | Sewers and pump stations | Urban stormwater | Forests |
| 5 | Sewage treatment plants | Sewers and pump stations | Urban stormwater |

Source: WaterNSW

Some notable points about these results:

- The 2016 results (**Table 8**) show an increased dominance by grazing and the inclusion for the first time of two modules, gully erosion and forests, which are not sources of pathogens. This reflects a focus in program activities over the past 8 years on reducing the risk of pathogen sources in the catchments, most notably STPs, dairies, and on-site sewage.
- Risk from STPs reduced significantly between 2008 and 2012, remaining out of the top five priority modules from 2012 onwards. This is the result of a STP upgrade program prior to 2012, resulting in a reduction in assessed risk for that module. However, results from this audit regarding water quality and population growth indicate that Moss Vale, Mittagong, Bowral and Berrima STPs in Wingecarribee Shire require upgrading. This information should be incorporated in future PSAT modelling.
- On-site wastewater management was highlighted as a priority by the 2012 PSAT run. Sewering programs and other work with councils have since been carried out to address this assessed risk (for example sewering of Robertson, Kangaroo Valley and Taralga) and as a result it is no longer a priority for 2016.
- There has been gradual expansion of urban areas, particularly around the Southern Highlands, Lithgow and Goulburn, and councils continue to minimise spending on stormwater treatment in existing urban areas. This has resulted in Urban Stormwater remaining a high priority in PSAT 2016. New developments are generally assessed as low risk due to stormwater controls implemented under the Neutral or Beneficial Effect (NoRBE) test developed and administered by WaterNSW.
- For the first time, PSAT results include comprehensive mapping of gully erosion in the catchments. Gully erosion risk remains widespread, hence its appearance in the top five priorities. However it is only considered a significant risk for suspended solids, which is generally considered to be a lower priority pollutant in comparison with pathogens, nitrogen and phosphorus.

- The risk associated with Forests was assessed for the first time in the 2016 PSAT run. The wide scale of forest in the Catchment, plus the combination of risk factors for pollutant runoff from forests (such as slope and susceptibility to fire) in some areas, has resulted in this module ranking in the top five. However, high risk areas make up only a small portion of total forested land in the Catchment. It is further noted that risk associated with Forests is not from timber harvesting or logging activities.

**Conclusion**

STP upgrades have reduced total nutrient loads to streams and storages, thus improving the Catchment health. Further investment in maintaining and improving sewerage infrastructure is considered worthwhile, especially in the context of increasing human populations in the Catchment.

Diffuse-source nutrient loads are more difficult to measure and determine trends. The auditors recognise that the WaterNSW PSAT represents a sophisticated approach for modelling the risk of nutrient loads and other key pollutants (sediment and pathogens). However, recommendations made in previous audits about PSAT and diffuse source nutrient modelling remain valid and estimations of that export rates for pollutants per hectare of different priority landuses should be improved through scientific studies of the Catchment. Results of such studies could be fed into future PSAT updates with actual pollutant generation information for catchment landuses. Such an approach would strengthen future revisions of the WNSW PSAT tool.

Widespread nutrient enrichment of many water storages and rivers is a concern. Many of the storages have increasing temporal trends with their trophic level showing signs of increasing towards mesotrophic or even eutrophic levels. The rising nutrient concentrations is often occurring at storages that suffer cyanobacteria blooms with Lake Burragorang, Lake Nepean, Lake Yarrunga, Fitzroy Falls Reservoir and Wingecarribee Reservoir of particular concern.

## 2.3 Cyanobacterial blooms

**Definition and context**

Cyanobacteria are a microscopic form of plant life found in water, commonly known as blue-green algae. Under some conditions, certain species of cyanobacteria can produce toxins that can be hazardous to human health, to fish and any animals that come into contact with it. Cyanobacteria levels are a key indicator of water quality for water supplies throughout the world. The proliferation of some species can cause mild water quality problems (such as taste and odour issues) ranging through to severe water quality problems that can cause illness and death of human and animals. A combination of natural and human factors can influence the abundance and types of cyanobacteria, with temperature, slow water flow, and availability of nitrogen and phosphorus well understood triggers.

Increasing cyanobacteria alerts (described below) in the Catchment are considered to be a **worsening** trend, whereas fewer alerts represents an **improving** trend.

**Data and methods**

There were two sources of information on cyanobacteria used for this Audit. The first was from the WaterNSW's Water Monitoring Program which includes collection of cyanobacteria data from catchment sites (streams and rivers) and water storages (dams and storages). This source of information was comprised of cyanobacteria cell counts, bio-volumes and toxic cyanobacteria cell counts and biovolumes.

The second source of information on cyanobacteria was provided to the auditors from the NSW Department of Primary Industries (DPI Water). This information was for water bodies sampled within the audit area and was based on notifications that they had received of cyanobacterial results, and public alerts issued, based on the NH&MRC (2008) recreational alert levels for cyanobacteria. The original source of the DPI Water information was data provided by the Metropolitan & South Coast Regional Algal Coordinating Committee for cyanobacterial bloom alerts at waterbodies in the catchment for the current period Audit. This source of information was particularly focussed on waterways of community water-based recreation. Data from a total of 11 sampling sites was provided for the first two audit years (2013/4 and 2014/5) and data from an extra site (Mulwaree River at Towers weir) was provided for the last audit year (2015/6).

The cyanobacteria alert criteria used in this audit is based on the NHMRC (2008) recreational guidelines. The same guidelines were used to determine the cyanobacteria alert levels for the WaterNSW data (cyanobacteria cell counts, bio-volumes and toxic cyanobacteria cell counts and biovolumes).

The cyanobacteria criteria used in this audit are based on the NHMRC recreational guidelines and are:

- **Good**: the biovolumes of potentially toxic cyanobacteria was greater than 0.04 $mm^3/L$ but less than 0.4 $mm^3/L$
- **Moderate**: the biovolumes of potentially toxic cyanobacteria was greater than 0.4 $mm^3/L$ but less than 4.0 $mm^3/L$
- **Poor**: the biovolumes of potentially toxic cyanobacteria was greater than 4.0 $mm^3/L$. The red trigger of greater than 4.0 $mm^3/L$ applies when known toxic species dominate (contributing more than 75% of the biovolume). When cyanobacteria species not thought to produce toxins are dominant, the threshold between Amber and Red is 10 $mm^3/L$.

**Cyanobacteria alerts**

**Figure 11** provides a yearly summary of weeks of cyanobacteria alerts at all water bodies monitored by DPI Water in the catchment area, for the current and previous audit period. The colour in the graph represents the cumulative number of weeks per year that each water sampling site was placed under a green, amber or red alert.

- Red alerts: Cyanobacterial blooms at catchment waterbodies resulted in the issuing of a total of 23 red alerts (cumulative weeks under red alert) over the current audit period. This included four red alerts in 2013-14; this increased to eight in 2014-15 and 11 red alerts in 2015-16. It is noteworthy that the 2015-16 included a new site, 'Mulwaree River at Towers weir' (near Goulburn), for the first time and this site alone accounted for 10 weeks of red alerts, which suggests that this site should be a focus for remedial action. Despite this, the results were an improvement on the previous audit period (2010-3) when a total of 50 weeks of red alerts were issued for a smaller number of waterbodies.

- Amber alerts: Cyanobacterial blooms at catchment waterbodies resulted in the issuing of a total of 126 weeks of amber alerts. This included 32 amber alerts (weeks under alert) by the Committee in 2013-14; this increased to 50 in 2014-15 and then declined to 44 amber alerts in 2015-16. This was a similar result to the previous audit period (2010-3) when a total of 127 weeks of amber alerts were issued for a smaller number of sites.
- Green alerts: Cyanobacterial blooms at catchment waterbodies resulted in the issuing of 139 green alerts (weeks under alert) by the Committee in 2013-14; this declined to 125 in 2014-15 and then increased to 143 amber alerts in 2015-16. This was a total of 407 weeks of green alerts, This was less than the previous audit period (2010-3) when a total of 450 weeks of green alerts were issued for a smaller number of sites.

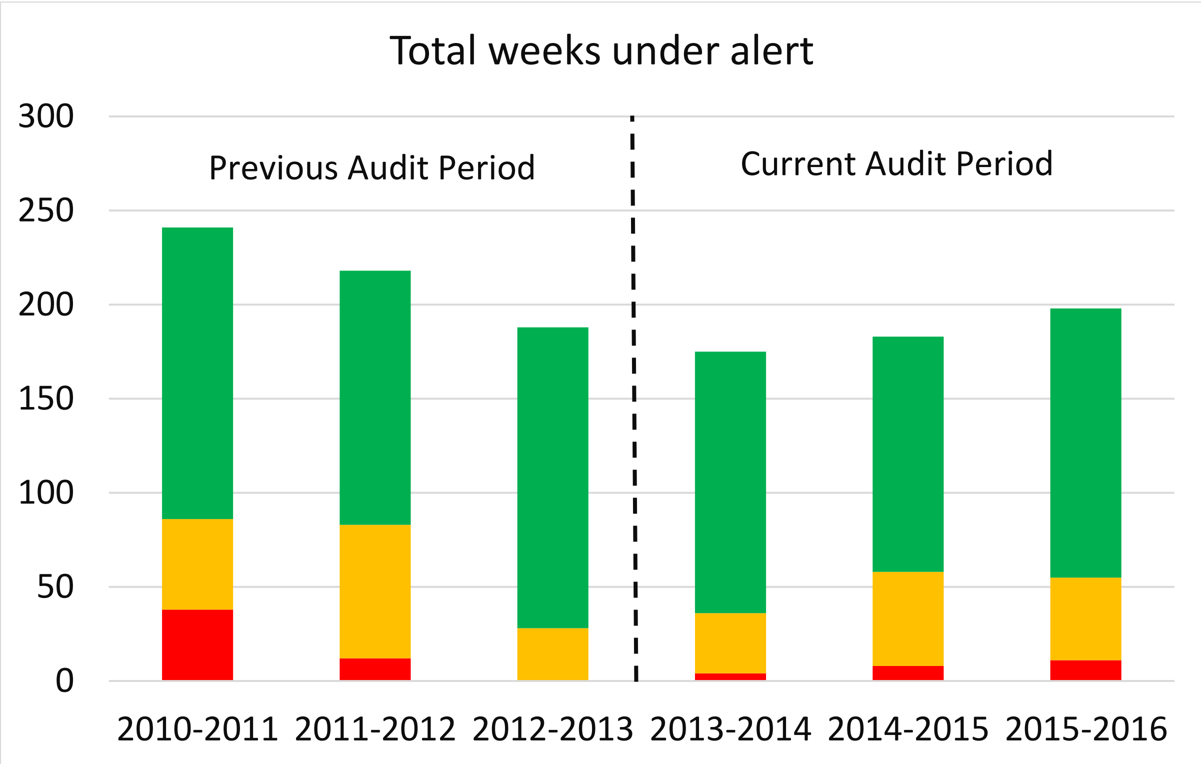



**Figure 11. Number of weeks of cyanobacteria bloom alerts (DPI Water)**

Fitzroy Falls Reservoir had the largest number of weeks recorded under cyanobacteria alert in the current audit period, with a total of 100 weeks of alerts. This comprised 20 weeks under amber alert and 80 under green alert, with no red alerts declared. Although there was no DPI Water data presented in the previous audit for this storage, DPI Water data showed that during the previous audit period (2010-13) this storage had slightly more weeks (114 weeks) under alert, with 18 amber and 96 green.

The equal largest number of weeks under red alert, in the current audit period, was for Lake Wallace, an impoundment used for recreation and power station cooling water on the upper Coxs River, near Wallerawang, upstream from Lithgow. Mulwaree River also had 10 weeks under red alert, based on data from DPI Water for 2015/16. There was no data provided for this site for previous years or in previous audits. For the three year audit period Lake Wallace spent 10 weeks under red alert, with 25 weeks under amber alert and an additional 27 weeks under green alert (a total of 62 weeks under alert). Very similar results were reported for this waterbody for the previous audit period, when it accumulated a total of 70 weeks of alerts, including 12 weeks under red alert, 33 amber and 25 green.

A major improvement in the current audit period was apparent at Farmers Creek downstream of Lithgow STP. In the current audit period, there were no alerts of any colour issued at all for this locality. This waterway has historically been the location of serious and protracted cyanobacteria blooms. In the previous audit this site recorded a total of 27 red alerts, with no amber or green alerts. Historic (pre 2010) DPI (Water) data examined by the auditors revealed that this waterway regularly suffered red alerts (8 weeks in 2006/7; 15 weeks in 2007/8; and 8 weeks in 2008/9). DPI Water advised the auditors that the chronic history of blooms in Farmers Creek was linked to algal blooms in the tertiary treatment ponds at the Lithgow STP, with cyanobacterial contaminated effluent then released to Farmers Creek and causing the high cyanobacterial numbers in the creek. DPI Water explained to the auditors that upgrades to the STP took place several years ago, which has since resulted in no cyanobacteria-contaminated effluent being released to the creek since that time. The STP upgrade also reduced the nitrogen and phosphorus loads released to Farmers Creek.

Results of statistical analysis are presented in **Volume 3** of this audit and summarised here:

- Findings for storages
    - The most problematic WaterNSW storage site (based on WaterNSW data) for cyanobacteria in this audit was site DWI1 'Wingecarribee Reservoir' where the median total cyanobacterial biovolume (0.052 $mm^3/L$) was at green alert level and the maximum result for toxic cyanobacteria biovolume (1.67 $mm^3/L$) was the highest recorded for any storage site and was at the amber alert level. There was no information provided to assess how many weeks this storage was at green or amber alert level.
    - Several WaterNSW storages recorded a green alert level for maximum cyanobacteria results including DTC 'Top Cascade', DGC1 'Greaves Creek', DNE2 'Lake Nepean', DCO1 'Lake Cordeaux', DAV7 'Lake Avon', DFF 'Fitzroy Falls', DTA8 'Lake Yarrunga at Kangaroo River' and several Lake Burragorang sites.
    - Lake Yarrunga and Fitzroy Falls Reservoir both triggered cyanobacteria alerts according to information provided by DPI Water. Of most concern was that Fitzroy Falls Reservoir triggered the largest number of alerts in two of the years in the current audit period (33 weeks in 2013-4 and 38 weeks in 2014-15). It also triggered the third highest number of weeks on cyanobacteria alert in 2015-6 (29 weeks).
- Findings for catchments
    - The most consistently problematic site in the catchment for cyanobacteria was site E332 Wingecarribee River at Berrima where median total cyanobacterial biovolume (0.039 $mm^3/L$) was just under the green alert level and the maximum result for toxic cyanobacteria was at the amber level.
    - The catchment site with the largest cyanobacteria biovolume was site E457 Mulwaree River at Towers Weir where the maximum toxic cyanobacteria biovolume (19.46 $mm^3/L$) reached (red alert level).
    - One other catchment site E409 Wollondilly River at Golden Valley also recorded an amber alert as the maximum toxic cyanobacteria biovolume (4.41 $mm^3/L$). This should have been classed as a red alert.
    - A major improvement on the previous audit period was catchment site E0406 Farmers Creek downstream of Lithgow STP. This is also support by DPI Water results. Lithgow STP had received a major upgrade. Previous audits had found that this site had the most problematic cyanobacteria results with red alerts for maximum values and amber alerts for median values. In the current audit period this site it never triggered any alert. In the previous audit period this site had triggered 27 weeks of alerts, all were red alerts.

Two of the WaterNSW storages, Lake Yarrunga and Fitzroy Falls reservoir, appear in the list of sites that generated cyanobacteria alerts for water bodies reported by NSW DPI (Water). Fiztroy Falls was highlighted for generating the largest number of weeks under cyanobacteria alerts, according the NSW DPI data, for two of the years of the current audit period (2013-14 and 2014-5). Results for this storage were not reported in the previous audit. NSW DPI data confirmed that Fitzroy Falls reservoir had a similar frequency of cyanobacteria alerts in the 2010-3 audit period.

Wingecarribee Reservoir  had the poorest cyanobacteria data according to WaterNSW cyanobacteria cell counts and biovolume data. This reservoir is linked to Lake Yarrunga and Fitroy Falls, which both had cyanobacteria problems. Together these three storages appear to be a 'hotspot', for cyanobacteria. The transfer and discharge of water may contribute to other cyanobacteria problems. The Wingecarribee River, immediately downstream of the dam, also has very problematic cyanobacteria results (according to DPI data). In addition, Lake Nepean and Lake Burragorang also have problematic cyanobacteria, according to WaterNSW data.

Cyanobacteria is often a cumulative problem that is closely associated with the nutrient enrichment status of water impoundments. It is also one of the most important biological measures of performance for storage and supply of potable water. The auditors suggest that WaterNSW should develop their own derived ANZECC (2000) water quality guidelines.  These should include water chemistry and physical variables associated with cyanobacteria blooms.

**Conclusion**
Upgrades to Lithgow STP have resulted in notable improvement to Farmers Creek, with no cyanobacteria alerts issued at this site in the current audit period.  In comparison, this site had 27 red alerts during the previous audit period.

Mulwaree River at Towers weir' (near Goulburn) accounted for 10 weeks of red alerts for cyanobacteria, which suggests that this site should be a focus for remedial action.

# 3 Primary indicators - water availability

## 3.1 Surface water flow

**Definition and context**
Surface water flow refers to the rate at which water moves in defined waterways (e.g. creeks or rivers) within the Catchment.

The availability of surface water flow was assessed for this audit by considering:

- the level and variability of streamflow at stream gauge locations throughout the Catchment
- compliance with surface water extraction licences within each sub-catchment.

**Level and variability of streamflow**

***Method***
WaterNSW operates a network of river gauging stations that measure the level and variability of streamflow. Data from stream gauges is published each week by WaterNSW to provide information about how much rainfall has been recorded, how full the dams are, and how much raw water they have supplied to their customers.

The availability of surface water in the Catchment has been determined by assessment of WaterNSW streamflow data from 64 river gauging stations. Gauging station locations referred to in this audit are mapped in **Figures 1** to **5**. The data was reviewed to identify flow variability and long term trends at nominated watercourse gauging stations across the Catchment. Median water levels were calculated and flow exceedance curves were created (provided in **Volume 3**) to compare the current audit period with the previous 2010-2013 audit period and the long-term data set for the stream gauges. This information indicates the percentage of time the flow can be expected to exceed a particular value that informs the nature of the stream and catchment characteristics.

Criteria adopted in this audit for **poor** level and variability of streamflow are:

- less than 50% of the long term median flow
- less than 50% of the 2010-2013 median flow
- longer dry periods or generally lower volumes of flow compared to the long-term average and/or the last audit period

The available datasets contained consistent gaps where data was not recorded. It is not clear whether these data gaps were due to zero flow within the creeks or whether the data was not recorded for some other reason. Data quality codes are required and recommended to determine the reliability of the flow data used in the analysis. For example, if the gauging data has a '0' value, it should be clear if this indicates that flow data is missing or if there has been no flow.

***Findings***
Median flow for each of the gauges was compared between the current audit period (2013-16), the last audit period (2010-13) and the long-term data set (all available records up to 30 June 2016) (see results in **Table 9**). The '2013-2016 Audit Median / long term Median' presents the ratio of the medians for the two datasets and provides an indication of changes in flow in the current audit period versus the longer record. The ratio of median flows for this audit period versus the previous audit period indicates any changes in flow in the shorter term.

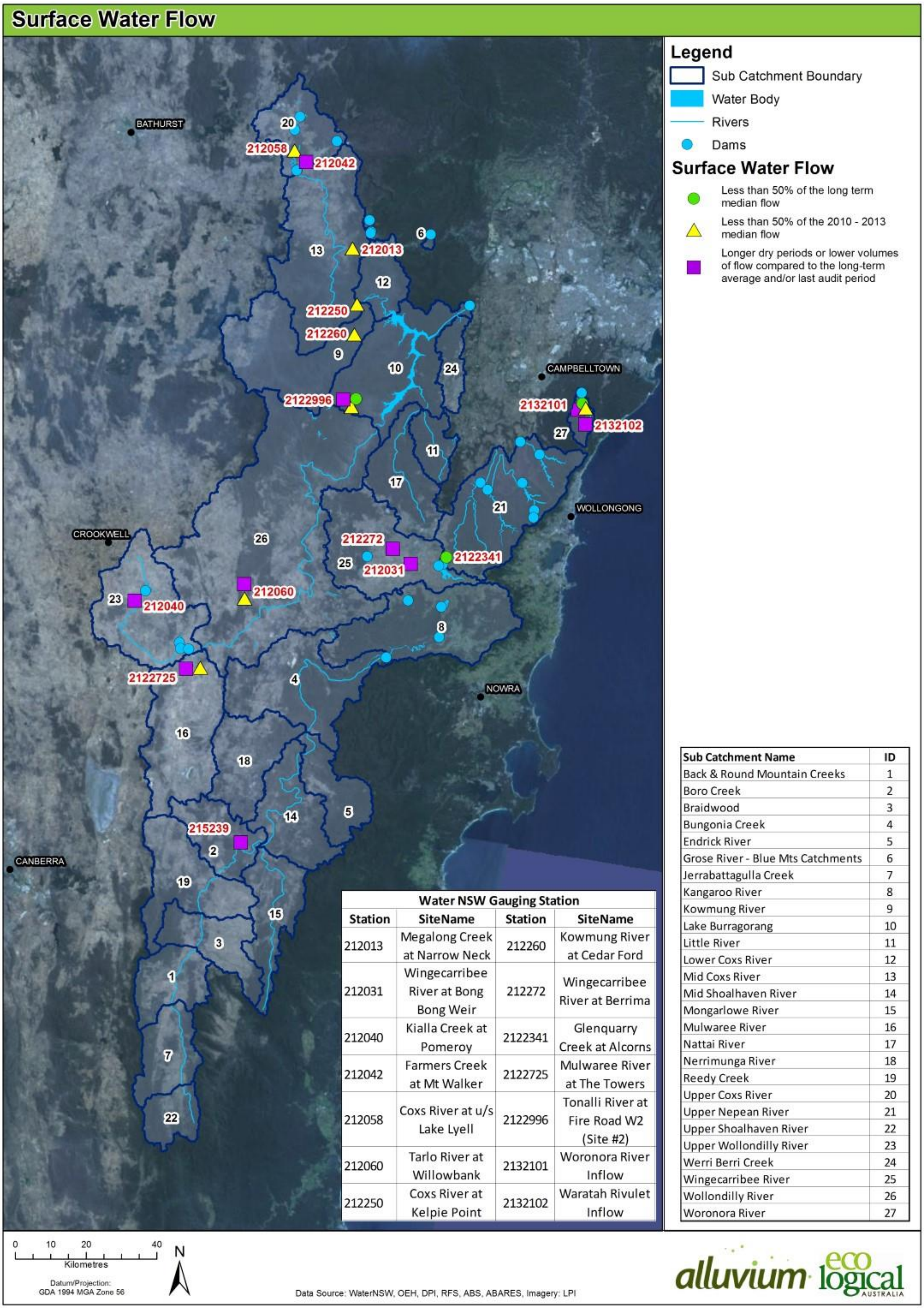
Monitoring sites that had a poor result are shown in **Figure 12** and identified as follows (refer to **Table 9**):

- four sites experienced less than 50% of the long term median flow
  - Boro Creek Sub-catchment - Boro Creek at Marlowe (215239)
  - Lake Burragorang sub-catchment - Tonalli River at Fire Road W2 (Site #2) (2122996)

- Upper Nepean River sub-catchment - Glenquarry Creek at Alcorns (2122341)
    - Woronora River sub-catchment - Woronora River Inflow (2132101)
- eight sites experienced less than 50% of the 2010-2013 median flow
    - Kowmung River sub-catchment - Kowmung River at Cedar Ford (212260)
    - Lake Burragorang sub-catchment - Tonalli River at Fire Road W2 (Site #2) (2122996)
    - Mid Coxs River sub-catchment - Megalong Creek at Narrow Neck (212013) and Coxs River at Kelpie Point (212250)
    - Mulwaree River sub-catchment - Mulwaree River at the Towers (2122725)
    - Upper Coxs River sub-catchment - Neubecks Creek at u/s Lake Lyell (212058)
    - Wollondilly River sub-catchment - Tarlo River at Willowbank (212060)
    - Woronora River sub-catchment - Woronora River Inflow (2132101)
- eight sites had longer dry periods or generally lower volumes of flow compared to the long-term average and/or the last audit period
    - Boro Creek Sub-catchment - Boro Creek at Marlowe (215239)
    - Lake Burragorang sub-catchment - Tonalli River at Fire Road W2 (Site #2) (2122996)
    - Mulwaree River sub-catchment - Mulwaree River at the Towers (2122725)
    - Upper Coxs River sub-catchment - Farmers Creek at Mt Walker (212042)
    - Upper Wollondilly River sub-catchment - Kialla Creek at Pomeroy (212040)
    - Wingecarribbee sub-catchment - Wingecarribee River at Bong Bong Weir (212031) and Wingecarribee River at Berrima (212272)
    - Wollondilly River sub-catchment - Tarlo River at Willowbank (212060)
    - Woronora River sub-catchment - Woronora River Inflow (2132101) and Waratah Rivulet Inflow (2132102)

Other findings of note are:

- Comparison of median flows in audit period to long-term
    - 42% of sites (27 of 64) experienced flows less than the long-term median flow
    - 55% of sites (35 of 64) experienced flows greater than the long-term median flow
    - One site (Gauge 215014) has the same median flow value for both periods
    - One site (Gauge 215237) had no data available for the 2013-2016 audit period
- Comparison of median flows in audit period (2013-16 to previous audit period (2010-2013)
    - 81% of sites (52 of 64) experienced flows less than the 2010-2013 median flow
    - 17% of sites (11 of 64) experienced flows higher than the 2010-2013 median flow
    - One site (Gauge 215237) had no data available for the 2013-2016 audit period
- Summary of flow exceedance curves for the 64 surface water gauges (refer to summary of exceedance curves table and exceedance curve graphs in **Volume 3**)
    - The majority of the sites (80%) are constantly flowing viable sources of water (based on flow volumes only)
    - Fifteen sites (23%) appear to be controlled by upstream controlled releases
    - Thirteen sites (20%) had periods during the 2013-2016 audit period where the system was dry




| Water NSW Gauging Station | | | |
|---|---|---|---|
| **Station** | **SiteName** | **Station** | **SiteName** |
| 212013 | Megalong Creek at Narrow Neck | 212260 | Kowmung River at Cedar Ford |
| 212031 | Wingecarribee River at Bong Bong Weir | 212272 | Wingecarribee River at Berrima |
| 212040 | Kialla Creek at Pomeroy | 2122341 | Glenquarry Creek at Alcorns |
| 212042 | Farmers Creek at Mt Walker | 2122725 | Mulwaree River at The Towers |
| 212058 | Coxs River at u/s Lake Lyell | 2122996 | Tonalli River at Fire Road W2 (Site #2) |
| 212060 | Tarlo River at Willowbank | 2132101 | Woronora River Inflow |
| 212250 | Coxs River at Kelpie Point | 2132102 | Waratah Rivulet Inflow |

| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 12. Summary of 'poor' results for surface water flows**

**Table 9. Summary of results from WaterNSW gauging stations**

| Station Number | Site name | Date records commenced | Long-term Median (ML/day) | 2010-2013 Median (ML/day) | 2013-2016 Median (ML/day) | 2013-2016 Audit Median / Long-term Median (ML/day) | 2013-2016 Audit Median / 2010-2013 audit Median (ML/day) |
|---|---|---|---|---|---|---|---|
| **Boro Creek Sub-catchment** | | | | | | | |
| 215239 | Boro Creek at Marlowe | 24/02/1994 | 3.43 | 2.12 | 1.61 | 0.47 | 0.76 |
| **Braidwood Creek Sub-catchment** | | | | | | | |
| 215241 | Shoalhaven River at Bendoura | 29/08/1994 | 13.11 | 19.42 | 20.52 | 1.57 | 1.06 |
| 215209 | Shoalhaven River at Mountview | 8/11/1973 | 133.41 | 204.80 | 199.71 | 1.50 | 0.98 |
| 215237 | Gillamatong Creek | 13/03/1994 | 3.11 | 11.87 | NO DATA | N/A | |
| **Bungonia Creek Sub-catchment** | | | | | | | |
| 215014 | Bungonia Creek at Bungonia | 15/04/1981 | 0.90 | 0.78 | 0.80 | 0.89 | 1.02 |
| 215207 | Shoalhaven River at Fossickers Flat | 15/07/1977 | 355.56 | 496.28 | 422.28 | 1.19 | 0.85 |
| **Grose River Sub-catchment** | | | | | | | |
| 212291 | Grose River at Burralow | 1/11/1987 | 103.34 | 191.02 | 99.29 | 0.96 | 0.52 |
| **Jerrabattgulla Sub-catchment** | | | | | | | |
| 215008 | Shoalhaven River at Kadona | 18/09/1950 | 39.62 | 77.86 | 76.75 | 1.94 | 0.99 |
| **Kangaroo River Sub-catchment** | | | | | | | |
| 215215 | Shoalhaven River at D/S Tallowa Dam | 20/07/1991 | 385.02 | 640.34 | 513.51 | 1.33 | 0.80 |
| 215220 | Kangaroo River at Hampden Bridge | 7/11/1973 | 152.73 | 201.63 | 168.38 | 1.10 | 0.84 |
| 215233 | Yarrunga Creek at Wildes Meadow | 15/11/1973 | 6.13 | 9.49 | 5.71 | 0.93 | 0.60 |
| 215234 | Yarrunga Creek at Fitzroy Falls | 2/03/1983 | 12.87 | 17.89 | 11.78 | 0.92 | 0.66 |
| **Kowmung River Sub-catchment** | | | | | | | |
| 212260 | Kowmung River at Cedar Ford | 1/05/1968 | 112.39 | 243.94 | 94.31 | 0.84 | 0.39 |
| **Lake Burragorang Sub-catchment** | | | | | | | |
| 2122996 | Tonalli River at Fire Road W2 (Site #2) | 1/07/2003 | 3.08 | 2.25 | 0.45 | 0.15 | 0.20 |
| **Little River Sub-catchment** | | | | | | | |
| 2122809 | Little River at Fire Road W4I | 21/08/1990 | 3.15 | 3.41 | 3.31 | 1.05 | 0.97 |
| **Lower Coxs River Sub-catchment** | | | | | | | |

| Station Number | Site name | Date records commenced | Long-term Median (ML/day) | 2010-2013 Median (ML/day) | 2013-2016 Median (ML/day) | 2013-2016 Audit Median / Long-term Median (ML/day) | 2013-2016 Audit Median / 2010-2013 audit Median (ML/day) |
|---|---|---|---|---|---|---|---|
| 212016 | Kedumba River at Maxwells Crossing | 3/06/1990 | 20.30 | 30.31 | 17.32 | 0.85 | 0.57 |
| **Mid Coxs River Sub-catchment** | | | | | | | |
| 212011 | Coxs River at Lithgow | 28/05/1960 | 11.88 | 15.01 | 22.68 | 1.91 | 1.51 |
| 212013 | Megalong Creek at Narrow Neck | 21/11/1968 | 4.15 | 8.88 | 3.82 | 0.92 | 0.43 |
| 212045 | Coxs River at Island Hill | 2/01/1981 | 49.87 | 93.51 | 50.56 | 1.01 | 0.54 |
| 212250 | Coxs River at Kelpie Point | 2/11/1966 | 133.38 | 221.33 | 107.44 | 0.81 | 0.49 |
| 2122512 | Coxs River at Glenroy Bridge | 1/05/1999 | 14.23 | 26.58 | 28.86 | 2.03 | 1.09 |
| **Mid Shoalhaven River Sub-catchment** | | | | | | | |
| 215004 | Corang River at Hockeys | 8/09/1924 | 26.29 | 35.39 | 26.94 | 1.02 | 0.76 |
| 215208 | Shoalhaven River at Hillview | 7/11/1973 | 258.29 | 342.09 | 334.43 | 1.29 | 0.98 |
| 215242 | Corang River at Meangora | 3/12/1994 | 21.24 | 34.52 | 22.49 | 1.06 | 0.65 |
| **Mongarlowe River Sub-catchment** | | | | | | | |
| 215007 | Mongarlowe River at Monga | 2/01/1950 | 20.60 | 36.61 | 27.40 | 1.33 | 0.75 |
| 215210 | Mongarlowe River at Mongarlowe | 8/11/1993 | 44.52 | 52.76 | 55.71 | 1.25 | 1.06 |
| **Mulwaree River Sub-catchment** | | | | | | | |
| 2122725 | Mulwaree River at The Towers | 7/06/1990 | 0.00 | 4.85 | 0.00 | 1.00 | 0.00 |
| **Nattai River Sub-catchment** | | | | | | | |
| 212280 | Nattai River at The Causeway | 7/07/1965 | 15.29 | 17.27 | 15.61 | 1.02 | 0.90 |
| 2122801 | Nattai River at The Crags | 12/07/1990 | 5.61 | 7.80 | 7.58 | 1.35 | 0.97 |
| **Nerrimunga River Sub-catchment** | | | | | | | |
| 215240 | Nerrimunga Creek at Minshull Trig | 3/12/1994 | 0.09 | 0.25 | 0.22 | 2.47 | 0.87 |
| **Reedy Creek Sub-catchment** | | | | | | | |
| 215002 | Shoalhaven River at Warri | 2/09/1914 | 136.63 | 222.53 | 205.92 | 1.51 | 0.93 |
| 215238 | Reedy Creek at Manar | 18/02/1995 | 5.71 | 17.05 | 10.05 | 1.76 | 0.59 |
| **Upper Coxs River Sub-catchment** | | | | | | | |

| Station Number | Site name | Date records commenced | Long-term Median (ML/day) | 2010-2013 Median (ML/day) | 2013-2016 Median (ML/day) | 2013-2016 Audit Median / Long-term Median (ML/day) | 2013-2016 Audit Median / 2010-2013 audit Median (ML/day) |
|---|---|---|---|---|---|---|---|
| 212008 | Coxs River at Bathurst Rd | 9/02/1951 | 12.85 | 24.27 | 28.55 | 2.22 | 1.18 |
| 212042 | Farmers Creek at Mt Walker | 25/09/1980 | 15.50 | 19.05 | 12.28 | 0.79 | 0.64 |
| 212055 | Neubecks Creek at u/s Walwang | 7/12/1991 | 0.58 | 1.60 | 0.53 | 0.92 | 0.33 |
| 212058 | Coxs River at u/s Lake Lyell | 15/12/2000 | 22.80 | 34.67 | 36.79 | 1.61 | 1.06 |
| 212054 | Coxs River at Wallerawang | 18/01/1992 | 14.61 | 22.29 | 31.14 | 2.13 | 1.40 |
| **Upper Nepean River Sub-catchment** | | | | | | | |
| 212203 | Nepean River at Pheasant's Nest | 17/11/1983 | 5.17 | 398.25 | 418.28 | 80.84 | 1.05 |
| 212204 | Nepean River at Avon Dam Road | 24/07/1986 | 86.54 | 151.45 | 134.94 | 1.56 | 0.89 |
| 212209 | Nepean River at McGuires Crossing | 6/02/1970 | 38.70 | 53.79 | 43.97 | 1.14 | 0.82 |
| 212210 | Avon River at Avon Weir | 27/06/1969 | 1.55 | 12.51 | 9.73 | 6.26 | 0.78 |
| 212221 | Cordeaux River at Cordeaux Weir | 18/07/1990 | 24.10 | 30.78 | 83.52 | 3.47 | 2.71 |
| 212231 | Cataract River at Jordans Crossing | 9/11/1967 | 122.79 | 160.01 | 127.14 | 1.04 | 0.79 |
| 212233 | Cataract River at Broughtons Pass Weir | 16/03/1983 | 0.00 | 14.16 | 14.80 | N/A | 1.05 |
| 2122051 | Nepean River at Nepean Dam Inflow | 18/02/1990 | 31.46 | 56.88 | 39.39 | 1.25 | 0.69 |
| 2122052 | Burke River at Nepean Dam Inflow | 19/02/1990 | N/A | N/A | N/A | N/A | N/A |
| 2122111 | Avon River at Summit Tank | 29/03/1990 | 4.67 | 6.72 | 4.87 | 1.04 | 0.72 |
| 2122112 | Flying Fox No3 Creek at Upper Avon | 27/06/1990 | 0.56 | 0.72 | 0.65 | 1.15 | 0.90 |
| 2122201 | Goondarrin Creek at Kemira D'Cast | 3/08/1991 | 0.97 | 0.83 | 0.53 | 0.54 | 0.63 |
| 2122322 | Loddon River at Bulli Appin Road | 9/03/1990 | 5.54 | 8.39 | 4.90 | 0.89 | 0.58 |
| 2122341 | Glenquarry Creek at Alcorns | 6/04/2003 | 7.01 | 3.81 | 2.17 | 0.31 | 0.57 |
| **Upper Wollondilly River Sub-catchment** | | | | | | | |
| 212040 | Kialla Creek at Pomeroy | 10/06/1979 | 3.08 | 3.25 | 2.35 | 0.76 | 0.72 |
| **Werriberri Creek Sub-catchment** | | | | | | | |
| 212244 | Werriberri Creek at Werombi | 1/06/1988 | 2.78 | 3.34 | 2.73 | 0.98 | 0.82 |

| Station Number | Site name | Date records commenced | Long-term Median (ML/day) | 2010-2013 Median (ML/day) | 2013-2016 Median (ML/day) | 2013-2016 Audit Median / Long-term Median (ML/day) | 2013-2016 Audit Median / 2010-2013 audit Median (ML/day) |
|---|---|---|---|---|---|---|---|
| **Wingecarribee Sub-catchment** | | | | | | | |
| 212009 | Wingecarribee River at Greenstead | 26/10/1989 | 50.51 | 55.43 | 46.93 | 0.93 | 0.85 |
| 212031 | Wingecarribee River at Bong Bong Weir | 7/06/1989 | 22.30 | 25.36 | 14.48 | 0.65 | 0.57 |
| 212272 | Wingecarribee River at Berrima | 22/08/1975 | 30.78 | 36.85 | 21.72 | 0.71 | 0.59 |
| 212274 | Caalang Creek at Maguire Crossing | 27/11/1986 | 7.19 | 10.45 | 6.84 | 0.95 | 0.65 |
| 212275 | Wingecarribee River at Sheepwash Bridge | 9/10/1996 | 9.69 | 5.72 | 5.07 | 0.52 | 0.89 |
| **Wollondilly River Sub-catchment** | | | | | | | |
| 212270 | Wollondilly River at Jooriland | 15/12/1961 | 193.68 | 254.60 | 135.85 | 0.70 | 0.53 |
| 212271 | Wollondilly River at Golden Valley | 2/01/1974 | 33.12 | 61.89 | 41.54 | 1.25 | 0.67 |
| 2122711 | Wollondilly River at Murray's Flat | 17/08/1990 | 11.50 | 20.99 | 11.20 | 0.97 | 0.53 |
| 212060 | Tarlo River at Willowbank | 10/02/2011 | 8.79 | 12.51 | 5.12 | 0.58 | 0.41 |
| **Woronora River Sub-catchment** | | | | | | | |
| 213211 | Woronora River at the Needles | 12/05/1992 | 10.61 | 18.33 | 10.89 | 1.03 | 0.59 |
| 2132101 | Woronora River Inflow | 21/02/2007 | 1.75 | 3.78 | 0.43 | 0.24 | 0.11 |
| 2132102 | Waratah Rivulet Inflow | 21/02/2007 | 5.86 | 7.79 | 4.26 | 0.73 | 0.55 |

**Extraction licences and volumes**

***Method***

DPI Water issues water access licences that set the maximum permissible annual volumes of surface water that can be extracted from each sub-catchment. Water access licence data were obtained from DPI Water for each Water Sharing Plan[1] management zone and compared directly to 2010 audit data (2013 audit data were presented by sub-catchment and are not directly comparable to Water Sharing Plan management zones).

***Findings***

The overall total surface water extraction licence entitlement has increased since the previous audit periods. In 2010 the total entitlement was recorded as 28,548 ML/year. This rose to 33,576 ML/year in 2013 and has subsequently increased again, and in the current 2016 audit period the total entitlement is 41,119 ML/year across 538 licenses (a 20% increase). **Table 10** provides a summary of the extraction licenses within the catchment and a comparison to the 2010 and 2013 audits.

**Table 10. Summary of water entitlements from licensed water extractions in the catchment**

| | 2010 Audit | | 2013 Audit | | 2016 Audit | |
|---|---|---|---|---|---|---|
| **Catchment** | **No. of licences** | **Total entitlement (ML/Year)** | **No. of licences** | **Total entitlement (ML/Year)** | **No. of licences** | **Total entitlement (ML/Year)** |
| Hawkesbury-Nepean (including Woronora) | 369 | 19,796 | 323 | 23,086 | 320 | 31,147 |
| Shoalhaven | 124 | 8752 | 215 | 10,490 | 218 | 9972 |
| Total | 473 | 28548 | 538 | 33,576 | 538 | 41,119 |

Data source: DPI Water

**Table 11** provides a breakdown of the total licences entitlement by Water Sharing Plan management zone. The largest entitlements are in the Wollondilly River zones (20,708 ML/year) and the Lower Kangaroo River zones (6,613 ML/year). This is consistent with the findings of the previous audit where the same Water Sharing Plan management zones held the largest total entitlements. There are no licenced water entitlements in the Boro Creek Water Sharing Plan management zone.

If the total entitlements are divided by total catchment area involved, then the greatest allocation on an area basis (14 ML/annum.km$^2$) occurs in the Werriberri Creek catchment. This figure has decreased since the 2010 audit as the total entitlement has reduced from 2,395 to 2,217 ML/year. The next highest allocation on an area basis (13 ML/annum.km$^2$) occurs in the combined Kangaroo River, Yarrunga Creek and Fitzroy Falls catchment. The Lower Kangaroo River sources, Wollondilly River sources, Wingecarribee sources, Reedy Creek, Wywandy, Upper Woronora River and Bungonia Creek have seen total allocation increases since the 2010 audit. All other Water Sharing Plan management zones have seen a decrease in total annual water allocations apart from the Jenolan River, Kowmung River and Boro Creek Water Sharing Plan management zones where total allocations have remained the same.

As with the previous audit, these numbers do not allow for varying rainfall across the Catchment or allocations for major water utilities.

[1] Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011 (NSW Office of Water 2011)

**Table 11. Total licenced entitlement by Water Sharing Plan management zone**

| Water Sharing Plan management zone | Area (km²) | 2010 Audit | | 2016 Audit | | |
|---|---|---|---|---|---|---|
| | | Total entitlement (ML/year) | Entitlement/ Area (ML/year/km²) | No. of licences | Total entitlement (ML/year) | Entitlement/ Area (ML/year/km²) |
| Werriberri Creek | 160 | 2394.8 | 15.0 | 49 | 2217.0 | 13.9 |
| Lower Kangaroo River (Kangaroo River, Yarrunga Creek and Fitzroy Falls) | 511 | 4542.0 | 8.9 | 133 | 6612.6 | 12.9 |
| Wollondilly River total (includes Upper and Lower Wollondilly) | 3369 | 10753.4 | 3.2 | 115 | 20878.0 | 6.2 |
| Wingecarribee total (includes upper and Lower Wingecarribee) | 743 | 2036.6 | 2.7 | 61 | 2612.5 | 3.5 |
| Grose River (most if not all downstream of Catchment areas) | 649 | 1582.8 | 2.4 | 1 | 80.0 | 0.1 |
| Mulwaree River | 759 | 1426.0 | 1.9 | 22 | 1215.5 | 1.6 |
| Mid Shoalhaven River | 1068 | 1826.0 | 1.7 | 15 | 839.0 | 0.8 |
| Dharabuladh | 646 | 911.5 | 1.4 | 18 | 502.0 | 0.8 |
| Upper Nepean (all zones) | 1188 | 1273.0 | 1.1 | 24 | 1165.5 | 1.0 |
| Kedumba | 158 | 157.0 | 1.0 | 1 | 50.0 | 0.3 |
| Shoalhaven Gorge | 853 | 806.0 | 0.9 | 1 | 5.0 | 0.0 |
| Upper Shoalhaven River | 573 | 527.0 | 0.9 | 13 | 499.0 | 0.9 |
| Mongarlowe River | 411 | 359.0 | 0.9 | 18 | 258.1 | 0.6 |
| Reedy Creek | 367 | 279.0 | 0.8 | 6 | 291.7 | 0.8 |
| Wywandy | 368 | 273.3 | 0.7 | 6 | 1709.0 | 4.6 |
| Nerrimunga River | 476 | 282.0 | 0.6 | 11 | 171.9 | 0.4 |
| Upper Woronora River | 152 | 62.9 | 0.4 | 6 | 286.8 | 1.9 |
| Jenolan River | 393 | 132.0 | 0.3 | 2 | 132.0 | 0.3 |
| Bungonia Creek | 271 | 50.0 | 0.2 | 18 | 1218.5 | 4.5 |
| Kowmung River | 825 | 151.0 | 0.2 | 3 | 151.0 | 0.2 |
| Nattai Lake, Burragorang (includes Nattai and Little River, and Burragorang) | 1343 | 224.1 | 0.2 | 12 | 147.5 | 0.1 |
| Corand and Endrick Rivers | 491 | 81.0 | 0.2 | 3 | 76.0 | 0.2 |
| Boro Creek | 210 | 0.0 | 0.0 | 0 | 0.0 | 0.0 |

**Conclusion**

The overall total surface water extraction licence entitlement has increased since the previous audit periods. A continued trend of increasing levels of extraction is not sustainable in the long term.

The Woronora River, Wingecarribee River and Lake Burragorang sub-catchments experienced the poorest results for surface water flows (see **Figure 12**). Monitoring in these sub-catchments found multiple sites that:

- experienced less than 50% of the long term median flow and/or
- experienced less than 50% of the 2010-2013 median flow and/or
- experienced longer dry periods or generally lower volumes of flow compared to the long-term average and/or the last audit period.

## 3.2 Environmental flows

**Definition and context**

Dams and weirs, such as those within the Sydney Catchment, affect the natural flow of water through waterways, and can impact the shape and structure of the river channels, their water quality and the ecological communities that depend on them (Poff et al. 2010). Environmental flows are commonly released from dams to reinstate a more natural flow regime within rivers to improve their overall ecological health.

Environmental flow rules in the Catchment for all dams except Tallowa and Warragamba were developed by exhaustive scientific investigations by the Independent Expert Panel of the Hawkesbury-Nepean River Management Forum. Tallowa's environmental flow rule was developed by DPI Water, based on rigorous scientific analysis and extensive community consultation. Warragamba Dam does not currently have an environmental flow rule as the fixed releases from Warragamba are for dilution and drinking water purposes only. The Government has recently approved a variable environmental flow rule for Warragamba Dam that is likely to commence in 2024.

All environmental flow releases are a delicate balance of water supply and release for ecological benefits downstream. The dams release a proportion of the inflows and retain a portion in the dam for water supply. While the dams have release works that have a maximum volume (e.g. Avon Dam, with a max release of 1400 ML/d), these are generally in the moderate to high flow range.

Provisions for the release of environmental flows are included in the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011 (NSW Office of Water 2011). Within this plan, environmental flow releases are defined for storages within the Shoalhaven, Upper Nepean and Upstream Warragamba, Hawkesbury and Lower Nepean Rivers and the Southern Sydney Rivers water sources. The calculation of the environmental flow releases is defined in the Water Licences and Approvals Package (NSW Office of Water 2012). Environmental flows released within the Catchment typically focus on maintaining the base flow or low flow component of the flow regime. They are defined as either a specified quantity of water over a set period for some storages (e.g. Warragamba Dam), or as a proportion of inflows for others (e.g. storages within the Nepean catchment). Commonly, environmental releases are not required when the storage is spilling at a rate equal to or greater than the defined environmental release (NSW Office of Water 2011).

WaterNSW operates a series of hydrometric gauging stations across the Sydney Catchment. Daily data from a selection of sites in the form of annual compliance reports was provided by WaterNSW for the audit over the period 2010-2016. This data was used in the audit analysis and included:

- daily inflows into target storages
- daily spill data from target storages
- daily environmental releases from target storages.

However, it is noted that assessment of environmental flows would be greatly improved by the separation of water actively released, and that which is lost from the system via uncontrolled spills.

**Method**

Environmental flows were assessed by measuring the degree of compliance of the environmental water deliveries during the audit period with the environmental flow rules defined in the Water Sharing Plan. Eleven locations were assessed for environmental flows (**Table 12; Figure 13**). These cover the Warragamba, Shoalhaven, Upper Nepean and Woronora systems, and are consistent with the sites used for the environmental flows assessment in the 2010-2013 audit (GHD 2013).

**Table 13** summarises the environmental flow rules and exceptions for each of the storages assessed. Calculations of the environmental flow releases defined in the Water Licences and Approvals Package (NSW Office of Water 2012) were used to assess the percentage of time that these flow rules were achieved.

**Table 12. Dams and weirs assessed in the environmental flows analysis**

| Dam/Weir | Sub-catchment | River System |
|---|---|---|
| Warragamba Dam | Lake Burragorang | Warragamba System |
| Wingecarribee Dam | Wingecarribee River | Shoalhaven System |
| Tallowa Dam | Kangaroo River | Shoalhaven System |
| Fitzroy Falls | Kangaroo River | Shoalhaven System |
| Cataract Dam | Upper Nepean | Upper Nepean System |
| Cordeaux Dam | Upper Nepean | Upper Nepean System |
| Avon Dam | Upper Nepean | Upper Nepean System |
| Nepean Dam | Upper Nepean | Upper Nepean System |
| Broughtons Pass Weir | Upper Nepean | Upper Nepean System |
| Pheasants Nest Weir | Upper Nepean | Upper Nepean System |
| Woronora Dam | Woronora River | Woronora System |

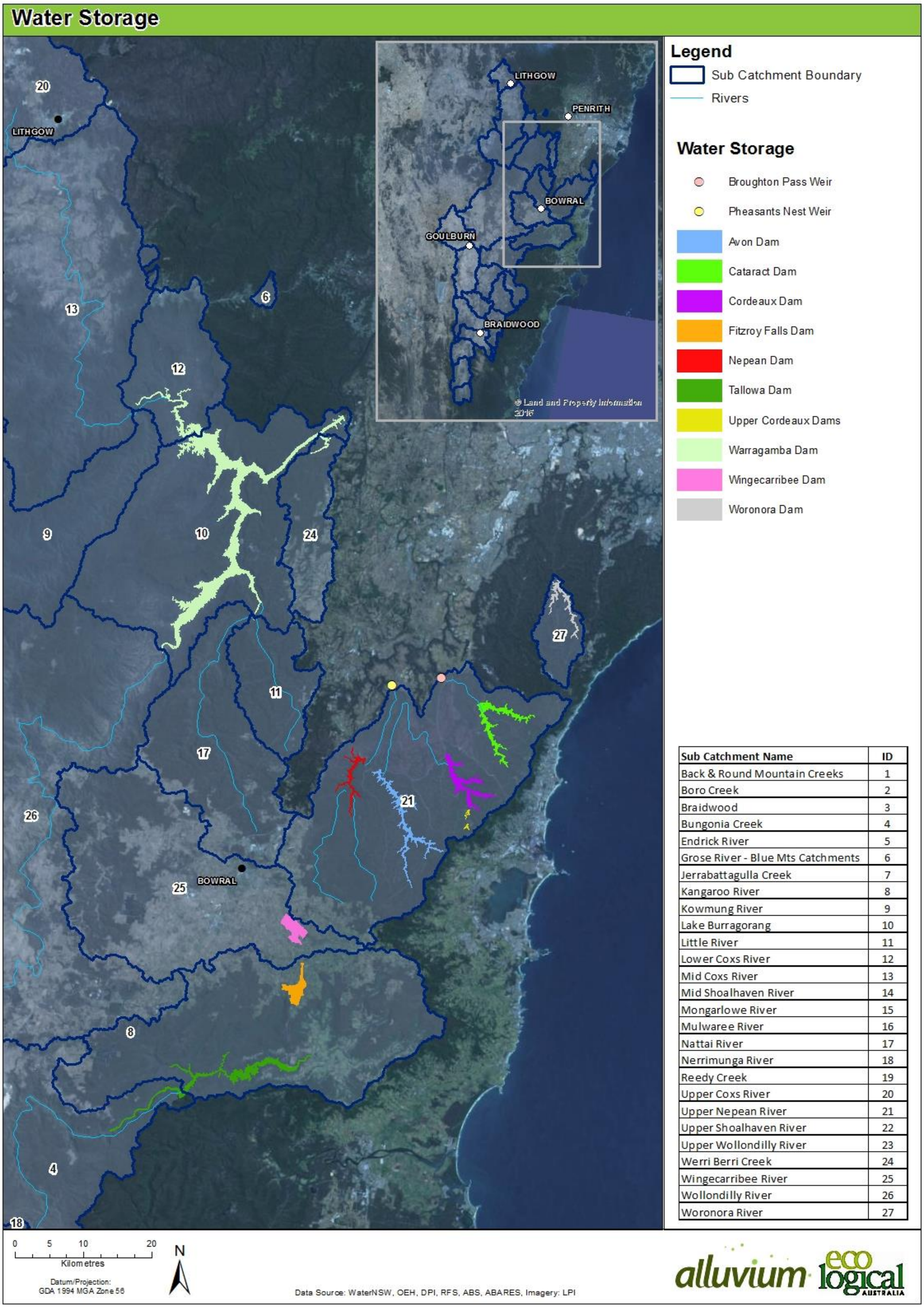



**Figure 13. Location of storages within the Sydney Catchment used in the environmental flows indicator analysis**

**Table 13. Environmental flow rules and exemptions for storages used in the audit analysis**

| Storage | Environmental flow rules | Exemptions |
|---|---|---|
| Warragamba Dam | - 5 ML/d from Warragamba pipeline to Megarritys creek all year<br>- 17 ML/d from 1 April to 31 October from Warragamba pipeline to Warragamba River<br>- 25 ML/d from 1 November to 31 March from Warragamba pipeline to Warragamba River | - The storage is spilling at a rate that equals or exceeds the release requirement<br>- The release cannot be met due to an emergency situation<br>- The release cannot be met due to capacity constraints or maintenance |
| Wingecarribee Dam | - Daily release = 3 ML/d measured at Sheepwash bridge (212275) | |
| Tallowa Dam | - When inflows to Lake Yarrunga are <= $80^{th}$ percentile daily flow* daily release equal to inflows must be made.<br>- When inflows into Lake Yarrunga are >$80^{th}$ percentile daily flow* then daily release of $80^{th}$ percentile + 20% of inflows must be released.<br>- Inflows measured at Kangaroo River at Hampden Bridge gauge (215220) and the Shoalhaven River at Fossickers Flat gauge (215207) | |
| Fitzroy Falls | - By the end of each month, five thirds of the month's inflow from Wildes Meadow Creek to Fitzroy Falls Reservoir has been released or met<br>- Inflows measured at Yarrunga Creek at Wildes Meadow gauge (215233) | - The storage is spilling at a rate that equals or exceeds the release requirement |
| Cataract Dam | - When inflows to Cataract Dam are <= $80^{th}$ percentile daily flow (14 ML/d) daily release equal to inflows must be made.<br>- When inflows into Cataract Dam are >$80^{th}$ percentile daily flow (14 ML/d) then daily release of 14 ML/d + 20% of inflows must be released.<br>- Inflows measured at Loddon River at Bulli Appin Road gauge (2122322) and the Cataract River at Corrimal No. 1 gauge (2122323) | - The storage is spilling at a rate that equals or exceeds the release requirement<br>- The release cannot be met due to an emergency situation<br>- The release cannot be met due to capacity constraints or maintenance |
| Cordeaux Dam | - When inflows to Cordeaux Dam are <= $80^{th}$ percentile daily flow (4.5 ML/d) daily release equal to inflows must be made.<br>- When inflows into Cordeaux Dam are >$80^{th}$ percentile daily flow (4.5 ML/d) then daily release of 6.8 ML/d + 20% of inflows must be released.<br>- Inflows measured at Goondarrin Creek at Kemira "D" Cast gauge (2122201) and the Sandy Creek at Cordeaux River gauge (2122205) | |
| Avon Dam | - When inflows to Avon Dam are <= $80^{th}$ percentile daily flow (6.8 ML/d) daily release equal to inflows must be made.<br>- When inflows into Avon Dam are >$80^{th}$ percentile daily flow (6.8 ML/d) then daily release of 6.8 ML/d + 20% of inflows must be released.<br>- Inflows measured at the Avon River at Summit Tank gauge (2122111) and the Flying Fox No. 3 Creek at Fire Road gauge (2122112) | |
| Nepean Dam | - When inflows to Nepean Dam are <= $80^{th}$ percentile daily flow (20.1 ML/d) daily release equal to inflows must be made.<br>- When inflows into Nepean Dam are >$80^{th}$ percentile daily flow (20.1 ML/d) then daily release of 20.1 ML/d + 20% of inflows must be released. | - The storage is spilling at a rate that equals or exceeds the release requirement |

| Storage | Environmental flow rules | Exemptions |
|---|---|---|
| | - Inflows measured at the Nepean River at Nepean Dam gauge (2122051) and the Burke River at Nepean Dam gauge (2122052) | - The release cannot be met due to an emergency situation<br>- The release cannot be met due to capacity constraints or maintenance |
| Broughtons Pass Weir | - Environmental flow released out of Cataract dam that day **PLUS**<br>- Inflows into catchment between Broughtons pass weir and cataract dam when inflow is <= $80^{th}$ percentile daily flow (4.4 ML/d)<br>- Flows into catchment between Broughtons pass weir and cataract dam are >$80^{th}$ percentile daily flow (4.4 ML/d) then daily release of 4.4 ML/d + 20% of inflows must be released.<br>- Inflows equal 0.24 x Inflows to Cataract Dam (NSW Office of Water, 2012) | |
| Pheasants Nest Weir | - Environmental flow released out of Avon, Nepean and Cordeaux dam that day **PLUS**<br>- Inflows into catchment between Pheasants nest weir and Avon, Nepean and Cordeaux dam when inflow is <= $80^{th}$ percentile daily flow (4.5 ML/d)<br>- Flows into catchment between Pheasants nest weir and Avon, Nepean and Cordeaux dam are >$80^{th}$ percentile then daily release of 4.5 ML/d + 20% of inflows must be released.<br>- Inflows equal 0.38 x Inflows to Avon Dam (NSW Office of Water, 2012) | |
| Woronora Dam | - When inflows to Avon Dam are <= $80^{th}$ percentile daily flow (20.1 ML/d) daily release equal to inflows must be made.<br>- When inflows into Woronora Dam are >$80^{th}$ percentile daily flow (20.1 ML/d) then daily release of 20.1 ML/d + 20% of inflows must be released.<br>- Inflows measured at Waratah Rivulet gauge (2132102) and the Woronora River (upstream of Woronora Dam) gauge (2132101) | |

* $80^{th}$ percentile inflows for Tallowa Dam are presented in **Table 14**
Source: Water Sharing Plan

**Table 14. 80th percentile inflows threshold to Tallowa Dam (to be read in conjunction with Table 13)**

| Month | Monthly flow threshold (ML/d) |
|---|---|
| January | 150 |
| February | 161 |
| March | 182 |
| April | 259 |
| May | 298 |
| June | 334 |
| July | 371 |
| August | 332 |
| September | 299 |
| October | 281 |
| November | 256 |
| December | 179 |

The analysis included comparing, on a daily time step, the required environmental flow requirement for each storage (as defined by the rules set out in **Table 13**) with the actual environmental flow release time series provided by WaterNSW. This was then compared to the time series of storage spill to account for days where the requirement was achieved with spills and hence a release wasn't required. The result was expressed as a percentage of days where the actual release met the environmental requirement.

***Status***

The status of the environmental flows indicator shows the degree of achievement of the environmental flow rules for each declared storage outlined in the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011. The categories used to determine status were:

- **Good** - Environmental flow rules were achieved more than 95% of the time.
- **Medium** - Environmental flow rules were achieved between 85-95% of the time.
- **Poor** – Environmental flow rules were achieved less than 85% of the time.

***Trend***

To assess the trend in environmental flow delivery at each declared storage, the degree of achievement of the environmental flow rules were compared between the 2010-13 audit period and the 2013-16 audit period. These periods were considered as they cover the duration of the current Water Sharing Plan for the Sydney Catchment and hence the current environmental rules. The categories used to determine the trend were:

- **Improving**: Proportion of time environmental flow rules were achieved increased by 5% or more from 2010-13 to 2013-16.
- **Stable**: Proportion of time environmental flow rules were achieved in 2013-16 was within 5% of the 2010-13 result
- **Worsening**: Proportion of time environmental flow rules were achieved reduced by 5% or more from 2010-13 to 2013-16.

***Data quality***

The data provided for this audit appeared to be of good quality and was complete over the years assessed for all stations. Therefore, for assessing compliance with environmental rules, the data was assessed as fit-for-purpose.

**Findings**

A total of 861,740 ML of environmental water was released from the 11 storages analysed during the 2013-16 audit period. This was less than the previous audit period, during which time 1,021,245 ML was delivered. This reduction is consistent with the reduced water availability across the Catchment in 2013-16 compared to the previous audit period (as discussed in **Section 3.1**). Releases from Tallowa Dam constituted around 50% of the environmental water released in 2013-16 (**Figure 14**), with Pheasants Nest Weir, which passes environmental flows out of Avon, Nepean and Cordeaux, being the next largest contributor of environmental water in the Catchment.

***Status***

**During the 2013-2016 audit period the environmental flow indicator achieved an overall good status rating, with nine of the storages obtaining a good rating and two storages a moderate rating (Table 15**

Table 15). Storages in the Warragamba, Upper Nepean and Woronora systems were all 98% or more compliant with the environmental flow requirement set out in the water sharing plan. However, in the Shoalhaven system, only Wingecarribee dam received a good rating, with Tallowa and Fitzroy Falls Dams achieving 93% and 92% compliance respectively, giving them a moderate rating. Interrogation of the data revealed that often, on the days (or months in the case of Fitzroy Falls dam) where the flow requirement was not met, the flow delivery was within 5-10 ML/d of the required flow. Therefore, only small improvements in environmental flow delivery would increase these storages to a good rating.

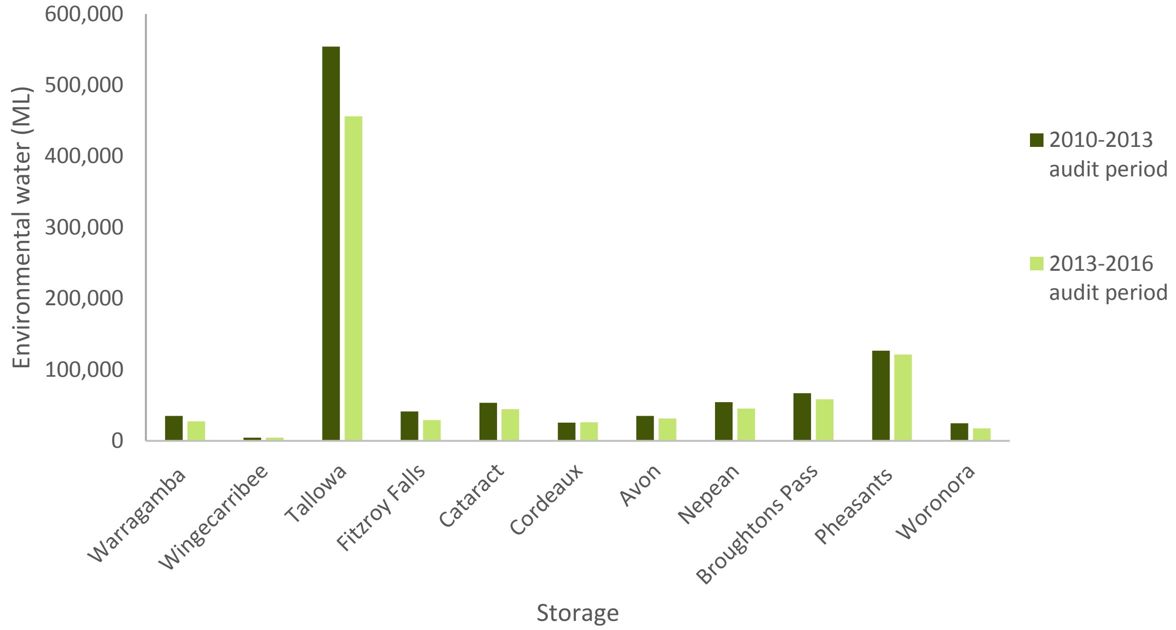



**Figure 14. Flow releases from the storages assessed in this audit (data from WaterNSW)**

**Table 15. Status results for the environmental flows indicator**

| Dam/Weir | Sub-catchment | River System | % Compliance | Status |
|---|---|---|---|---|
| Warragamba Dam | Lake Burragorang | Warragamba System | 99% | Good |
| Wingecarribee Dam | Wingecarribee River | Shoalhaven System | 100% | Good |
| Tallowa Dam | Kangaroo River | Shoalhaven System | 93% | Medium |
| Fitzroy Falls | Kangaroo River | Shoalhaven System | 92% | Medium |
| Cataract Dam | Upper Nepean | Upper Nepean System | 99% | Good |
| Cordeaux Dam | Upper Nepean | Upper Nepean System | 100% | Good |
| Avon Dam | Upper Nepean | Upper Nepean System | 98% | Good |
| Nepean Dam | Upper Nepean | Upper Nepean System | 99% | Good |
| Broughton Pass Weir | Upper Nepean | Upper Nepean System | 100% | Good |
| Pheasants Nest Weir | Upper Nepean | Upper Nepean System | 100% | Good |
| Woronora Dam | Woronora River | Woronora System | 100% | Good |
| | | Average | 98% | Good |

***Trend***
Comparison between the 2010-2013 and 2013-2016 audit periods (**Table 16**) revealed an overall stable trend with most of the storages remaining compliant with their environmental flow requirements. Exceptions to this were Fitzroy Falls dam which showed a worsening trend reducing in compliance from 100% in 2010-13, to 92% in 2013-16, and Nepean Dam which increased from 94% in 2010-13 to 99% in 2013-16. As discussed above, the worsening trend at Fitzroy Falls Dam in unlikely to be of major concern given the relatively small volumes of water needed to improve this trend in the future.

**Table 16. Trend results for the environmental flows indicator**

| Dam/Weir | Sub-catchment | River System | % Compliance | | Trend |
|---|---|---|---|---|---|
| | | | 2010-13 | 2013-16 | |
| Warragamba Dam | Lake Burragorang | Warragamba System | 100% | 99% | **Stable** |
| Wingecarribee Dam | Wingecarribee River | Shoalhaven System | 100% | 100% | **Stable** |
| Tallowa Dam | Kangaroo River | Shoalhaven System | 90% | 93% | **Stable** |
| Fitzroy Falls | Kangaroo River | Shoalhaven System | 100% | 92% | **Worsening** |
| Cataract Dam | Upper Nepean | Upper Nepean System | 99% | 99% | **Stable** |
| Cordeaux Dam | Upper Nepean | Upper Nepean System | 98% | 100% | **Stable** |
| Avon Dam | Upper Nepean | Upper Nepean System | 97% | 98% | **Stable** |
| Nepean Dam | Upper Nepean | Upper Nepean System | 94% | 99% | **Improving** |
| Broughton Pass Weir | Upper Nepean | Upper Nepean System | 96% | 100% | **Stable** |
| Pheasants Nest Weir | Upper Nepean | Upper Nepean System | 98% | 100% | **Stable** |
| Woronora Dam | Woronora River | Woronora System | 99% | 100% | **Stable** |
| | | Average | 97% | 98% | **Stable** |

**Conclusion**
The analysis considered the degree of compliance with the environmental flow rules outlined within the relevant resource plan and concluded that there are high levels of compliance. However future environmental flow accounting would be improved by separating the volume of water that is actively released from that which is lost from storages via uncontrolled spills. This would provide improved resolution on the effect of environmental flow rules on the water supply system, and as drivers for maintaining healthy aquatic ecological communities. This accounting will better inform any future inter-agency review of environmental flow rules.

## 3.3 Groundwater availability

**Definition and context**

Groundwater in the Sydney Catchment is a significant environmental and anthropogenic resource. Extraction of groundwater for human consumption, such as for drinking water or for agricultural and industrial use can reduce the water that is available for environmental water requirements, such as surface water base flow and maintaining of wetlands and other Groundwater Dependent Ecosystems (GDEs).

Groundwater use within the Sydney Catchment is managed by the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011, which covers 13 groundwater sources, eight of which are relevant for the Sydney Catchment (**Figure 15**). The Water Sharing Plan was made a statutory document in July 2011, which was within the audit period of the last Sydney Catchment Audit (GHD 2013). With the introduction of the Water Sharing Plan, the take of groundwater by consumptive uses and aquifer interference activities is required to be accounted for by a Water Access Licence unless an exemption applies.

Water sharing plans provide a legislative basis for sharing water between the environment and other purposes, and address licensing of the take and the use of groundwater. Through the separation of land and water the water sharing plans provide users with increased opportunities to trade water within a defined water source in accordance with the rules of the plan.

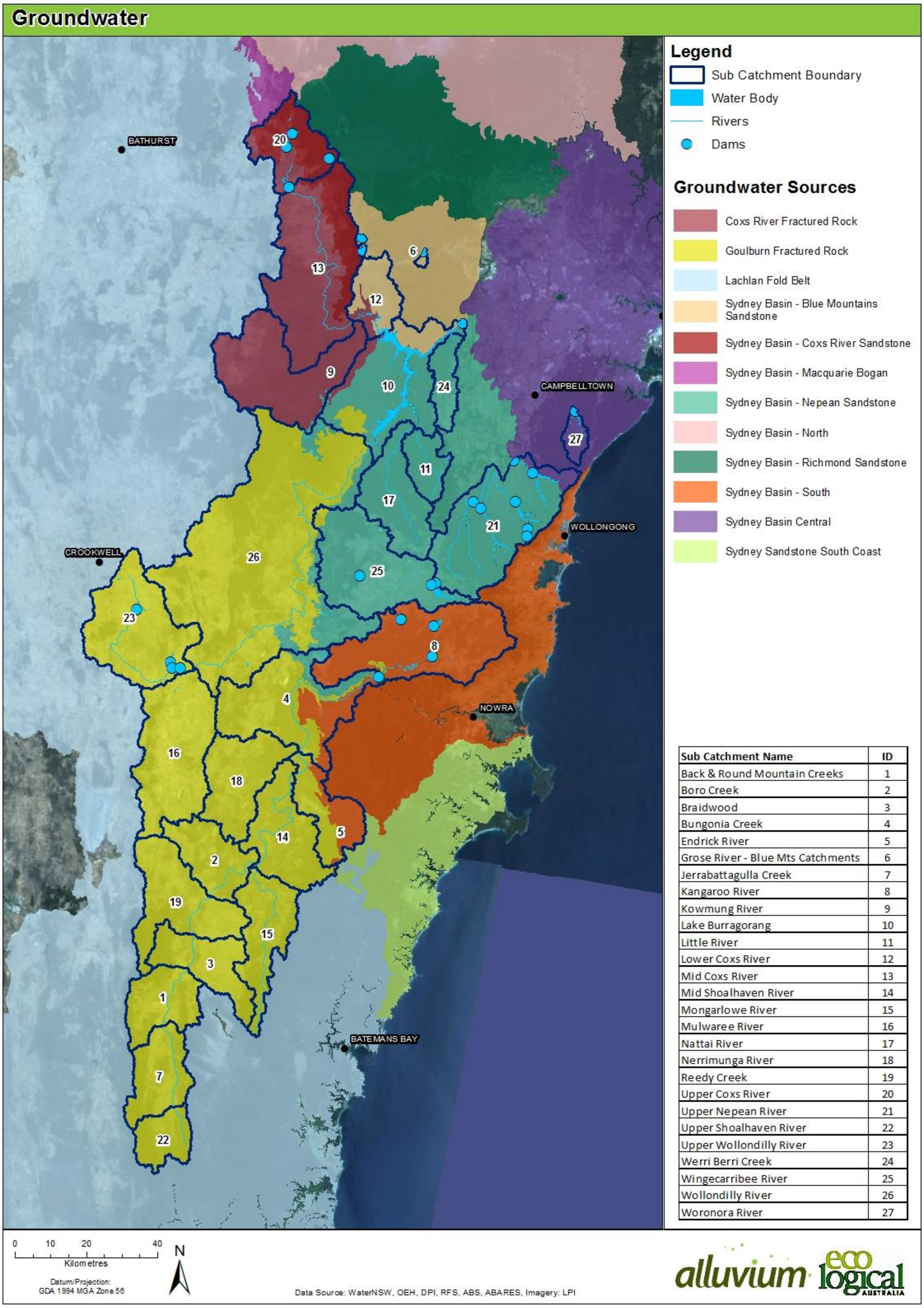
**Recharge rates and sustainable extraction limits**

Sustainable water trading requires a solid understanding of the volumes of groundwater recharge in each water source. For the Water Sharing Plan, recharge is estimated based on a percentage of infiltration of average annual rainfall. Initially the average rainfall for the time period between 1921 and 1995 was used to determine recharge (NOW 2011). However, the rainfall period has recently been extended up to 2012, which has resulted in small changes to recharge estimates in recent versions of the Plan (**Table 17**).

**Table 17. Groundwater recharge allocation for sustainable extraction limit estimation**

| | Low socio-economic risk | Moderate socio-economic risk | High socio-economic risk |
|---|---|---|---|
| **Low environmental risk** | 95% | 75%<br>Goulburn Fractured Rock<br>Cox River Fractured Rock | 50% |
| **Moderate environmental risk** | 75%<br>Sydney Basin North<br>Sydney Basin Blue Mountains<br>Sydney Basin Central | 50%<br>Sydney Basin South<br>Metropolitan Coastal Sands<br>Botany Sands<br>Hawkesbury Alluvium | 40%<br>Sydney Basin Richmond<br>Sydney Basin Nepean<br>Maroota Tertiary Sands |
| **High environmental risk** | 50% | 40%<br>Sydney Basin Cox River | 30% |

Source: Water Sharing Plan




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 15. Groundwater sources and the Catchment**

Recharge in high value conservation areas (such as national parks, nature reserves and historic and Aboriginal sites) are treated separately to recharge in the rest of the water source in that 95 or 100% of this recharge is reserved as planned environmental water and is therefore not available for water trading. In the remainder of the water source the percentage of recharge that is reserved as environmental water is determined by the sustainability factor, which weighs the environmental values in each groundwater source against the socio-economic dependence on groundwater. The sustainability factors used in the plan are determined based on a risk matrix and vary from 40 to 75%.

The part of the recharge that is not reserved as environmental water is included in the volume of water that is potentially available for extraction, which is termed the long-term average annual extraction limits (LTAAEL). Changes in the rainfall period used for recharge estimates have resulted in one small change in the LTAAEL in recent versions of the plan (**Table 18**).

**Table 18. Recharge and LTAAELs groundwater sources relevant to the Sydney Catchment**

| | | Recharge (ML/yr) | | LTAAEL (ML/yr) | |
|---|---|---|---|---|---|
| | Infiltration rates (%) [a] | 2013 audit [b] | Current audit [c] | 2013 audit [d] | Current audit [c] |
| Sydney Basin North | 6 | 269187 | 269187 | 19682 | 19682 |
| Sydney Basin South | 6 | 225326 | 225326 | 69892 | 69892 |
| Sydney Basin Nepean | 6 | 224483 | 224483 | 99568 | 99568 |
| Sydney Basin Richmond | 6 | 127878 | 127878 | 21103 | 21103 |
| Sydney Basin Blue Mountains | 6 | 78475 | **78474** | 7039 | 7039 |
| Sydney Basin Central | 6 | 229224 | **229223** | 45915 | 45915 |
| Sydney Basin Coxs River | 6 | 31312 | 31312 | 17108 | 17108 |
| Coxs River Fractured Rock | 4 | 66297 | **67087** | 6806 | **7005** |
| Goulbourn Fractured Rock | 4 | 259784 | 259784 | 53074 | 53074 |

[a] NOW (2011), [b] WSP (historical version 2011-2013), [c] WSP (version 1/1/2015), [d] GHD (2013)

The Water Sharing Plan included a provision to review recharge volumes and LTAAELs during the 5th year of the plan. This review has not been carried out. Instead it was decided to review recharge and LTAAELs for the issue of the updated plan in 2021. However, DPI Water has recently commissioned a review of rainfall recharge rates for coastal porous rock groundwater sources. This review has identified that the recharge rates that were used for coastal porous rock aquifers might be overestimating true recharge to the system (EMM 2015). This is relevant for the seven Sydney Basin groundwater sources in **Table 18**. Rather than a 6% infiltration rate as used in the plan, EMM (2015) recommend to use a 1% infiltration rate for Permian and 5% infiltration rate for Triassic sandstone in the Sydney Basin.

**Water allocations**

Part of the LTAAEL is reserved for basic landholder rights (BLR), which includes water for domestic and stock purposes that is extracted from an aquifer underlying the landholder's property. Under section 52 of the *Water Management Act 2000*, groundwater may be extracted to meet defined domestic and stock purposes without a licence, although the work (usually a bore) must still be approved by DPI Water. The *Water Management Act 2000* requires that water sharing must protect BLR, which is achieved by reserving a water volume for the water requirements for domestic and stock users.

The total licensed groundwater entitlement (TLGE) includes the volume for all current groundwater access licenses (WAL) under the *Water Management Act 2000*. These are licenses for local water utilities, for aquifer interference, for stock and domestic water use (other than BLR), as well as for general purpose water access for consumptive purposes such as industrial, irrigation and recreation. The TLGE does not include unresolved water licence applications and current aquifer interference activities that have not yet been assigned a volume (ie for which a WAL has yet to be issued).

Due to the separation of land and water, the WALs are not assigned to a specific location, but to an entire groundwater source. During this audit process the water volumes are therefore compared by groundwater source, rather than by the boundary of the Sydney Catchment. To be consistent with the 2013 audit this is carried out for the eight groundwater sources that were assessed during the 2013 audit (**Table 19**).

**Table 19. Water allocations for basic landholder rights and total licensed groundwater entitlement**

| | Volume reserved for BLR (ML/yr) | | TLGE (ML/yr) | | | | |
|---|---|---|---|---|---|---|---|
| **Groundwater source** | **2013 Audit [a]** | **2016 Audit [b]** | **2013 Audit [a]** | **2012/13 [c]** | **2013/14 [c]** | **2014/15 [c]** | **2015/16 [c]** |
| Coxs River Fractured Rock | 179 | **190** | 114 | **83.5** | 83.5 | 83.5 | **125.5** |
| Goulburn Fractured Rock | 3114 | 3114 | **3151** | **4370** | **4344** | 4344 | 4344 |
| SB Blue Mountains | 421 | 421 | 138 | **114.7** | **113.7** | 113.7 | 113.7 |
| SB Central | 2601 | 2601 | 2592 | **2475** | **2930.5** | **2940.5** | 2940.5 |
| SB Coxs River | 454 | 454 | 6926 | **6772.5** | **7092.5** | 7092.5 | **7421.5** |
| SB Nepean | 5971 | 5971 | 16294 | **18458.4** | **20359.4** | **20264.4** | **24577.4** |
| SB North | 722 | 722 | 557 | **692** | **812** | 812 | **912** |
| SB Richmond | 1623 | 1623 | 15923 | **957.5** | **3819.5** | **16460.5** | **16605.5** |
| SB South | 2098 | 2098 | 2880 | **3012** | **4549** | 4549 | **3102** |

[a] GHD (2013), [b] WSP (version 1/1/2015), [c] DPI NSW water registry

**Table 19** shows that the TLGE volumes extracted from the NSW water licence registry on the DPI website do not match the values given in the 2013 Audit. Closer inspection of this mismatch shows that the TLGE values used in the 2013 Audit were the approximate allocation volumes from the Water Sharing Plan background document (NOW 2011), which were based on allocation estimates of active water licences under the *Water Act 1992* rather than the total volume of WALs under *the Water Management Act 2000*.

GHD (2013) state that since 2011 most licences have been converted to WALs, however no quantification is given of how many licences were still managed under the *Water Act 1912*. As of the end of the 2016 Audit period the Sydney Catchment contained a total of three licences that were still managed under the *Water Act 1912*, with a total of 42 ML of entitlement. The differences in the TLGE given in the 2013 audit and those extracted from the NSW water registry is likely to be due to incomplete conversion of licences that were still managed under the *Water Act 1912*.

The percentage of LTAAEL that is allocated either as BLR or as TLGE is shown in **Figure 16**. It needs to be noted that these percentages do not include water allocations still managed under the *Water Act 1912*.

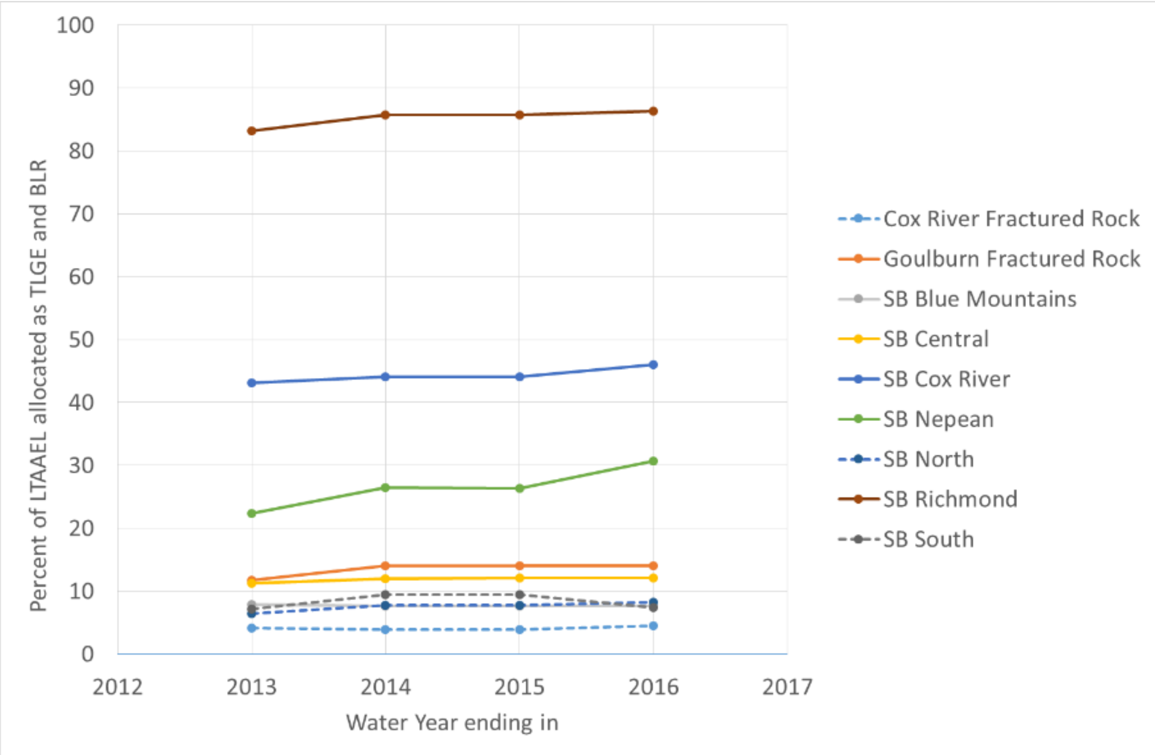



**Figure 16. Percent of LTAAEL allocated as TLGE and BLR**

The current groundwater allocations in all groundwater sources in the Sydney Catchment are within the limits set by the current water plan. However, it needs to be noted that these are the LTAAELs that were based on recharge rates, which based on EMM (2015) are likely to be overestimated for six of the water sources within the Sydney Catchment. These revised estimates will be considered as part of the remake of the Water Sharing Plan in 2021.

Recharge volumes and LTAAELs were recalculated based on the recommended recharge rates by EMM (2015). Results show that if these updated recharge rates were adopted, two of these groundwater sources are likely to be over allocated. These are the Sydney Basin Richmond Groundwater Source, due to its already high allocation percentage and the Sydney Basin Coxs River Groundwater Source, which has a large percentage of surface expression of Permian Sandstone and therefore a recommended recharge rate of 1% for large parts of the groundwater source.

**Water supply works**

Water Supply Work Approvals authorise a holder to construct and use a specific water supply work at a specific locations. Water supply works are either linked to a WAL, which specifies the volumetric extraction limits or they entitle the holder to extract water as part of BLR. Water supply works can include installation works such as wells, excavations, bores or spear points.

After removal of duplicates from the data, a total of 3598 licensed water supply works were identified in the Sydney Catchment at the end of the 2016 Audit period. 63 of these were licensed in the current Audit period (**Figure 17**). A total of 333 of these licences showed an 'ACTIVE' status, indicating that they have not yet been converted to the *Water Management Act 2000* and are still managed under the *Water Act 1912*. The majority of the bores that have not yet been converted are monitoring bores (292 bores) with the remainder being BLR bores for domestic, stock and farming purposes.

The total number of registered water supply works is about 6% higher than at the number reported during the previous audit period, when 3369 licensed bores were identified.

The 3598 licensed water supply works show a total of 51 registered purposes.  Eleven of these water works have a single bore purpose assigned to them, while the remaining 40 have multiple bore purposes assigned. Assignment of the works to one of the seven purpose categories used in the previous audit periods does therefore include a degree of interpretation bias.  For consistency the purposes categories used in the 2013 audit are maintained in **Table 20**.  To allow sensible assignment of all bore purposes three additional purpose categories were added.

As with the 2013 Audit, the majority of water supply works (80%) have a registered purpose of water use for stock and domestic purposes.  Other significant bore use categories are monitoring (8%) and irrigation (5%). Bore purposes have changed slightly between the 2013 audit and the current audit as can be seen in **Table 20**.

**Table 20. Registered water supply works**

| | 2013 Audit | | 2016 Audit | |
|---|---|---|---|---|
| | number of water supply works [a] | % of water supply works [b] | number of water supply works | % of water supply works |
| **Total number of Bores** | **3369** | N/A | **3598** | N/A |
| Contamination/Remediation | 68 | 2 | 1 | 0.03 |
| Mining | 17 | 0.5 | / | / |
| Aquaculture | 21 | 0.6 | 2 | 0.06 |
| Water Supply | 11 | 0.3 | 4 | 0.11 |
| Industrial | 108 | 3.2 | 43 | 1.20 |
| Irrigation | 260 | 7.7 | 195 | 5.42 |
| Stock/Domestic | 2884 | 85.6 | 2907 | 80.79 |
| Monitoring | / | / | 292 | 8.12 |
| Recreation | / | / | 24 | 0.67 |
| Other | / | / | 28 | 0.19 |
| No purpose listed | / | / | 102 | 2.83 |

[a] estimated based on percentages and total number of water supply works, [b] GHD 2013 Figure 4.6

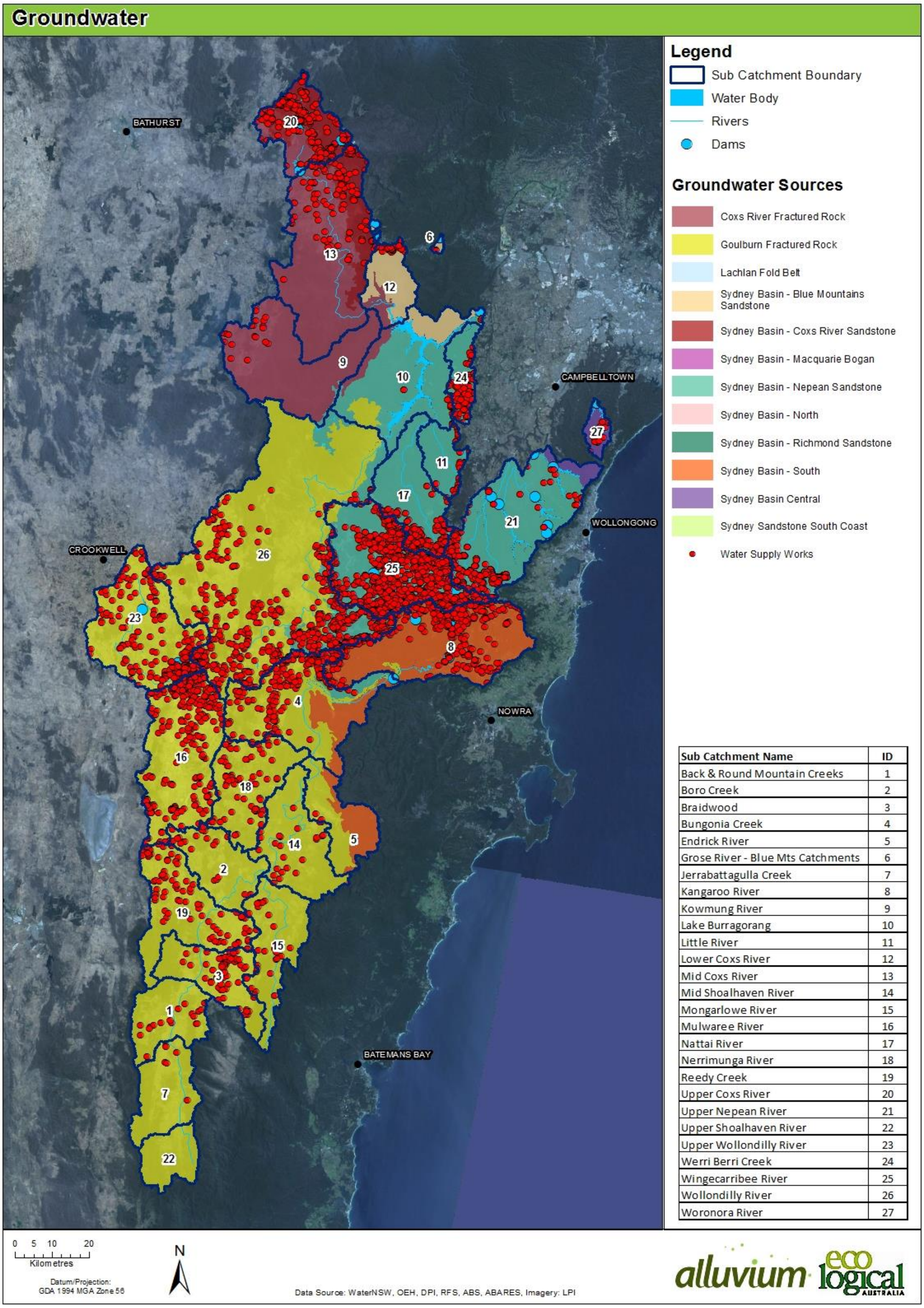
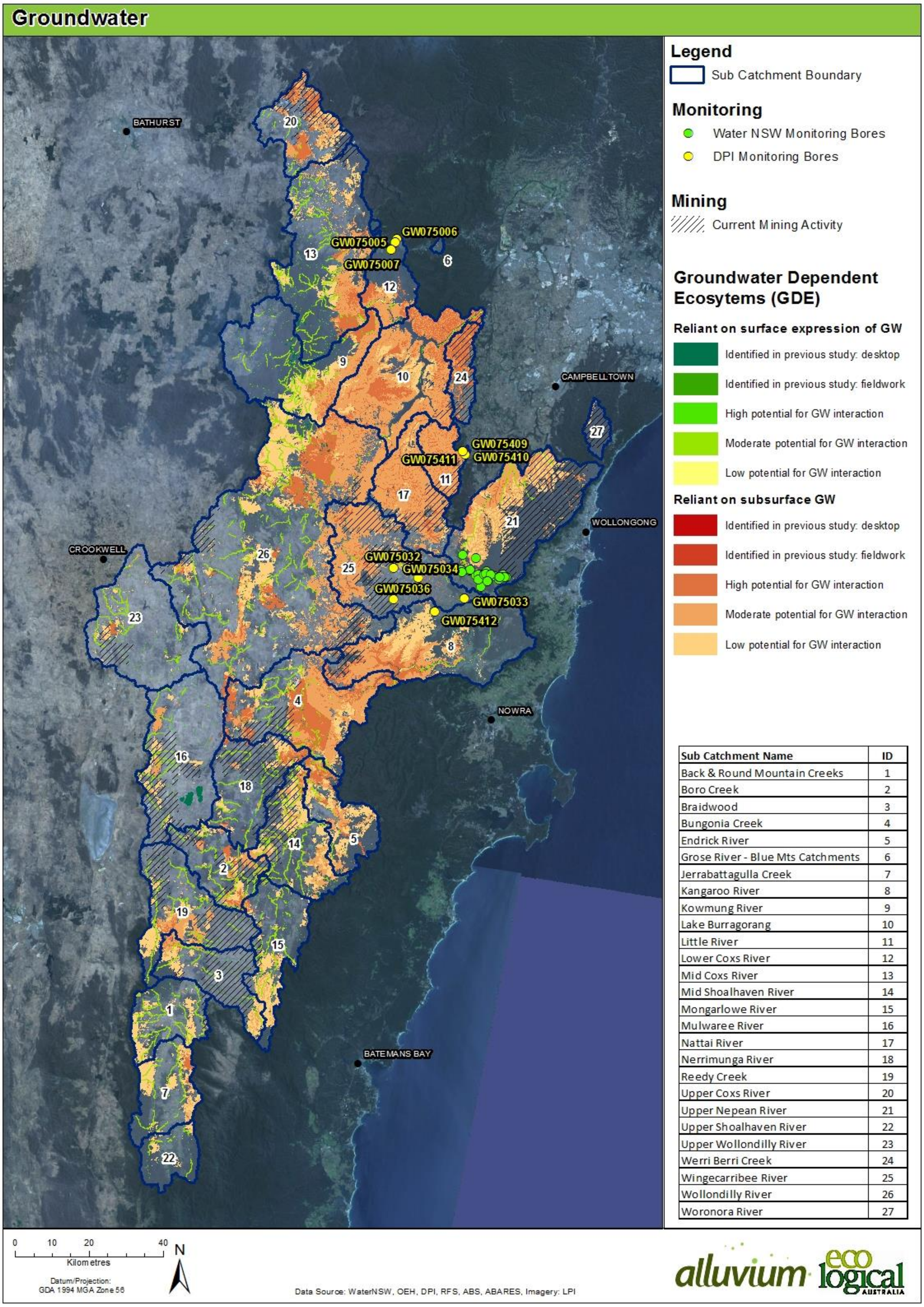



**Figure 17. Water supply works within the Sydney Catchment (data from DPI Water)**




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 18. Groundwater monitoring bores in relation to GDEs and active mining areas (from WaterNSW & DPI Water)**

**Groundwater level monitoring**
Groundwater level data has been provided by DPI Water and WaterNSW (**Figure 18**) for a total of 63 bores in the Sydney Catchment. DPI Water previously operated 18 monitoring bores that log groundwater level with automated data loggers. Those assets are now the responsibility of WaterNSW. Four of these monitoring locations are newly established in the Thirlmere Lakes area, and another two were installed in the Southern Highlands district as part of the same drilling campaign. These monitoring bores started collecting data in late 2012 and had therefore not been included in the 2013 Audit. One of the bores that was included in the 2013 Audit ceased data collection in 2012 and is therefore not included in this audit.

WaterNSW operates 45 monitoring bores in the south of the Upper Nepean River Surface Water Catchment. These bores were installed as a potential source of water during drought.

A summary table with water level observations for all monitoring bores is listed in **Volume 3**. Bore Hydrographs with daily rainfalls as well as cumulative rainfall departure curves (CRSC) of the nearest climate station are plotted in **Volume 3**. None of the 63 observation bores show any indication of a downward trend that would indicate a decline in groundwater storage in the Sydney Catchment. However, as shown in **Figure** 18, the monitoring bores cover a very small part of the catchment only and therefore are only able to provide a very localised picture of groundwater level trends in the catchment. Monitoring bores are not necessarily located near key extractive industries, such as mining areas, or near key GDEs within the catchment. This shortcoming of the monitoring locations in the Sydney Catchment has been highlighted during the 2013 audit and has been highlighted in a more general sense for NSW during the Independent Review of Coal Seam Gas Activities in NSW by the NSW Chief Scientist and Engineer.

It is anticipated that some of these monitoring shortcomings in the Sydney Catchment will be addressed by the NSW Water Monitoring Framework (WMF), which is a high profile commitment by the NSW Government to expand its groundwater monitoring network. A key element of the WMF is the Water Monitoring strategy for Coal Basins in NSW, which was guided by recommendations made in the Independent Review of Coal Seam Gas Activities in NSW by the NSW Chief Scientist and Engineer. The WMF identifies eight priority areas to target an expansion of the NSW public groundwater monitoring network, two of which are relevant for the Sydney Catchment. These are the Western Coalfields (South) and Southern Coalfields.

Capital funds of $22.8 million are anticipated to be used to update the public groundwater monitoring network in the eight priority areas through to 2019/20. Each monitoring bore will be equipped with logging instrumentation to measure water level, temperature and electrical conductivity of the groundwater and each bore will be constructed to allow regular water quality sampling. In addition to the expansion of the public monitoring network the WMF aims to harness water data collected by coal and CSG industries and to make this data publicly available through portals such as the DPI website.

**Conclusion**
The NSW Government has recognised the need to expand its groundwater monitoring network. This will include the Western Coalfields (South) and Southern Coalfields. Improved groundwater level monitoring in the Sydney Catchment means that subsequent audits will be able to carry out more relevant water level analysis. This will be important in determining the long term sustainability of groundwater resources across the Catchment.

# 4 Complementary catchment health indicators

## 4.1 Macroinvertebrates

**Definition and context**

Aquatic macroinvertebrates are small aquatic organisms that live in creeks and rivers, mainly on the stream bed. They are mostly aquatic insects and they perform several ecological functions such as processing stream organic matter and making nutrients and energy available for other organisms in river food chains (such as fish, birds, lizards and platypus). Aquatic ecosystems mostly have abundant macroinvertebrates present that represent complex assemblages of different species, and higher groupings (genera, families and orders).

Aquatic macroinvertebrates are widely used for measuring the ecological dimensions of water quality and they are generally highly responsive to water pollution and habitat quality (Rosenberg and Resh 1993). They are regarded as being very effective indicators of the biological health of rivers as they have demonstrated a very wide range of sensitivities to impaired water quality and disturbance of aquatic habitats (Cairns and Pratt 1993). Macroinvertebrate studies have well established utility for detection of ecological impairment of river ecosystems due to human activities such as urban development (Walsh et al. 2001), sewage (Wright et al. 1995) and water pollution from mining (Wright and Ryan 2016).

Macroinvertebrate data is often regarded as being complementary to water chemistry data (ANZECC 2000). Whilst water chemistry represents a series of 'snap-shots' of water quality, macroinvertebrates represent a cumulative measure of water quality (and habitat) conditions over their life cycles that range from weeks to years (Cairns and Pratt 1993).

**Data and methods**

The AUSRIVAS (Australian River Assessment System) is a widely used Australian methodology for conducting sampling, assessment and reporting of aquatic macroinvertebrates (ANZECC 2000). It compares actual (observed) macroinvertebrate results collected from sampling sites with modelled data that compares those results with predicted results (expected) for macroinvertebrate data in regional models based on collection from undisturbed reference sites (Turak and Waddel, undated). The AUSRIVAS ratio of observed to expected macroinvertebrates is used to classify the samples into a number of results bands (**Table 21**). This varies from Band X and Band A that represent healthy macroinvertebrate assemblages, to Band B, C and D that represent from moderate to severe biological impairment. The cause of the impairment is not revealed, and can be due to water pollution or to disturbance of river habitats.

**Table 21. AUSRIVAS criteria applied in this audit**

| Band Label (and traffic light shading for graphs) | Band Name | Comments |
|---|---|---|
| Band X | More biologically diverse than reference sites | More families found than expected. Indicative of a potential biodiversity hot-spot. |
| Band A | Reference condition | Most or all of the expected families found. Indicative that water quality and/or habitat condition is roughly equivalent to reference sites. |
| Band B | Significantly impacted | Fewer families than expected. Potential impact on water quality and/or habitat, or both. |
| Band C | Severely impacted | Many fewer families than expected. Loss of macroinvertebrate biodiversity due to substantial water quality and/or habitat quality. |
| Band D | Extremely impacted | Few of the expected families remain. Extremely poor water quality and /or habitat quality. |
| OEM | Outside experience of model | |

The Macroinvertebrate Monitoring Program for WaterNSW collected 376 samples of macroinvertebrates over the 2013-16 audit period. Sampling was conducted annually in autumn to early summer (October to December). According to information provided to the auditors there have been approximately 77 sampling sites investigated, spread across the 27 sub-catchments. Within each sub-catchment there were between 12 and 20 samples collected over the audit period.

The results for this indicator are grouped by sub-catchment for the audit period or annually across all sub-catchments. Average results are coloured green, amber and red based on the respective AUSRIVAS category. There are two shades of green representing a 'very good' (Band X: dark green) or 'good' (Band A: light green) classifications. The impairment categories of 'poor' representing significant ecological stress (Band B: Amber) or 'very poor' representing severe ecological stress (Band C: Red) were used. The poorest category that is indicative of extreme ecological stress is 'extremely poor' (Band D – Purple) was available, but no samples fell in that category.

**Findings**

Results from the previous audit period (2010-13) found that about 50% of macroinvertebrate samples collected were indicative of significant or severe ecological impact (AUSRIVAS results: Band B and Band C). This was considerably larger than earlier audits (2001 to 2009) where an average of 28% of samples were identified as being in either of these impaired categories (**Figure 19**). This worsening trend appears to have stabilised or slightly reversed during the current audit period (2013-16), although ongoing monitoring will be required to confirm this.

Results from the current audit period found that largest individual category was for AUSRIVAS Band A (Reference condition) which represented an average of 45% of samples. This is lower than the historic average (2001 to 2009) which recorded 52% of samples in this category. However, it does represent an improvement over the previous audit period (2010-13) which reported between 13% (2010), 40% (2011) and 28% (2012) of annual samples in Band A (**Figure 19**).

Some of the sub-catchment macroinvertebrate results showed substantial improvements compared to results from the previous audit (

**Table 22. Percentage of macroinvertebrate samples collected in 2013-16**

| Sub-catchment | Number of samples | Band X | Band A | Band B | Band C | Band D | Outside of Model Experience |
|---|---|---|---|---|---|---|---|
| Lower Cox's | 12 | 0.00 | 91.67 | 0.00 | 8.33 | 0 | 0.00 |
| Kowmung | 12 | 0.00 | 83.33 | 16.67 | 0.00 | 0 | 0.00 |
| Wollondilly | 24 | 8.33 | 70.83 | 8.33 | 4.17 | 0 | 8.33 |
| Kangaroo | 12 | 0.00 | 75.00 | 25.00 | 0.00 | 0 | 0.00 |
| Mid Cox's | 12 | 8.33 | 66.67 | 16.67 | 0.00 | 0 | 8.33 |
| Upper Shoalhaven | 16 | 0.00 | 68.75 | 31.25 | 0.00 | 0 | 0.00 |
| Mulwaree | 12 | 8.33 | 58.33 | 25.00 | 8.33 | 0 | 0.00 |
| Nattai | 12 | 0.00 | 66.67 | 33.33 | 0.00 | 0 | 0.00 |
| Upper Cox's | 12 | 16.67 | 41.67 | 16.67 | 0.00 | 0 | 25.00 |
| Upper Wollondilly | 12 | 0.00 | 58.33 | 33.33 | 8.33 | 0 | 0.00 |
| Endrick | 12 | 0.00 | 50.00 | 41.67 | 8.33 | 0 | 0.00 |
| Grose | 18 | 5.56 | 44.44 | 33.33 | 5.56 | 0 | 11.11 |
| Mongarlowe | 12 | 0.00 | 50.00 | 50.00 | 0.00 | 0 | 0.00 |
| Upper Nepean | 24 | 0.00 | 50.00 | 45.83 | 4.17 | 0 | 0.00 |
| Werri Berri | 12 | 0.00 | 50.00 | 50.00 | 0.00 | 0 | 0.00 |
| Wingecarribee | 12 | 8.33 | 41.67 | 41.67 | 8.33 | 0 | 0.00 |
| Reedy | 18 | 0.00 | 38.89 | 55.56 | 5.56 | 0 | 0.00 |
| Jerrabattgulla | 12 | 0.00 | 33.33 | 66.67 | 0.00 | 0 | 0.00 |
| Back + Round Mountain | 12 | 0.00 | 25.00 | 75.00 | 0.00 | 0 | 0.00 |
| Braidwood | 12 | 0.00 | 25.00 | 75.00 | 0.00 | 0 | 0.00 |
| Bungonia | 16 | 12.50 | 12.50 | 68.75 | 6.25 | 0 | 0.00 |
| Lake Burragorang | 12 | 0.00 | 25.00 | 50.00 | 25.00 | 0 | 0.00 |
| Little River | 12 | 0.00 | 25.00 | 75.00 | 0.00 | 0 | 0.00 |
| Nerrimunga | 20 | 0.00 | 20.00 | 60.00 | 20.00 | 0 | 0.00 |
| Boro | 12 | 0.00 | 16.67 | 58.33 | 25.00 | 0 | 0.00 |
| Mid Shoalhaven | 12 | 0.00 | 16.67 | 83.33 | 0.00 | 0 | 0.00 |
| Woronora | 12 | 0.00 | 8.33 | 83.33 | 8.33 | 0 | 0.00 |
| **Total** | **376** | **2.66** | **45.21** | **44.41** | **5.59** | 0 | **2.13** |

). The Lower Coxs sub-catchment had the largest proportion of samples in Band A (92%), compared to all sub-catchments in the current audit. This was a major improvement on the previous audit (44% of samples were in Band A; GHD 2013). The most substantial improvement in the current audit period was recorded in the Wollondilly sub-catchment which recorded the third highest proportion of samples in the highest two categories (Band X and Band A combined: 79%) compared to the second lowest result in the previous audit (17%; GHD 2013).

## Conclusion

The worsening trend for macroinvertebrates observed in the previous audit period appears to have stabilised or slightly reversed during the current audit period (2013-16), although ongoing monitoring will be required to confirm this result.

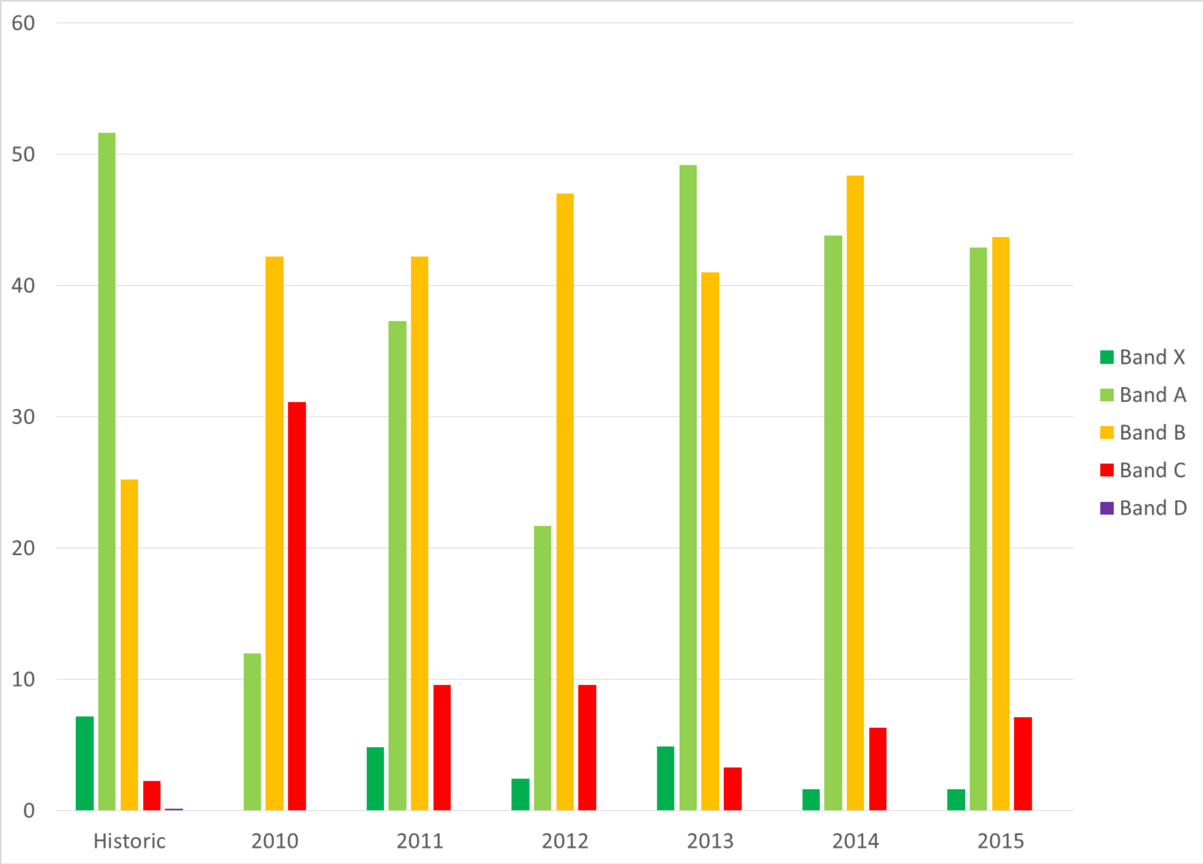



**Figure 19. Average annual AUSRIVAS categories for macroinverbrates across all catchment sites**

**Table 22. Percentage of macroinvertebrate samples collected in 2013-16**

| Sub-catchment | Number of samples | Band X | Band A | Band B | Band C | Band D | Outside of Model Experience |
|---|---|---|---|---|---|---|---|
| Lower Cox's | 12 | 0.00 | 91.67 | 0.00 | 8.33 | 0 | 0.00 |
| Kowmung | 12 | 0.00 | 83.33 | 16.67 | 0.00 | 0 | 0.00 |
| Wollondilly | 24 | 8.33 | 70.83 | 8.33 | 4.17 | 0 | 8.33 |
| Kangaroo | 12 | 0.00 | 75.00 | 25.00 | 0.00 | 0 | 0.00 |
| Mid Cox's | 12 | 8.33 | 66.67 | 16.67 | 0.00 | 0 | 8.33 |
| Upper Shoalhaven | 16 | 0.00 | 68.75 | 31.25 | 0.00 | 0 | 0.00 |
| Mulwaree | 12 | 8.33 | 58.33 | 25.00 | 8.33 | 0 | 0.00 |
| Nattai | 12 | 0.00 | 66.67 | 33.33 | 0.00 | 0 | 0.00 |
| Upper Cox's | 12 | 16.67 | 41.67 | 16.67 | 0.00 | 0 | 25.00 |
| Upper Wollondilly | 12 | 0.00 | 58.33 | 33.33 | 8.33 | 0 | 0.00 |
| Endrick | 12 | 0.00 | 50.00 | 41.67 | 8.33 | 0 | 0.00 |
| Grose | 18 | 5.56 | 44.44 | 33.33 | 5.56 | 0 | 11.11 |
| Mongarlowe | 12 | 0.00 | 50.00 | 50.00 | 0.00 | 0 | 0.00 |
| Upper Nepean | 24 | 0.00 | 50.00 | 45.83 | 4.17 | 0 | 0.00 |
| Werri Berri | 12 | 0.00 | 50.00 | 50.00 | 0.00 | 0 | 0.00 |
| Wingecarribee | 12 | 8.33 | 41.67 | 41.67 | 8.33 | 0 | 0.00 |
| Reedy | 18 | 0.00 | 38.89 | 55.56 | 5.56 | 0 | 0.00 |
| Jerrabattgulla | 12 | 0.00 | 33.33 | 66.67 | 0.00 | 0 | 0.00 |
| Back + Round Mountain | 12 | 0.00 | 25.00 | 75.00 | 0.00 | 0 | 0.00 |
| Braidwood | 12 | 0.00 | 25.00 | 75.00 | 0.00 | 0 | 0.00 |
| Bungonia | 16 | 12.50 | 12.50 | 68.75 | 6.25 | 0 | 0.00 |
| Lake Burragorang | 12 | 0.00 | 25.00 | 50.00 | 25.00 | 0 | 0.00 |
| Little River | 12 | 0.00 | 25.00 | 75.00 | 0.00 | 0 | 0.00 |
| Nerrimunga | 20 | 0.00 | 20.00 | 60.00 | 20.00 | 0 | 0.00 |
| Boro | 12 | 0.00 | 16.67 | 58.33 | 25.00 | 0 | 0.00 |
| Mid Shoalhaven | 12 | 0.00 | 16.67 | 83.33 | 0.00 | 0 | 0.00 |
| Woronora | 12 | 0.00 | 8.33 | 83.33 | 8.33 | 0 | 0.00 |
| **Total** | **376** | **2.66** | **45.21** | **44.41** | **5.59** | 0 | **2.13** |

## 4.2 Fish

**Definition and context**

The *Fisheries Management Act 1994* defines a 'fish' as any marine, estuarine or freshwater fish or other aquatic animal life at any stage of their life history (whether alive or dead). However, it excludes whales, mammals, reptiles, birds and amphibians which are managed under other legislation. Therefore, a 'fish' includes not only fin fish (including sharks), but also crustaceans, molluscs, worms, insects and other invertebrates.

**Data and method**

In 2016, DPI Fisheries released two state-wide models that identify likely current distribution of threatened fish and rate the condition of major waterways in respect to fish community status (Riches et al 2016). A third dataset for the study area was sourced from fish research conducted by DPI Fisheries.

**Potential distribution of threatened fish**

Using records of threatened species collected over the last 20 years, DPI Fisheries mapped indicative distributions for freshwater threatened species in NSW. A geographic model (maximum entropy) was used to predict the distribution for each listed freshwater species. The maps were created for regional and site based planning and assessments, and represent the last remaining known populations of the species in NSW or similar environmental areas that are suitable. The modelling excluded translocated populations, such as stocked Macquarie Perch in the Mongarlowe River, which is considered likely to be the result of a translocation from the Murray-Darling Basin (Lintermans 2008). Several threatened species were data-deficient and could not be modelled to the required accuracy, including the Adams Emerald Dragonfly and Sydney Hawk Dragonfly that have historically been recorded in the catchments.

Two threatened fish species are currently likely to occur within the Catchment: Fitzroy Falls Spiny Crayfish (49 km in Kangaroo River and Wingecarribee River sub-catchments) and Macquarie Perch (507 km in Lake Burragorang, Little River, Mid/Lower Coxs, Nattai River, Upper Nepean, Werri Berrie Creek, Wollondilly River and Woronora River sub-catchments) (**Figure 20**). Fitzroy Falls Spiny Crayfish is Critically Endangered species (*Fisheries Management Act 1994*) and can be confused with the common yabbie. It is only found in Wildes Meadow Creek, surviving as a remnant population, restricted to a small length of the waterway upstream from Fitzroy Falls.

The Australian Grayling is also mapped in the Catchment, but only as a result of mapping 'line work' crossing over a barrier (i.e. Shoalhaven River downstream of the Tallowa Dam towards Nowra).

**Fish community status**

A map using three conditions indicators including Expectedness, Nativeness and Recruitment was created by DPI Fisheries to show the condition of fish communities in NSW. The indicators were built from DPI Fisheries datasets, field sampling, environmental variables (National Hydrological Geospatial Fabric Version 2) and other modelling. The condition outcomes rate the fish communities as **Very Good, Good**, **Fair**, **Poor** or **Very Poor**.

A total of 3,547 km were assessed in the mapping project. Of this, fish community status is comprised of Fair (12%), Poor (63%) and Very Poor (24%) (**Figure 21**). Sub-catchments that have waterways with a predominantly very poor status are:

- Mulwaree River
- Nerrimunga River
- Upper Wollondilly River
- Wollondilly River

**Fish surveys**

DPI Fisheries conducted very few field surveys within the drinking water catchments during 2014-2016. Studies were conducted at six sites in Wildes Meadow Creek (Kangaroo River sub-catchment) (**Figure 22** and **Table 23**). Site selection and survey methods were driven by research and monitoring goals. For example, sites on Wildes Meadow Creek were equally spaced to survey for Fitzroy Falls Spiny Crayfish, using bait traps (pers comm DPI Fisheries, Narrandera). As bait traps were the only method applied for targeted crayfish surveys, large-bodied fish were not captured. Therefore, those data are not a reflection of the entire fish community. Although the surveys suited the individual research program, the resulting data do not reflection the condition of the entire Catchment. Therefore, the fish data for this audit are insufficient to determine a trend across time. Other fish surveys or sightings were obtained from one mining fish monitoring report (Cardno 2015 – other mines either don't sample fish or don't release records), Blue Mountains City Council crayfish surveys (McCormack 2016) and other records lodged on The Atlas of Living Australia database (accessed 06/02/2017) (**Table 24**).

Results of fish surveys are presented in **Table 25**, formatted to build on previous audit results. In summary, at the six survey sites seven species were caught, comprised of five native and two introduced fishes. Unlike previous audits, these data include invertebrates (crayfish and yabbies).

**Table 23. Location of fish surveys sites during the audit period**

| Sub-catchment | Waterbody name | Site name | Latitude | Longitude | Source |
|---|---|---|---|---|---|
| Kangaroo River | Wildes Meadow Creek | Grants | -34.60068 | 150.52959 | DPI Fisheries |
| Kangaroo River | Wildes Meadow Creek | Boote's | -34.5973 | 150.5399 | DPI Fisheries |
| Kangaroo River | Wildes Meadow Creek | Mid Canal | -34.6239 | 150.50964 | DPI Fisheries |
| Kangaroo River | Wildes Meadow Creek | Fitzroy Falls NPWS Picnic Area | -34.64608 | 150.48405 | DPI Fisheries |
| Kangaroo River | Wildes Meadow Creek | Wildes Down | -34.62358 | 150.50946 | DPI Fisheries |
| Kangaroo River | Wildes Meadow Creek | Wildes Bridge | -34.60612 | 150.51897 | DPI Fisheries |
| Kangaroo River | Wildes Meadow Creek | Fitzroy Falls | -34.64608 | 150.48405 | Atlas of Living Australia (2014) |
| Mid Coxs River | Jenolan River | Blue Lake | -33.81972 | 150.02507 | Atlas of Living Australia (2016) |
| Reedy Creek | Shoalhaven River | Kings Hwy | -35.34266 | 149.73806 | Atlas of Living Australia (2013) |
| Upper Coxs River | Jamisons Creek | Lithgow | -33.43139 | 150.19471 | McCormack (2016) |
| Upper Nepean River | Wongawilli Creek | Dendrobium | -34.37872 | 150.72520 | Cardno (2015) |

**Conclusion**

Lack of data means that it is not possible to determine the state or trends of populations of threatened fish species, fish communities or diversity of fish species. The streams across the Catchment are rated by the DPI Fish Community Status model as Fair (12%), Poor (63%) and Very Poor (24%). This is the first time this approach has been used and no trend can be drawn at this stage. Similarly fish survey data are insufficient to determine trends since the previous audit.

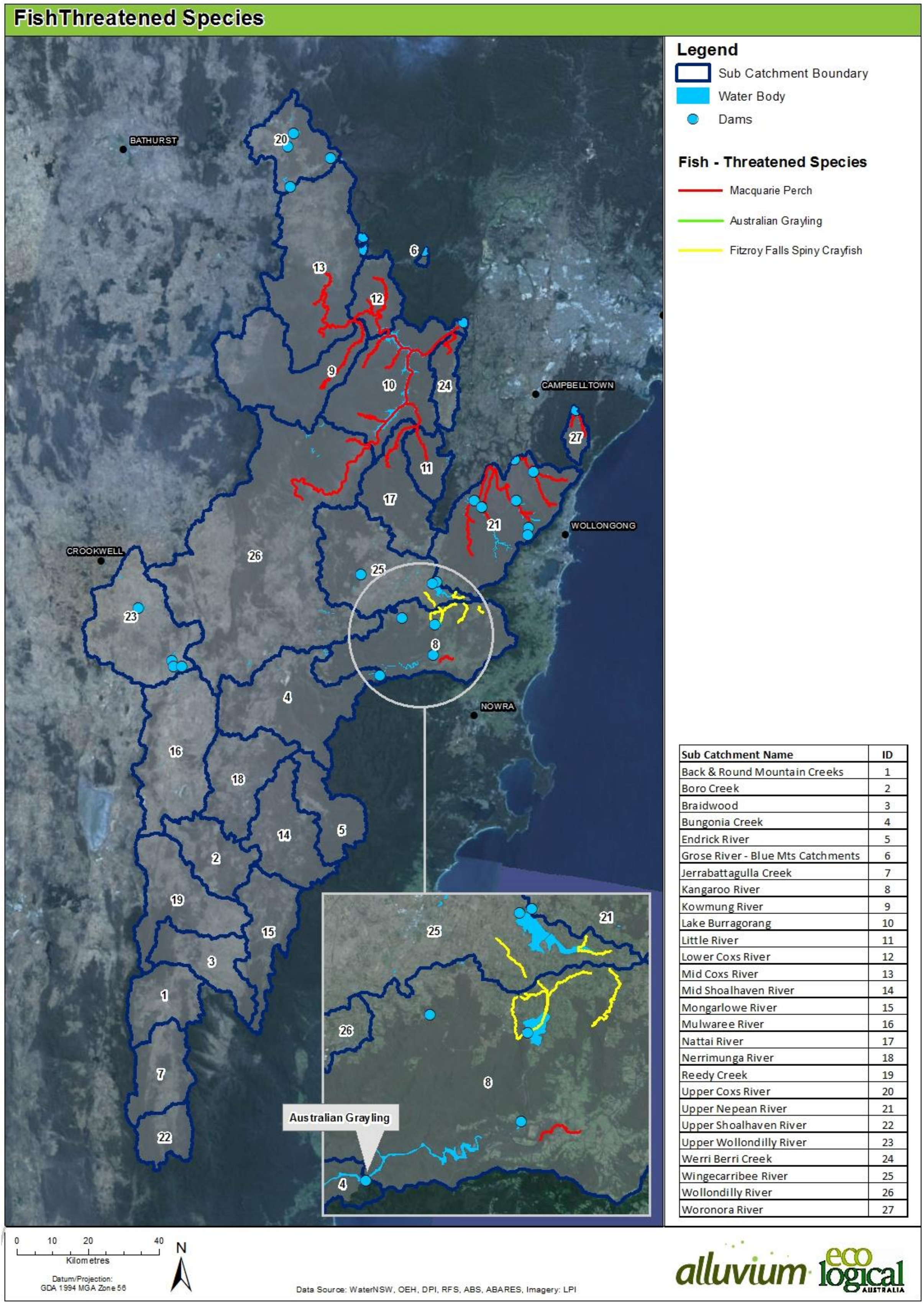



**Figure 20. Likely threatened species distribution in the study area (from Riches et al 2016)**

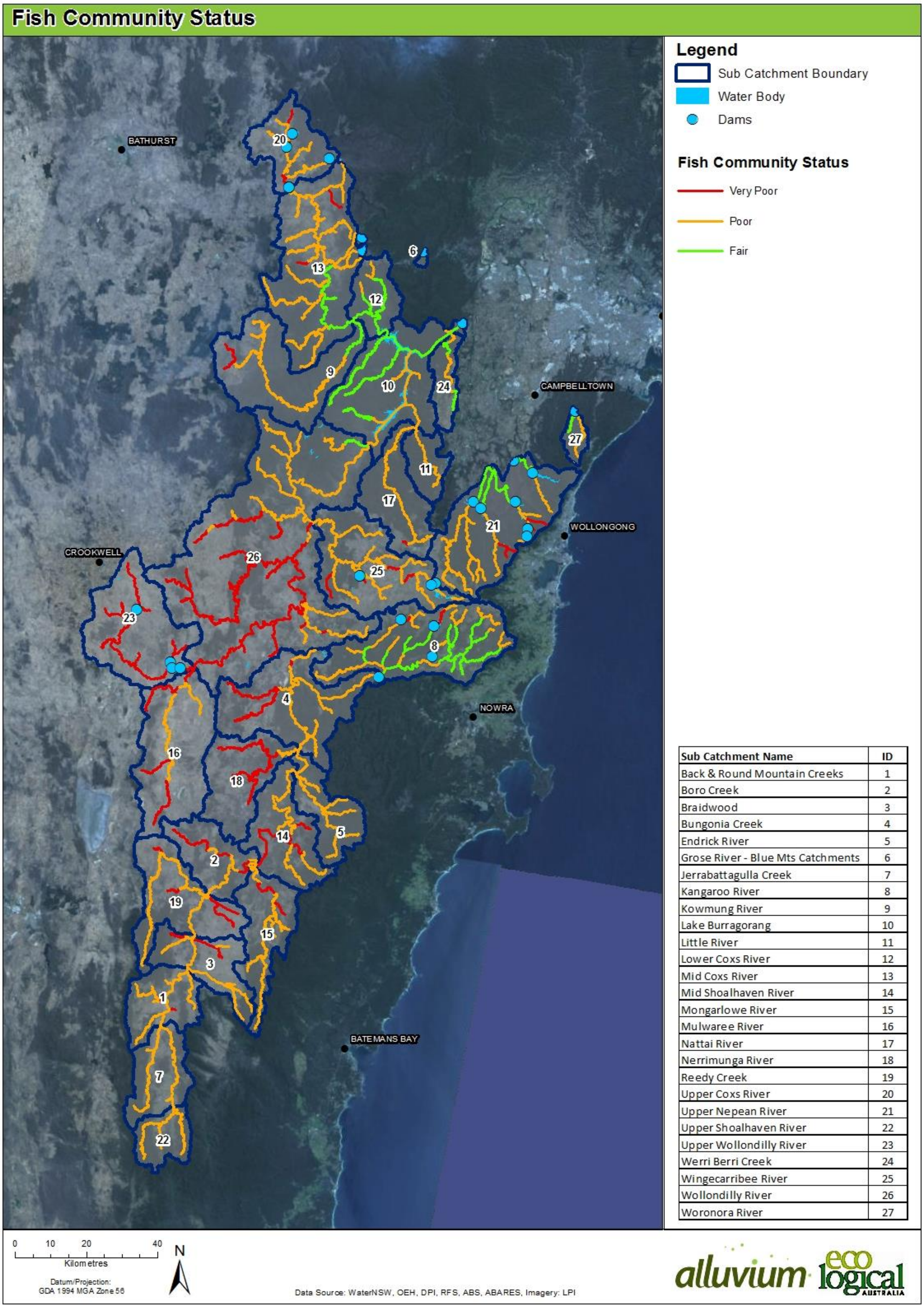



**Figure 21. Fish community status in the study area (from Riches et al 2016)**

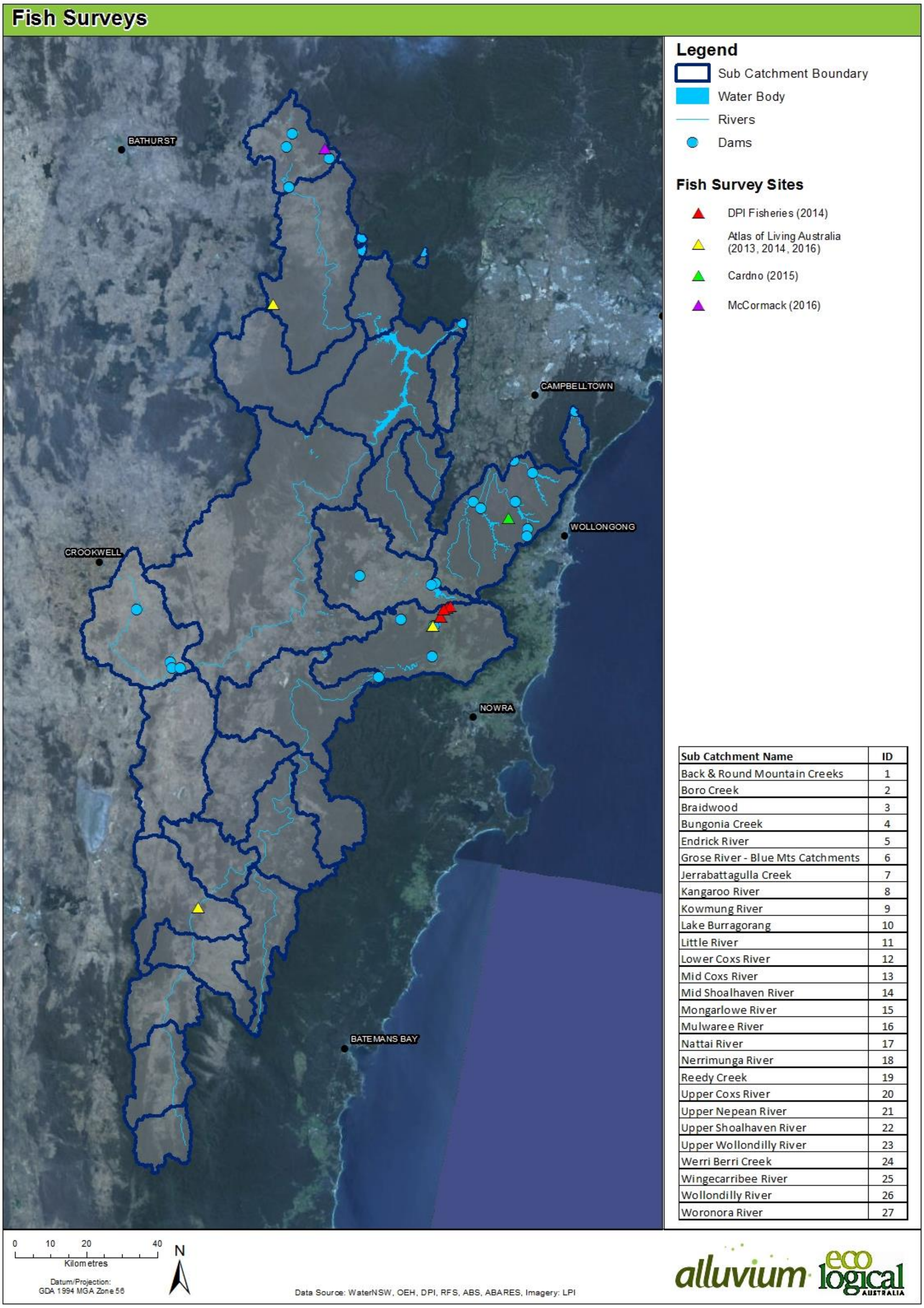



**Figure 22. Location of fish surveys conducted by DPI Fisheries (June 2013 to June 2016)**

**Table 24. Fish species expected to occur and collected between June 2005 and June 2016 in the Catchment**

| Family | Common name | Species | Status | Expected to occur | June 2005 – June 2007 | July -2007 – June 2010 | July 2010 – June 2013 | July 2013 – June 2016 |
|---|---|---|---|---|---|---|---|---|
| Anguilidae | Short-finned eel | *Anguilla australis* | Native | x | x | x | x | x |
| | Long-finned eel | *Anguilla reinhardtii* | Native | x | x | x | x | |
| | Silver perch | *Bidyanus bidyanus* | Native | | x | | x | |
| Clupeidae | Freshwater herring | *Potamalosa richmondia* | Native | x | | | x | |
| Galaxiidae | Climbing galaxias | *Galaxias brevipinnis* | Native | x | x | | x | |
| | Common jollytail | *Galaxias maculatus* | Native | x | | | x | |
| | Mountain galaxias | *Galaxias olidus* | Native | x | x | x | x | x |
| Eleotridae | Striped gudgeon | *Gobiomorphus australis* | Native | x | x | x | x | |
| | Cox's gudgeon | *Gobiomorphus coxii* | Native | x | x | x | x | x |
| | Empire gudgeon | *Hypseleotris compressa* | Native | x | | | x | |
| | Firetail gudgeon | *Hypseleotris gaii* | Native | x | | x | x | |
| | Western carp-gudgeon | *Hypseleotris klunzingeri* | Native | | x | x | x | x |
| | Unidenfitied carp-gudgeon | *Hypseleotris spp* | Native | | x | | x | |
| | Flat-headed gudgeon | *Philypnodon grandiceps* | Native | x | x | x | x | x |
| | Dwarf flat-headed gudgeon | *Philypnodon macrostomus* | Native | x | x | x | x | x |
| Mordaciidae | Shortheaded lamprey | *Mordacia mordax* | Native | x | | | | |
| Mugilidae | Sea mullet | *Mugil cephalus* | Native | x | | | x | |
| | Freshwater mullet | *Trachystoma petardi* | Native | x | | | x | |
| Parastacidae | Sydney Crayfish | *Euastacus australasiensis* | Native | x | | | | x |
| | Fitzroy Falls spiny crayfish | *Euastacus dharawalus* | Native | x | | | | x |
| | Giant Spiny Crayfish | *Euastacus spinifer* | Native | x | | | | x |
| | Yabby | *Cherax destructor* | Native | x | | | | x |
| Percichthyidae | Macquarie Perch | *Macquaria australasica* | Native | x | x | x | x | |
| | Estuary Perch | *Macquaria colonorum* | Native | x | | | | |
| | Australian bass | *Macquaria novemaculeata* | Native | x | x | x | x | |
| | Trout cod | *Maccullochella macquariensis* | Native | | | | x | |
| | Murray cod | *Maccullochella peelii* | Native | | x | | | |
| | Trout cod-Murray cod hybrid | *Maccullochella hybrid* | Native | | | | x | |
| Petromyzontidae | Lamprey | *Mordacia praecox* | Native | | | x | | |
| Plotosidae | Freshwater catfish | *Tandanus tandanus* | Native | | x | x | x | |
| Pseudomugilidae | Southern blue eye | *Pseudomugil signifer* | Native | x | | | | |
| Retropinnidae | Australian smelt | *Retropinna semoni* | Native | x | x | x | x | x |
| | Australian grayling | *Prototroctes maraena* | Native | x* | | | | |

| Family | Common name | Species | Status | Expected to occur | June 2005 – June 2007 | July -2007 – June 2010 | July 2010 – June 2013 | July 2013 – June 2016 |
|---|---|---|---|---|---|---|---|---|
| Tetrarogidae | Bullrout | *Notesthes robusta* | Native | x | | | x | |
| | Goldfish | *Carassius auratus* | Introduced | | x | x | x | |
| | Common carp | *Cyprinus carpio* | Introduced | | x | x | x | |
| Poeciliidae | Eastern gambusia | *Gambusia holbrooki* | Introduced | | x | x | x | x |
| Cobitidae | Oriential weatherloach | *Misgurnus anguillicaudatus* | Introduced | | x | x | x | x |
| Salmonidae | Rainbow trout | *Oncorhynchus mykiss* | Introduced | | x | x | x | x |
| | Brown trout | *Salmo trutta* | Introduced | | x | x | x | |
| Percidae | Redfin perch | *Perca fluviatilis* | Introduced | | x | x | | |

* Australian Grayling (listed as Endangered under the FM Act in 2015) was previously thought to be expected in the Catchment, but no longer likely except downstream of Tallowa Dam (see distribution mapping in Riches et al 2016).

**Table 25. Number of native and introduced fish species collected in the Catchment between June 2005 and June 2016**

| | June 2005 -June 2007 | | | | July 2007 - June 2010 | | | | July 2010 - June 2013 | | | | July 2013 - June 2016 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sub-catchment** | **Sites Sampled** | **Native** | **Introduced** | **Species richness** | **Sites Sampled** | **Native** | **Introduced** | **Species richness** | **Sites Sampled** | **Native** | **Introduced** | **Species richness** | **Sites Sampled** | **Native** | **Introduced** | **Species richness** |
| Boro Creek | | | | | 2 | 0 | 3 | 3 | | | | | | | | |
| Bungonia Creek | 4 | 7 | 2 | 9 | 5 | 8 | 3 | 11 | 7 | 17 | 4 | 21 | | | | |
| Endrick Creek | | | | | 1 | 3 | 0 | 3 | 1 | 2 | 0 | 2 | | | | |
| Kangaroo River | 5 | 7 | 2 | 9 | 8 | 7 | 3 | 10 | 24 | 9 | 2 | 11 | 7 | 5 | 2 | 7 |
| Kowmung River | | | | | 3 | 0 | 3 | 3 | 3 | 1 | 1 | 2 | | | | |
| Lake Burragorang | 4 | 7 | 1 | 8 | 3 | 10 | 3 | 13 | 1 | 3 | 2 | 5 | | | | |
| Little River | 1 | 1 | 0 | 1 | 4 | 4 | 2 | 6 | 4 | 6 | 2 | 8 | | | | |
| Lower Coxs River | 2 | 5 | 2 | 7 | 1 | 4 | 1 | 5 | | | | | | | | |
| Mid Coxs River | 2 | 1 | 2 | 3 | 4 | 2 | 3 | 5 | 4 | 2 | 3 | 5 | 1 | | 1 | 1 |
| Mid Shoalhaven River | 1 | 2 | 0 | 2 | | | | | 1 | 2 | 1 | 3 | | | | |
| Mongarlowe River | 3 | 5 | 0 | 5 | 1 | 4 | 3 | 7 | 2 | 5 | 3 | 8 | | | | |
| Mulwaree River | 1 | 0 | 2 | 2 | 1 | 2 | 1 | 3 | 1 | 0 | 2 | 2 | | | | |
| Nattai River | 2 | 3 | 1 | 4 | | | | | | | | | | | | |
| Reedy Creek | | | | | | | | | 1 | 2 | 0 | 2 | 1 | 1 | | 1 |
| Upper Coxs River | | | | | | | | | 7 | 3 | 4 | 7 | 6 | 5 | 0 | 5 |
| Upper Nepean River | 12 | 12 | 1 | 13 | 17 | 11 | 2 | 13 | 16 | 13 | 2 | 15 | 16 | 4 | 0 | 4 |
| Upper Shoalhaven River | | | | | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 4 | | | | |
| Upper Wollondily River | 3 | 2 | 2 | 4 | | | | | 2 | 3 | 3 | 6 | | | | |
| Werri Berri Creek | 1 | 2 | 2 | 4 | | | | | | | | | | | | |
| Wingecarribee River | 2 | 2 | 0 | 2 | 3 | 2 | 3 | 5 | 1 | 2 | 1 | 3 | | | | |
| Wollondily River | 6 | 6 | 5 | 11 | 11 | 6 | 4 | 10 | 2 | 4 | 2 | 6 | | | | |
| Woronora River | | | | | 2 | 2 | 1 | 3 | 1 | 1 | 0 | 1 | | | | |

## 4.3 Riparian vegetation

**Definition and context**

The riparian zone is the land adjacent to watercourses that is influenced by the stream, and has an influence on the stream. The width of a riparian zone varies depending on soil type, hydrology and topography. Riparian zones are widely acknowledged as important elements of the landscape because they influence the flows of energy and nutrients across the terrestrial and aquatic ecosystems, perform functions that help to maintain aquatic ecosystems, and provide a range of ecosystem services. The importance of riparian vegetation is detailed in the *Fisheries Management Act 1994* (FM Act), which identifies 'the degradation of native riparian vegetation along New South Wales watercourses' as a key threatening process.

Under the *Water Management Act 2000* (WM Act) the expected width of the riparian zone is more prescriptive, with set riparian widths required for certain developments on waterfront land. Waterfront land includes the bed and bank of any river, lake or estuary and all land within 40 m of the highest bank of the river, lake or estuary. The prescribed riparian corridor widths are based on a hierarchical system, termed Strahler Stream Order, where small headwater streams have a 10 m riparian corridor on each side, up to the largest stream requiring a 40 m zone on each side. The following analysis adopts this classification when summarising riparian land.

**Data**

The previous 2013 audit presented detail regarding length of rivers with associated riparian zones, extent and connectivity of vegetated riparian land, proportion of native vs invasive plants, and length of streams accessed by stock. However, those data were mostly drawn from older reports and datasets:

- 110,000 km of river length with associated riparian zone (2009 data)
- 81,125 ha of riparian zone, of which native vegetation covered 54,787 ha (64.5%) and 23,806 ha was pasture (2003 data)
- 38,753 km (35% of stream length) of watercourse currently being, or had the potential to be, accessed by stock (2009 data)
- Proportion of native woody/non-woody and non-native/invasive vegetation presented in the Riparian Vegetation Extent (RVE) dataset and Hybrid Riparian Native Vegetation Extent (HRNVE) dataset that contributed to the NSW River Condition Index (RCI) (2010 data).

The type of data available for the current 2016 audit is limited to broad mapping and assumptions, and may not be directly comparable to data presented in previous audits. The RCI, RVE and HRNVE datasets have not been updated. New or updated methods have been developed for assessing river (and wetland) condition, but application of those studies are focused on inland draining catchments (i.e. west of the study area). For example, the RCI (DPI 2012) draws on the Framework for the Assessment of River and Wetland Health (FARWH) (Turak et al. 2011), but that has only been applied in the Murray-Darling Basin (pers comm. OEH). As such, only three datasets were available for this audit:

- Strahler stream order mapping and associated riparian buffers
- Riparian buffers in grazing
- Collated information from local councils on riparian management

Other data that may include the riparian zone is presented elsewhere in this audit, such as wetlands (**Section 4.6**), physical form (**Section 4.7**) and soil (gully) erosion (**Section 5.3**).

**Strahler stream order mapping and associated riparian buffers**

Drainage lines identified on 1:25,000 topographic maps are used by DPI Water as a trigger for waterfront land, or at least use that as a starting point for ground validation at a finer scale. Each drainage line has a prescribed Strahler stream order classification between 1 and 11 across NSW. The study area contains 52,948 km of watercourses: 30,467 km of 1$^{st}$ order streams, 11,044 km of 2$^{nd}$ order, 5,549 km of 3$^{rd}$ order and 5,889 km of 4$^{th}$ order and above (**Figure 23**).

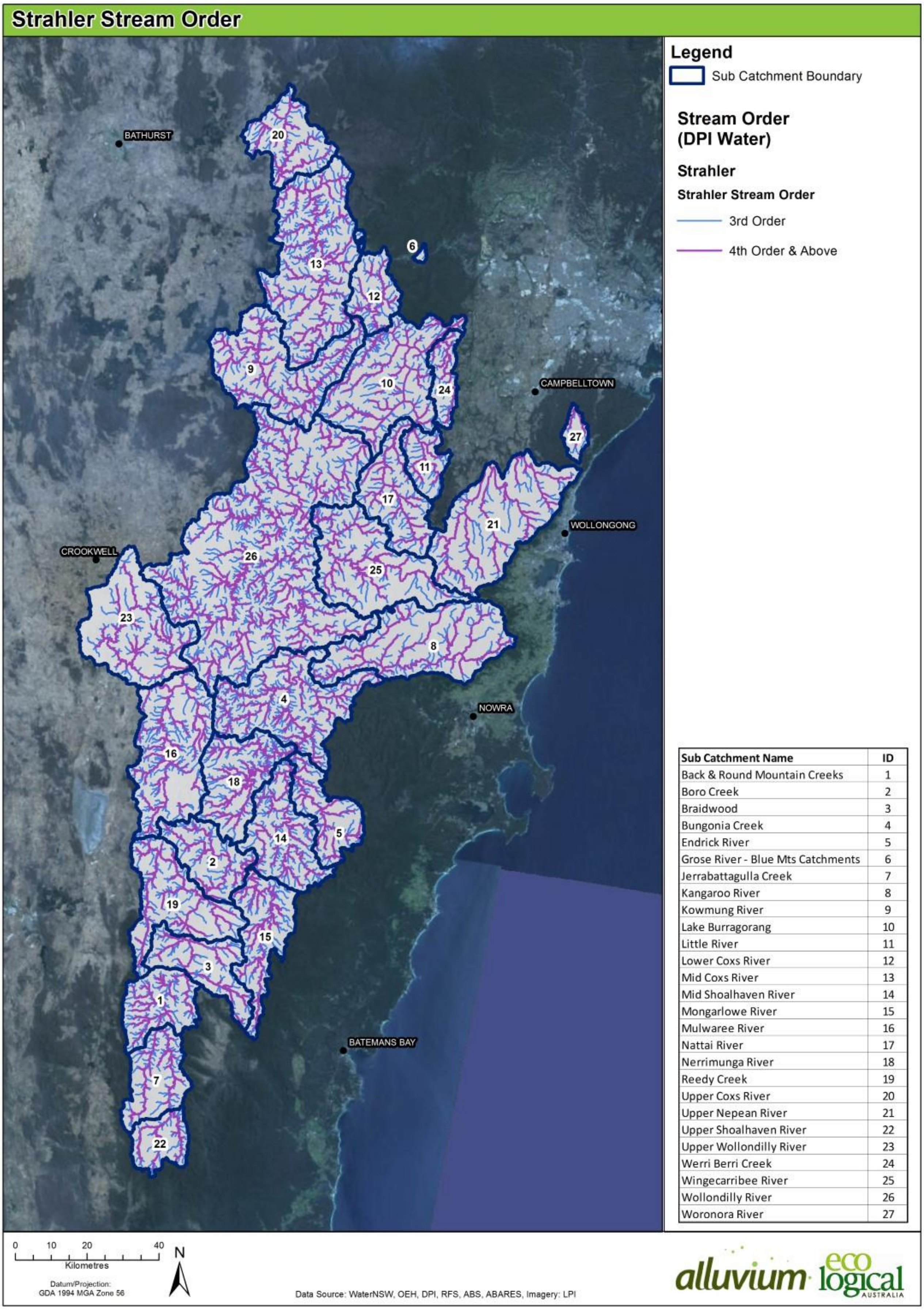



**Figure 23: Watercourses in the study area classed by Strahler Stream Order**

There is 64,153 ha of riparian zone (or potential riparian zone) in the study area according to DPI Water's riparian guidelines to quantify the spatial extent of the riparian zone (NOW 2012). The condition of this defined riparian land would vary dramatically, from cleared grazing land to near-pristine forest. It is, however, a reference point for understanding the extent of land valued under the WM Act and FM Act.

DPI Water has advised that there is no central database that informs us which waterways have vegetation management plans enforced under Controlled Activity Approvals (works on waterfront land), or which creeks have been approved for removal (e.g. the legislative requirement for works on waterfront land can be removed if the waterway does not meet the definition of a 'river' under the WM Act) (pers comm., DPI Water). Therefore, if a creek is removed it will still remain on the mapping. Also, some low-value 'rivers' (usually degraded 1st or 2nd order creeks) may be removed on a case-by-case basis if they are offset elsewhere to retain the net riparian area. As such, there is no measurable way to identify a change in waterfront land since the previous audit.

**Riparian buffers in grazing**

Grazing land is extensive within the study area, contrasting with the protected forests that share the landscape. Grazing is predominantly from cattle and sheep, but may also include horses, goats and other hoofed livestock. The impacts of grazing in riparian corridors is well documented, and can occur directly through plant consumption and trampling, or indirectly through effects on nutrient cycling and soil structure. The impacts of livestock on vegetation near water depends on animal physiology, population numbers and the time spent near the water source. Native grazers, such as kangaroos, are efficient water users so are able to spend more time further away from water sources, resulting in less impact on the vegetation around the water (Jones and Vesk 2016).

Protection of riparian vegetation and waterways is achieved through exclusion fencing or managed stock numbers and rest periods. Fencing waterways has its merits if the riparian zone is also managed for biodiversity and bank stability. Poorly managed riparian zones may lead to an increase in weed invasion and shift in plant composition. Controlled grazing in these instances may reduce weed infestations and fuel for bushfires. As such, classifying a waterway as either 'protected' or 'unprotected' does not necessarily imply the riparian zone is for better or worse. It does, however, give an indication that the riparian corridor has some form of physical protection, rather than undocumented owner-driven controls (rotational, timed, seasonal or crash grazing) (Jones and Vesk 2016).

Available data on grazing and riparian protection is presented in **Figure 24**. Of the 19,118 km of waterways identified in grazing country, 15% are 'protected', 47% are 'unprotected' and 38% have 'protection unknown'. Most sub-catchments have some degree of grazing land, except the large areas of native forest. The highest proportion of 'protected' riparian zones across grazing land occurs in sub-catchments Upper Nepean River (54% protected), Kangaroo River (53% protected), Bungonia Creek (36% protected) and Werri Berri Creek (29% protected). Sub-catchments with the highest proportion of 'unprotected' riparian land are Braidwood (87% unprotected), Reedy Creek (63% unprotected), Upper Wollondilly River (60% unprotected) and Kangaroo River (46% unprotected).

The previous audit presented 2009 data that identifies 38,753 km of watercourses currently, or with the potential to be, accessed by stock (double what this 2016 audit found). The apparent ~50% reduction in stock access in this audit may be because the previous audit includes both sides of the watercourse in its calculation. This may also explain the difference in river/riparian length calculations, where the previous audit presented approximately 110,000 km of river length with associated riparian zone, whereas this audit shows 52,948 km of watercourses (DPI hydroline layer).

The above discussion demonstrates there is no detailed assessment of grazing impacts on riparian corridors, beyond broad 'protection' labels. Therefore, there is insufficient data and lack of clarity (across all audits) to identify a meaningful trend.

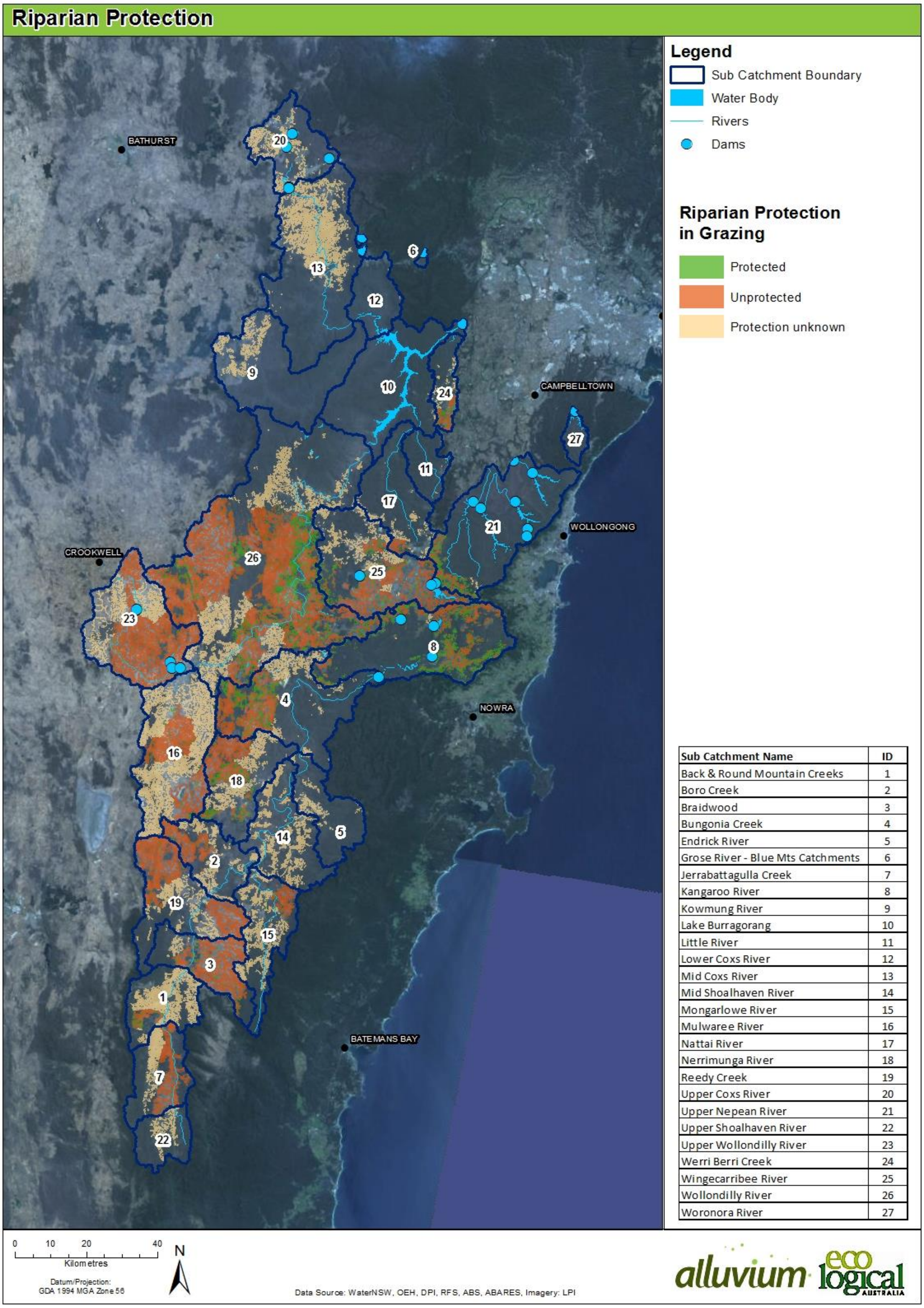



**Figure 24. Riparian protection from grazing in the study area**

**Local council riparian management**

Several local councils contributed to riparian protection or management in the Catchment (**Table 26**) during the recent audit period. Few data were received for the Audit, and those presented below may not represent the full extent of riparian programs. In addition, some works include a larger landscape area, which is assumed to include some form of riparian land. Strictly non-riparian works and sites more than 40 m from a watercourse have been excluded from this table, as have Councils responding with 'no works conducted'.

**Table 26. Local Council riparian management programs**

| Council | Regeneration or rehabilitation | Weed management | Property Vegetation Plans |
|---|---|---|---|
| Blue Mountains City Council | >50 Bushcare and Landcare groups operate in the Blue Mountains | >50 Bushcare and Landcare groups operate in the Blue Mountains | |
| Goulburn Mulwaree Council | Wollondilly Walking Trail – tree planting.<br><br>Also see Wetlands chapter. | Weed control at the Goulburn Recreation Area.<br>Weed control at Operational sites – including Council's storage dams, irrigation areas.<br>Wollondilly Walking Trail – willow removal and blackberry control. | |
| Lithgow City Council | 2 x unnamed creek. | 2 x Farmers Creek.<br>3 x unnamed creek.<br>Blackmans Creek.<br>River Lett.<br>State Mine Creek. | Moyne Creek and tributaries.<br>Oaky Creek.<br>11 x unnamed creek. |
| Oberon Council | 2016 revegetation work (150 native tubestock) along riparian zone of the Fish River (funded by an LLS grant). To be continued with collaborative project with Bathurst Council.<br>2016 Green Army Round 3 Project organised by private landowners planted over 10,000 tubestock on private properties along the Fish River between O'Connell and Tarana.<br>Green Army Round 4 Project (current) that will plant another 300 trees along the Fish River. | 2016 willow clearing along 1.5 km of riparian zone of the Fish River (funded by an LLS grant). To be continued with collaborative project with Bathurst Council.<br>Green Army Round 4 Project (current) that will control another 1.5 km of willows along the Fish River. | None issued. |
| Wingecarribee Shire Council | Land for Wildlife – private properties with >0.5 ha of habitat to conserve.<br>Vegetation Conservation Program – private properties with >2 ha of high conservation land where participants are engaged through 5-15 year management agreements.<br>Mittagong Creek Rehabilitation project, and Rivercare (Bushcare) Group – includes revegetation works post weed removal, and approximately 6,000 native plants for native grassland and wetland habitat. Over 1 km of new fencing was installed along a section of the creek to exclude cattle. | Mittagong Creek Rehabilitation project – blackberry, woody weeds and other environmental weeds were removed along a 500 m stretch of creek. And, extensive woody weed infestations (willows, black alder & hawthorn) were treated along a 1.2 km stretch of the creek (due to be removed completely 2016-17).<br><br>Burradoo Woody Weed removal – control of large infestations of blackberry and willow along banks and island in Wingecarribee River. | - |

| Council | Regeneration or rehabilitation | Weed management | Property Vegetation Plans |
|---|---|---|---|
| | National Tree Day Plantings on Mittagong (2015) and Whites Creek (2014).<br><br>Wingecarribee River Project – various works.<br><br>Green Army Sites – planting native trees, sedges and rushes to protect the Wingecarribee River from erosion whilst providing habitat for small native birds. | | |

**Conclusion**

Corridors of native riparian vegetation contribute to healthy waterways and improved water quality outcomes. Unfortunately, the lack of riparian vegetation data means that it is not possible for the auditors to determine the status or trends for this indicator. Riparian management activities in Blue Mountains, Goulburn Mulwaree, Lithgow, Oberon and Wingecarribee Council areas are likely to have had a positive contribution to Catchment health. Improved coordination of riparian vegetation management and monitoring by agencies is recommended. This should include records of the length of streams protected from stock either through conservation land use or fencing of agricultural lands.

## 4.4 Native vegetation

**Definition and context**

The NSW *Native Vegetation Act 2003* defines native vegetation as any species of vegetation that existed in NSW before pastoral settlement and includes trees, shrubs, understorey, groundcover or wetland plants. The extent and condition of native vegetation across the Catchment affects ecosystem services such as water quality and availability by helping to stabilise soils, and filter nutrients and pathogens. Widespread healthy native vegetation within a catchment supports good quality surface water and groundwater, and biodiversity.

An increase in the extent of native vegetation is therefore considered to be an **improving** trend, whereas loss of native vegetation indicates a **worsening** trend.

**Data**

Information about native vegetation within the Catchment is available from the following publicly accessible OEH databases:

- The Bionet database comprises data collected by ecologists undertaking surveys in accordance with a scientific licence under section 132 of the NSW TSC Act. This data relates to the type and location of species rather than the type, condition or extent of native vegetation communities.
- The Southeast NSW Native Vegetation Classification and Mapping (SCIVI) – classifies, describes and maps native vegetation types at 1:100 000 interpretation scale. The vegetation classification is based on a compilation of ~ 8,500 full-floristic field survey sites from previous studies. This dataset was last updated by OEH in 2011.

OEH has also created a map of woody vegetation extent and foliage projection cover (FPC) derived from multi-temporal 5 m SPOT-5 satellite imagery. This is referred to as the Statewide Landcover and Trees Survey (SLATS). The 2011 SLATS map is publicly available. For the purposes of this Audit, OEH provided the SLATS map that shows changes in woody vegetation extent and FPC during the period 2013-14. 'Woody vegetation' includes both native and non-native vegetation, so does not directly relate to the gazetted native vegetation indicator required by the Audit.

In 2013, OEH prepared a *Native Vegetation Information Strategy 2014-2018* that defines the 'Vision for NSW' as 'conservation, planning and regulation are enabled through easy access to consistent, relevant and scientifically robust native vegetation information'. The strategy identifies eight objectives for the production, maintenance and delivery of native vegetation information for NSW. OEH advised that an updated native vegetation spatial database is being developed.

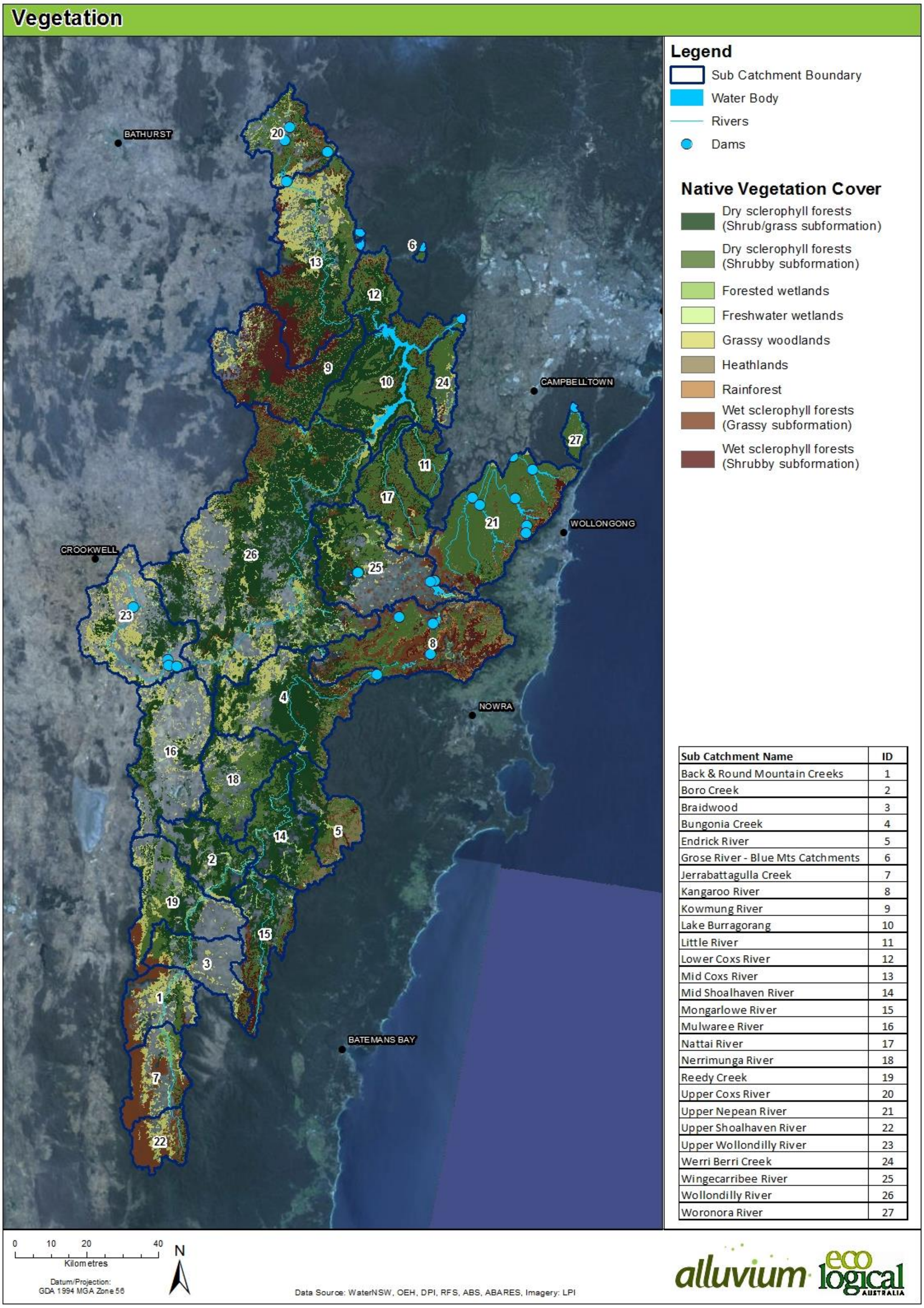
**Native vegetation extent**

The extent of native vegetation across the Catchment is shown in **Figure 25** based on data compiled by WaterNSW from SCIVI and other sources such as the Sydney Metropolitan vegetation mapping, Cumberland Vegetation Information System and Blue Mountains Vegetation Information System. The area of native vegetation in each sub-catchment is tabulated below (**Table 27**). This indicates that:

- the Enrick River, Little River, Lower Coxs River and Woronora River sub-catchments have greater than 90% of their area with native vegetation
- the Mulwaree River and Upper Wollondilly River sub-catchments have relatively little (<20%) native vegetation cover as a proportion of the sub-catchment area
- the Wollondilly River sub-catchment has the greatest extent (150497 ha or 10%) of native vegetation within the total Catchment.

**Table 27. Native vegetation extent within each sub-catchment**

| ID | Sub-catchment | Area of native vegetation (ha) | Native vegetation extent | |
|---|---|---|---|---|
| | | | % of sub-catchment | % of whole catchment |
| 1 | Back & Round Mountain Creeks | 14,767 | 43 | 1 |
| 2 | Boro Creek | 20,612 | 59 | 1 |
| 3 | Braidwood | 14,124 | 38 | 1 |
| 4 | Bungonia Creek | 61,002 | 76 | 4 |
| 5 | Endrick River | 30,943 | 91 | 2 |
| 6 | Grose River - Blue Mts Catchments | 1,687 | 79 | <1 |
| 7 | Jerrabattagulla Creek | 21,069 | 59 | 1 |
| 8 | Kangaroo River | 62,890 | 73 | 4 |
| 9 | Kowmung River | 62,648 | 81 | 4 |
| 10 | Lake Burragorang | 71,695 | 89 | 5 |
| 11 | Little River | 17,899 | 97 | 1 |
| 12 | Lower Coxs River | 22,510 | 91 | 1 |
| 13 | Mid Coxs River | 77,369 | 72 | 5 |
| 14 | Mid Shoalhaven River | 37,465 | 75 | 2 |
| 15 | Mongarlowe River | 26,436 | 62 | 2 |
| 16 | Mulwaree River | 15,373 | 19 | 1 |
| 17 | Nattai River | 38,147 | 86 | 2 |
| 18 | Nerrimunga River | 26,158 | 54 | 2 |
| 19 | Reedy Creek | 25,439 | 44 | 2 |
| 20 | Upper Coxs River | 22,820 | 60 | 1 |
| 21 | Upper Nepean River | 78,394 | 88 | 5 |
| 22 | Upper Shoalhaven River | 17,480 | 80 | 1 |
| 23 | Upper Wollondilly River | 14,387 | 19 | 1 |
| 24 | Werri Berri Creek | 10,119 | 61 | 1 |
| 25 | Wingecarribee River | 32,025 | 42 | 2 |
| 26 | Wollondilly River | 150,497 | 56 | 10 |
| 27 | Woronora River | 6,919 | 93 | <1 |




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 25. Native vegetation cover (WaterNSW)**

**Change in native vegetation extent**

Temporary or permanent changes to the extent, condition or type of vegetation typically result from one or more of the following:

- Natural cycles of native vegetation death and regeneration
- Bushfire or controlled fire (refer to **Section 4.5** for further details)
- Natural disasters such as flood, drought or windstorm
- Managed regeneration, revegetation and rehabilitation in accordance with BioBanking offsets, Property Vegetation Plans (PVPs), Vegetation Management Plans (VMPs) etc.
- Anthropogenic climate change* directly impacting vegetation through changes to temperatures and rainfall, and intensifying threats such as weeds, bushfire and disease
- Clearing native vegetation* by illegal activities or approved land uses (e.g. infrastructure, forestry, mining, urban/rural development, agriculture)
- Dieback / disease* - exotic fungal infections (such as Phytophthora and Myrtle rust), viruses and other pathogens which can weaken and kill native vegetation species at a local or landscape scale
- Weed invasion* and control – weeds out-compete native vegetation, and aquatic weeds in particular can adversely impact water quality

*These are listed as 'key threatening processes' under the NSW *Threatened Species Conservation Act 1995*[2] and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*

During the audit period, the NSW *Native Vegetation Act 2003* regulated the clearing of native vegetation on all land in NSW except for national parks and other conservation areas, state forests and reserves, and urban areas. The legislation aimed to prevent broadscale clearing unless it improved or maintained environmental outcomes. This legislation and associated regulations was repealed in November 2016 (see footnote).

No data is available to show changes in native vegetation for the Catchment within the audit period 2013-16. An alternative approach is given here which refers to the woody vegetation mapping (SLATS) compiled by OEH using data from 2013-14 (**Figure 26**). It is acknowledged that this may misrepresent changes in native vegetation extent, but is presented as the best available sources of information within the audit period. **Figure** 26 shows that wildfire had the greatest impact on woody vegetation cover in 2013-14.

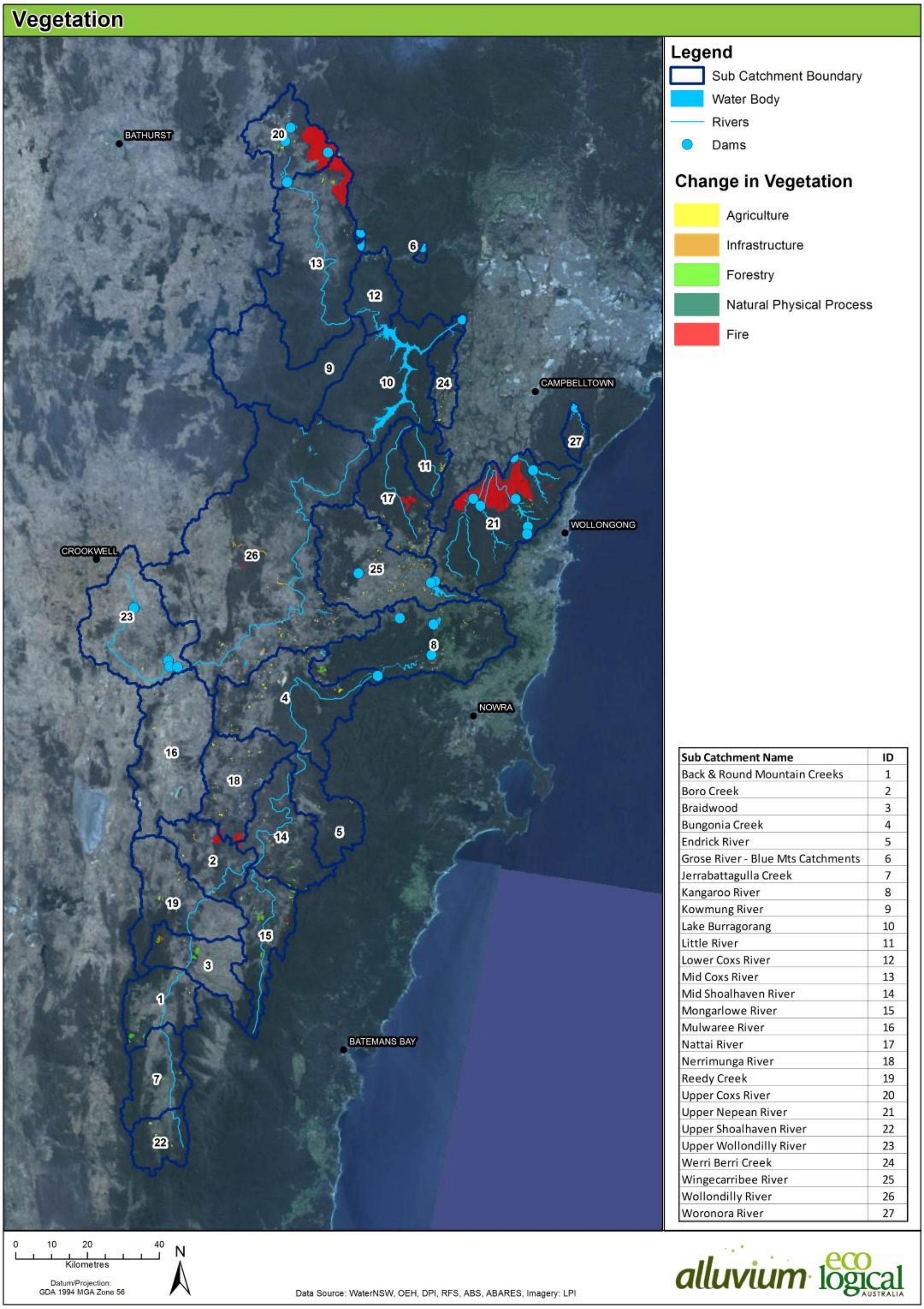
Longer term changes in woody vegetation since the previous audit period are identified in **Table 28** based on SLATS data. This highlights the impact that fire had on vegetation in the Catchment in recent years. While vegetation may grow back following fire so the loss of cover would be temporary, the ecological community may change, especially following frequent and intense fires.

**Table 28. Changes in woody vegetation (SLATS) 2010-14**

| Cause of change | 2010/11 (ha) | 2011/12 (ha) | 2012/13 (ha) | 2013/14 (ha) |
|---|---|---|---|---|
| Agriculture | 103 | 121 | 112 | 99 |
| Fire | 13 | 507 | 208 | **9518** |
| Forestry* | 1984 | 1458 | 954 | 461 |
| Infrastructure | 44 | 70 | 98 | 111 |
| Natural Physical Process | 0 | 2 | 0 | 0 |
| **Total** | **2145** | **2160** | **1373** | **10190** |

*Much of the forestry change related to clearing of mature pine plantations by NSW State Forests at Penrose, Tallaganda and Bombala

[2] In November 2016 the NSW Parliament passed the *Biodiversity Conservation Act 2016* and the *Local Land Services Amendment Act 2016* which will replace the *Threatened Species Conservation Act* and *Native Vegetation Act*.




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 26. Woody vegetation cover lost to other land uses in the Catchment 2013-14 (OEH 2017)**

### Native vegetation condition

The condition of native vegetation is affected by the proportion of weeds present. While data is not available regarding the condition of native vegetation across the Catchment, records of weeds that have been identified are available from the Bionet database (**Table 29**). This is not a comprehensive list as it is based on various studies that are conducted across the Catchment. Since the previous audit, additional species that are known to occur in the Catchment have been listed as Weeds of National Significance, as identified in **Table 29**.

The NSW Biosecurity Strategy 2013-2021 and the NSW Invasive Species Plan 2015-2020 aim to reduce the impact of weeds on the environment and community. The 2013-14 review of weed management in NSW by the Natural Resources Commission resulted in the establishment of new Regional Weeds Advisory Committees to better coordinate project resources and funding.

**Table 29. Weeds of National Significance and National Alert species**

| Scientific Name | Common Name | Comparison to GHD 2013 audit (p.228) |
|---|---|---|
| **Weeds of National Significance** | | |
| *Anredera cordifolia* | Madeira Vine | |
| *Asparagus aethiopicus* | Asparagus Fern | Previously classed as an emerging |
| *Asparagus plumosus* | Climbing Asparagus-fern | New listing |
| *Asparagus scandens* | Asparagus Fern | New listing |
| *Austrocylindropuntia spp.* | Prickly Pear | New listing |
| *Chrysanthemoides monilifera* subsp. *monilifera* | Boneseed | New listing |
| *Cytisus scoparius* | English Broom | |
| *Eichhornia crassipes* | Water Hyacinth | Previously classed as an emerging |
| *Genista linifolia* | Flax-leaf Broom | New listing |
| *Genista monspessulana* | Montpellier Broom | New listing |
| *Lantana camara* | Lantana | |
| *Lycium ferocissimum* | African Boxthorn | New listing |
| *Nassella trichotoma* | Serrated Tussock | |
| *Opuntia* spp. | Prickly Pear | New listing |
| *Rubus fruticosus aggregate* | Blackberry | |
| *Salvinia molesta* | Salvinia | New listing |
| *Salix* spp. | Willows | |
| *Senecio madagascariensis* | Fireweed | New listing |
| *Ulex europaeus* | Gorse | New listing |
| **National Environmental Alert List** | | |
| *Cyperus teneristolon* | Cyperus | |

### Conclusion

It is acknowledged that OEH is in the process of updating the native vegetation spatial database in accordance with the *Native Vegetation Information Strategy 2014-2018*. However, lack of data about the extent and / or condition of native vegetation in the Catchment means that it is not possible to determine if trends are improving or worsening during the current audit period.

## 4.5 Fire

**Definition and context**

Fire is a natural part of the landscape and ecology of the Australian environment. The ecological effects of fires in the landscape are influenced by fire frequency, intensity, seasonality, and type (e.g. prescribed burning, Aboriginal 'cultural' burn or bushfire). Native plant and animal species are adapted to particular fire regimes, and respond to fire according to their life cycle. High frequency or intense fire resulting in the disruption of plants and animals and loss of vegetation is a key threatening process to the biodiversity of the Catchment.

Large scale, high intensity fires can also destabilise the hydrological characteristics of the Catchment, resulting in large amounts of sediment, nutrients, ash and other pollutants being washed or leached into waterways and stored waters. Fire activity in the Catchment can result in poorer water quality, including higher turbidity levels entering waterways as a result of erosion caused by the loss of vegetation.

Bushfires can be caused by both natural and human activities; arson and accidental fires are common where access to bushland areas is relatively easy. Natural fires started by lightning are also common, with dry thunderstorms a regular occurrence in late spring and summer. These fires have the potential to burn large areas of bushland, as they often originate where access is difficult and may burn for some time before suppression commences, by which time they are of considerable size. Under hot, dry weather conditions fire can spread rapidly and threaten life, property, assets and other values of the wider region. Suppression within the Catchment is often difficult due to remoteness, access and rugged terrain and if fires are not controlled while small they typically require a significant and extended commitment of firefighting resources.

The environmental impacts of unplanned fire are difficult to mitigate with higher intensity, fast moving fires often experienced with limited capacity to implement erosion and water quality controls. Ash from bushfires and sediment from impacted areas washes into streams during heavy rain on burnt areas that are no longer stabilised by groundcover or protected by tree and shrub canopies. The most important factors influencing this are the timing and intensity of rain that follows a fire. High intensity rains (associated with thunderstorms) can lead to increased wash off rates than in moderate storm (eWater CRC 2007). Thunderstorms occur most frequently in summer and early autumn (e.g. during the bushfire season) within the Catchment area, increasing the likelihood of ash, charcoal, nutrients and sediment being washed into streams after bushfire. These materials can more readily enter streams if the vegetation alongside them has been burnt.

Water quality may be directly affected as a result of increased wash off of ash and fine soil particles into streams which delivers higher concentrations of phosphorus (but low concentrations of nitrogen) to the river (eWater CRC 2007). As a consequence, there will be a higher risk of blue-green algal blooms if the water enters the surface layer of a water storage reservoir. The impact of fire on water quality for drinking water supplies will depend on the degree of water treatment that is available, and the characteristics of water storage.

In the eucalypt forests of the catchment, there is a naturally high water-repellence in the soils. A relatively deep litter layer in unburnt areas absorbs rainfall, maintaining soil stability during higher rainfall events, and reduces erosion. Low to moderate fires (utilised for prescribed burning) reduce the litter layer but allow for higher overland flows once soil saturation is achieved, with minimal impact on erosion. In areas of higher fire intensity (common during bushfires) the litter layer is removed and overland flow may occur more readily, transporting soil material leading to enhanced erosion events (eWater CRC 2007).

**Data**

The Rural Fire Service (RFS) maintains the BRIMS and ICON spatial databases using data provided by a range of NSW and local government agencies.

- BRIMS provides a consolidated record of hazards, risks and mitigation activities in a bushfire context across NSW (e.g. for the Prevention phase of the Prevention, Preparedness, Response and Recovery model). BRIMS also includes information relevant to fire and development impact assessments, and community engagement activities and complaints.

- ICON is used by the firefighting agencies from an operational perspective to provide a consolidated record of bushfires (and other emergencies) across NSW (e.g. for the Response phase of the Prevention, Preparedness, Response and Recovery model).

Agencies within the Catchment that input data to BRIMS and ICON include the RFS, NSW Fire and Rescue, OEH and WaterNSW. Consultation with these agencies suggests that data is being entered more reliably than in the past. However, the functionality of the database may affect the accuracy of the data ie. what is represented in the spatial database may not exactly match what occurred on the ground because of the capabilities of the software.

**Uncontrolled bushfire**

BRIMS and ICON data (**Table 30** and **Figure 27**) show that the incidence of bushfire varies each year across the Catchment and is closely linked to prevailing weather patterns and climate. The main factors contributing to the severity and spread of bushfire in the Catchment area are:

- weather and climate conditions, including wind speed, temperature, relative humidity and drought index
- dryness of the fuel, the type of fuel (surface, elevated, bark or canopy) and the fuel load (surface and overall
- physical structure and arrangement of vegetation
- the terrain in which the fire is burning
- effectiveness of fire management (prevention and preparation) actions.

The most significant fires impacting on the Catchment occurred during the 2013/14 fire season during which 27,019 ha was burnt. High fuel loads, combined with warm, dry winds fuelled bushfires within the Catchment and adjoining areas. Rainfall in the Catchment during this period was average to very much below average. The northern and eastern sub-catchments in particular had very much below average rainfall, from the Lower Cox's River in the north to the Nepean River in the east and Mid Shoalhaven River in the south.

During this period the well-documented State Mine Fire and Mt York Road (Mt Victoria) Fire in October / November 2013 burnt an area of over 11,454 ha of catchment land within the Upper Coxs River and Mid Coxs River Sub Catchments. In the same period a large expanse of land (over 13,058 ha) within the Upper Nepean River Sub Catchment was also burnt by the Hall Road, Balmoral Fire. The (then) Sydney Catchment Authority worked alongside RFS and National Parks and Wildlife Service personnel to extinguish the bushfires. Over 7000 ha of Special Areas around the Upper Nepean dams were burnt and fire came close to the Nepean Water Filtration Plan (SCA 2014a).

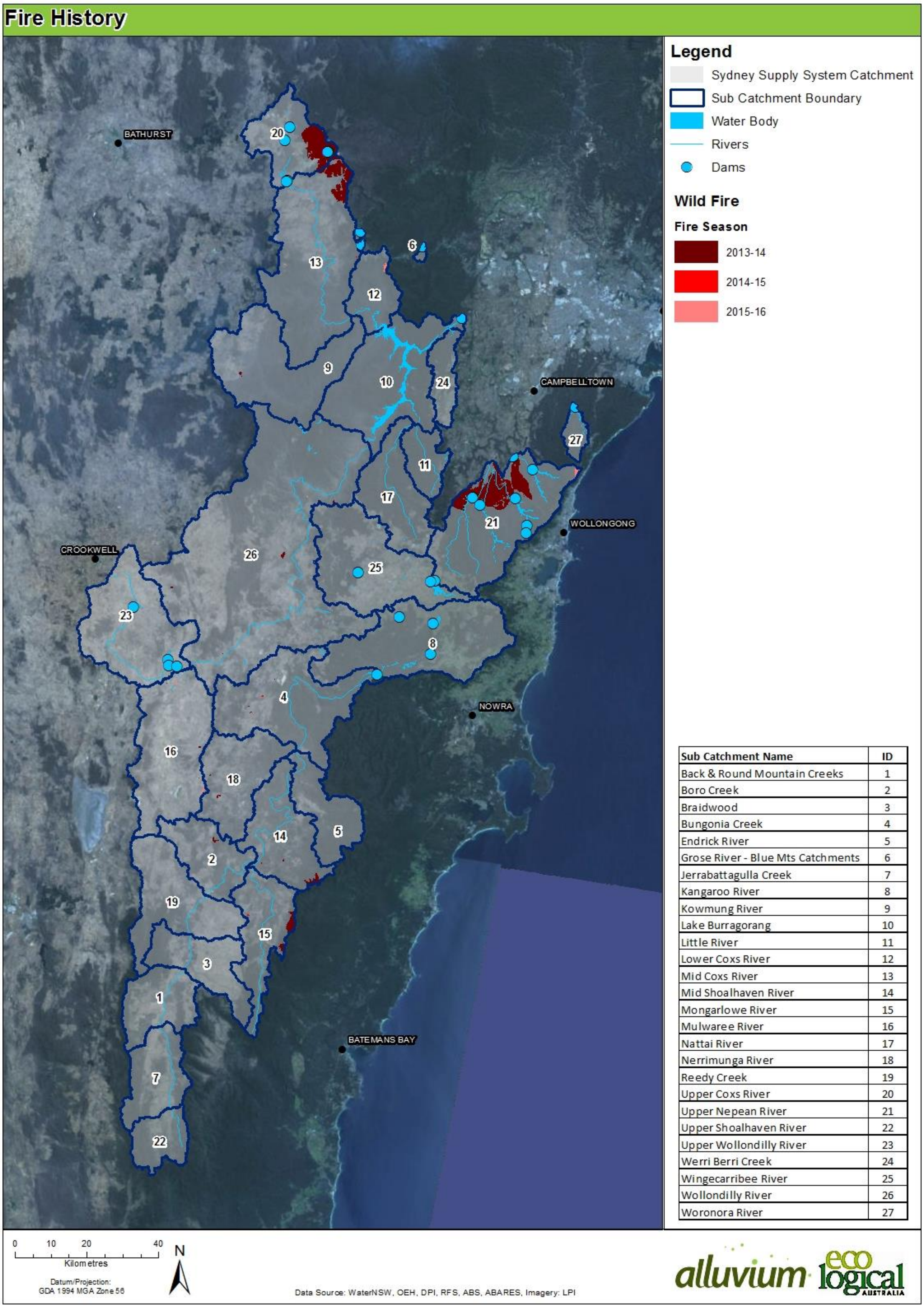
The bushfires of 2013/2014 amounted to 97% of the overall area burnt in the Catchment by bushfire during the entire audit period and was also significantly larger than the preceding six years as shown in **Table 30**.

Rainfall for the period July 2014 to June 2015, and for the period July 2015 to June 2016 was above average in most sub-catchments and average elsewhere. Areas burnt by bushfires in the 2014/15 and 2015/16 bushfire seasons reflected the increased rainfall and was significantly lower than average, and much less than the 27,019 ha burnt in the 2013/14 period.

**Table 30: Area (ha) burnt by bushfires 2007-16**

| Sub-catchment | 2007-08[1] | 2008-09[1] | 2009-10[1] | *Total 2007-10* | 2010-11[2] | 2011-12[2] | 2012-13[2] | *Total 2010-13* | 2013 – 14[3] | 2014 – 15[3] | 2015 – 16[3] | *Total 2013-16* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Back & Round Mountain Creeks | 74.4 | | 215.9 | *290.3* | | | | *0* | 0.39 | 0.56 | | *0.95* |
| Boro Creek | 174.23 | 49.65 | | *223.88* | | | | *0* | 94.1 | 0.21 | | *94.31* |
| Braidwood | | | | *0* | | | | *0* | | | | *0* |
| Bungonia Creek | | 14.28 | 7.3 | *21.58* | | | 105.5 | *105.5* | 24.63 | 20.52 | | *45.15* |
| Endrick River | | | | *0* | | | | *0* | | | | *0* |
| Grose River-Blue Mountains | | | | *0* | | | | *0* | | | | *0* |
| Jerrabattagulla Creek | 11.92 | | | *11.92* | | | | *0* | | | | *0* |
| Kangaroo River | 11.61 | 1131.24 | 8.5 | *1151.35* | 454.0 | | 14.5 | *468.5* | | 3.26 | | *3.26* |
| Kowmung River | | | | *0* | 249.0 | | | *249* | 86.43 | | | *86.43* |
| Lake Burrangorang | | 21.9 | 137.1 | *159* | 369.0 | | 3.5 | *372.5* | | | 1.66 | *1.66* |
| Little River | | 8.65 | | *8.65* | 616.0 | | 0.1 | *616.1* | 13.46 | | | *13.46* |
| Lower Coxs River | | 23.95 | | *23.95* | | 34.5 | 538.5 | *573* | | 0.2 | 175.92 | *176.12* |
| Mid Coxs River | | | 21.1 | *21.1* | 130.0 | | 29 | *159* | 4757.79 | 22.4 | 21.17 | *4801.36* |
| Mongarlowe River | 31.5 | 4.71 | | *36.21* | | | | *0* | 1185.41 | 40.66 | | *1226.07* |
| Mid Shoalhaven River | | | | *0* | | | 2.5 | *2.5* | 574.17 | 11.34 | | *585.51* |
| Mulwaree River | | | | *0* | | | | *0* | 38.86 | | 149.78 | *188.64* |
| Nattai River | | 1.34 | | *1.34* | 56.0 | | 4.5 | *60.5* | | | | *0* |
| Nerrinmunga River | | 110.98 | | *110.98* | | | | *0* | 72.85 | | 24.82 | *97.67* |
| Reedy Creek | | 4.52 | | *4.52* | | | | *0* | 12.3 | | | *12.3* |
| Upper Coxs River | | | | *0* | 4.0 | | | *4* | 6702.96 | 9.86 | 17.51 | *6730.33* |
| Upper Nepean River | 66.41 | 22.64 | | *89.05* | 226.0 | | 1097 | *1323* | 13242.73 | 0.33 | 296.95 | *13540.01* |
| Upper Shoalhaven River | | | | *0* | | | 1 | *1* | | | | *0* |
| Upper Wollondilly River | | | | *0* | | | | *0* | | | | *0* |
| Werri Berri Creek | | | | *0* | | 63 | | *63* | | | | *0* |
| Wingecarribee River | | 3.07 | | *3.07* | | | | *0* | 0.13 | | | *0.13* |
| Wollondilly River | | | 11.0 | *11* | 10.0 | | 57 | *67* | 213.04 | 3.79 | 14.46 | *231.29* |
| Woronora River | | | | *0* | | | 21 | *21* | | | | *0* |
| **Total (ha)** | **370** | **1,397** | **401** | ***2,168*** | **2,114** | **98** | **1,874** | ***4,086*** | **27,019** | **113** | **702** | ***27,834*** |

[1] Sourced from 2007 Audit; [2] Sourced from 2010 Audit; [3] Data provided by RFS




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 27: Bushfire occurrence 2013-16**

**Prescribed burns**
Goal 28 of NSW 2021 (NSW Government 2011) is to 'ensure NSW is ready to deal with major emergencies and natural disasters'. Prescribed burning (hazard reduction) targets within Goal 28 are set as follows:

- Increase the number of properties protected by hazard reduction works across all bushfire prone land tenures by 20,000 ha per year by 2016.
- Increase the annual average level of area treated by hazard reduction activities by 45 per cent by 2016.

This increase is across all NSW land management agencies and applies state-wide, and has not been refined down to a local government or agency level. Many agencies will have their own internal priorities and targets to be met across their area of jurisdiction to achieve this goal. OEH carries out most prescribed burning (by area) across NSW and has a state-wide target of doubling the area burnt compared to pre-2010 levels. Whilst WaterNSW has various plans and policies to manage fire across the Catchment, it does not have specific internal targets of areas to be burnt through prescribed burning.

Unplanned bushfires do not contribute to the overall targets required by Goal 28; however they will inform the location and timing of prescribed burning undertaken within the Catchment. For example, an area recently burnt by a bushfire will not be considered for prescribed burning until it is within the fire threshold for that particular vegetation community.

Prescribed burning on public land within the Catchment is undertaken by NSW Fire and Rescue, RFS, Forestry Corporation, WaterNSW and the OEH. The RFS undertake prescribed burning in areas of native vegetation on private lands within the Catchment, at a smaller scale than burning of public land. An emphasis is placed by these agencies on vegetation at the urban/bushland interface to reduce fire risk to life and property. The prescribed burning program shows a mosaic of burning across the catchment area, contributing to the retention of biodiversity values similar to traditional Aboriginal land burning patterns.

The area of prescribed burning in the Catchment during the audit period and in previous years is presented in **Table 31**. The annual prescribed burning program has continued at a steady state since 2012/13, and is greater than previously. There was a slight decrease in activity due to drier, riskier conditions in 2013/14 season limiting the 'window of opportunity' in which prescribed burning could occur (e.g. fuels cannot be too dry, or humidity too low). This trend was consistent with overall hazard reduction activities across NSW (RFS 2016).

**Table 31: Area (ha) of prescribed burning 2007-16**

| Sub-catchment | *Total 2007-10*[1] | 2010-11[2] | 2011-12[2] | 2012-13[2] | *Total 2010-13* | 2013 – 14[3] | 2014 – 15[3] | 2015 – 16[3] | *Total 2013-16* |
|---|---|---|---|---|---|---|---|---|---|
| Back & Round Mountain Creeks | | | | | | | | 3.30 | *3.30* |
| Boro Creek | | | | | | 332.87 | | | *332.87* |
| Braidwood | | | | | | 753.41 | 5.99 | 3.44 | *762.85* |
| Bungonia Creek | | | 5.5 | 1963 | *1968.5* | 0.33 | 769.04 | 0.64 | *770.01* |
| Endrick River | | | | | | 3720.58 | | 2336.38 | *6056.96* |
| Grose River-Blue Mountains | | | 3.5 | 58.5 | *62* | | | 56.59 | *56.59* |
| Kangaroo River | | 381 | 481 | 1655 | *2517* | 369.39 | 683.48 | 632.83 | *1685.69* |
| Kowmung River | | | | 4235.5 | *4235.5* | | | 514.56 | *514.56* |
| Lake Burrangorang | | | 6.5 | | *6.5* | 918.26 | 10546.10 | 340.80 | *11805.16* |
| Little River | | 454.5 | | | *454.5* | 11.02 | 340.99 | 1332.65 | *1684.66* |
| Lower Coxs River | | | 837 | 31.5 | *868.5* | 1.62 | 39.65 | 812.98 | *854.25* |
| Mid Coxs River | | | | 6322.5 | *6322.5* | 3.58 | 1.08 | 161.78 | *166.44* |
| Mid Shoalhaven River | | | | | | 2433.54 | | | *2433.54* |
| Mongarlowe River | | | | 216.5 | *216.5* | 16.59 | 1613.88 | 40.28 | *1670.75* |
| Mulwaree River | | | | | | | | 2.02 | *2.02* |
| Nattai River | | 1500.5 | | 201.5 | *1702* | 1186.64 | 57.63 | 2605.88 | *3850.15* |
| Nerrimunga River | | | | 577.5 | *577.5* | 1184.30 | | | *1184.30* |
| Reedy Creek | | | | | | 0.12 | | 776.60 | *776.73* |
| Upper Coxs River | | | | | | 270.78 | 177.33 | 139.58 | *587.68* |
| Upper Nepean River | | 401.5 | 81.5 | 367.5 | *850.5* | 192.63 | 65.02 | 1549.35 | *1807.00* |
| Upper Shoalhaven River | | | | | | | 1685.47 | 2509.20 | *4194.67* |
| Werri Berri Creek | | | 459 | | *459* | 248.19 | 38.46 | 42.90 | *329.55* |
| Wingecarribee River | | | | 780 | *780* | 81.06 | | 1946.20 | *2027.27* |
| Wollondilly River | | | | 42 | *42* | 2150.04 | 38.96 | 741.59 | *2930.59* |
| Woronora River | | | | 0.1 | *0.1* | 0.63 | | 0.08 | *0.72* |
| **Total** | ***16,430*** | **2,738** | **1,874** | **16,451** | ***21,063*** | **13,876** | **16,063** | **16,550** | ***46,488.31*** |

[1] Sourced from 2007 Audit; [2] Sourced from 2010 Audit; [3] Data provided by RFS (BRIMS and ICON 2013-16 shapefiles)

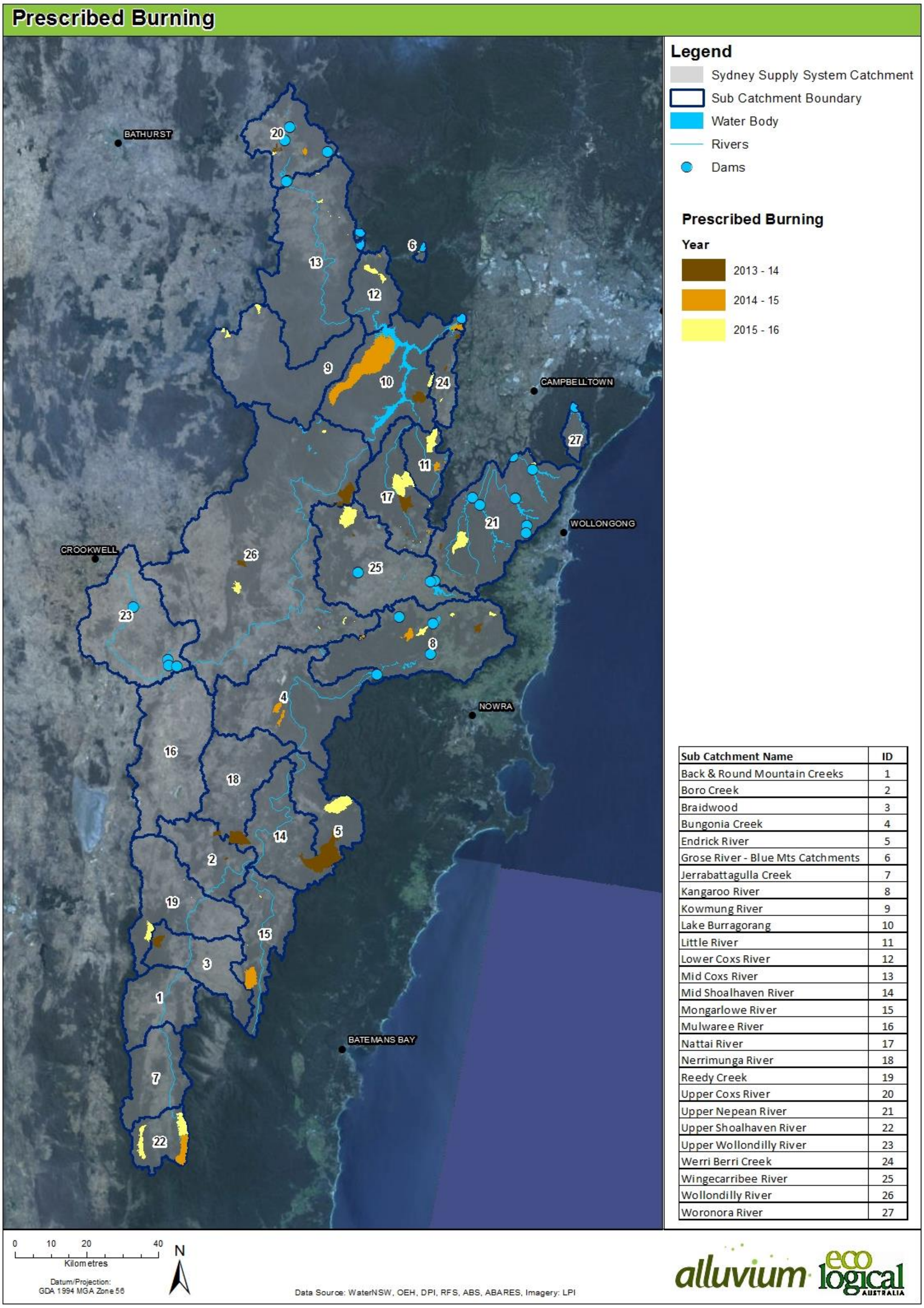



**Figure 28: Prescribed burning 2013-16**

**Bushfire management plans**
Bushfire management in NSW is a cooperative effort of the whole community including government. All land managers have a clear obligation to prevent the occurrence or spread of bushfires on and from land it directly manages as outlined in Section 63 of the *Rural Fires Act 1997* (RF Act).

Bushfire mitigation activities, including prescribed burning, are undertaken within the Catchment to mitigate the risk of unplanned bushfires adversely impacting on life and property. Landscape scale bushfire risk management in NSW is coordinated through the multi-agency Bush Fire Management Committees (BFMCs) in place throughout the State. The following BFMCs apply to land within the Catchment:

- Blue Mountains
- Cumberland Zone (incorporating Penrith, Blacktown and Fairfield Local Government Areas (LGAs))
- Macarthur Zone (incorporating Campbelltown, Liverpool and Camden LGAs)
- Sutherland
- Wollondilly
- Wingecarribee
- Illawarra (incorporating Wollongong, Shellharbour, Kiama LGAs)
- Lake George (incorporating Palerang and Queanbeyan City Local Government Areas)
- Southern Tableland Zone (incorporating Yass Valley, Upper Lachlan and Goulburn/Mulwaree LGAs)

Each BFMC is required to develop a Bush Fire Risk Management Plan (BFRMP) in accordance with Section 52 of the RF Act. Annual fire management works for land management agencies are derived from the plans and focus on the protection of human life and property. Bushfire management is implemented across the Catchment and in adjacent lands in accordance with these plans.

BFRMP are to be reviewed every five years following constitution of the BFMC in accordance with Section 52 of the RF Act. The majority of the BFMCs have plans exceeding this timeframe and therefore are not meeting their obligations under Section 52. Dates when the latest BFRMPs were issued for each zone in the Catchment are as follows:

- Blue Mountains – September 2010
- Cumberland Zone – September 2010
- Macarthur Zone – June 2012
- Sutherland – October 2016
- Wollondilly – January 2011
- Wingecarribee – December 2010
- Illawarra – August 2008
- Lake George – March 2010
- Southern Tableland Zone – November 2009

The BFRMP allows for the identification and mapping of land and infrastructure in the Catchment as an asset at risk of bushfire. As part of the risk assessment process the consequence of fire on these type of assets is determined by assessing the recovery costs of the asset and the level of economic impact. Given the outdated status of the various BFRMPs applying to the Catchment area, there is potential for key infrastructure within the Catchment to not be adequately captured and therefore appropriate treatments against bushfire may not be implemented. To address this issue the outdated BFRMP should be reviewed and updated.

**Conclusion**
Despite an increase of more than 120% in the area of prescribed burns compared to the previous audit, this represented a small part of the overall Catchment. The busy fire season in 2013/14 created a significant increase in the area affected by uncontrolled bushfires although this area was still less than the area of prescribed burns over the audit period. Risks of bushfires and associated impacts to Catchment health (e.g. soil runoff) are expected to increase with climate change. Maintaining up-to-date Bushfire Risk Management Plans and implementation of targeted prescribed burns (including Aboriginal cultural burns) can help to mitigate these risks.

## 4.6 Wetlands

**Definition and context**

Wetlands provide essential ecosystem services such as water storage and flood mitigation, and a sink for sediments, nutrients and other pollutants mobilised from the catchment. Within the Catchment, the term 'wetland' applies to 12 types identified in the *Directory of Important Wetlands in Australia* (DIWA):

- Inland wetlands
  - B1 - Permanent rivers and streams and waterfalls
  - B2 - Seasonal and irregular rivers and streams
  - B4 - Riverine floodplains including river flats, flooded river basins and seasonally flooded grassland
  - B6 - Seasonal/intermittent freshwater lakes (>8 ha) and floodplain lakes
  - B8 - Seasonal/intermittent saline lakes
  - B9 - Permanent freshwater ponds (<8 ha) marshes and swamps on inorganic sols, with emergent vegetation waterlogged for at least most of the growing season
  - B10 - Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes
  - B13 - Shrub swamps, shrub dominated freshwater marsh, shrub carr, alder thicket on inorganic soil
  - B15 - Peatlands, forest, shrubs or open bogs
  - B17 - Freshwater springs, oasis and rock pools
- Human-made wetlands
  - C1 - Water storage areas; reservoirs, barrages, hydro-electric dams, impoundment's (generally >8 ha)
  - C2 - Ponds, including farm ponds, stock ponds, small tanks.

Several wetlands in the Catchment are listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) and with different/overlapping nomenclature under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (BioNet database accessed 05/02/2017):

- Blue Mountains Swamps in the Sydney Basin Bioregion – Vulnerable (TSC Act) Endangered (EPBC Act)
- Coastal Upland Swamp in the Sydney Basin Bioregion – Endangered (TSC Act) Endangered (EPBC Act)
- Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions – Endangered (TSC Act) Endangered (EPBC Act)
- Newnes Plateau Shrub Swamp in the Sydney Basin Bioregion – Endangered (TSC Act) Endangered (EPBC Act)
- Sydney Freshwater Wetlands in the Sydney Basin Bioregion – Endangered (TSC Act).

In addition, wetlands are protected under various policies and legislation, such as the NSW Wetlands Policy and the *Water Management Act 2000*. These instruments promote the sustainable conservation, management and wise use of wetlands in NSW and the need for all stakeholders to work together to protect wetland ecosystems and their catchments.

Threats to wetlands are similar to those for rivers and riparian zones (as discussed in other sections in this audit, such as riparian grazing) but have additional vulnerabilities, even in remote forested areas. For example, longwall mining has the potential to impact wetlands above or hydrologically-connected to the mine's sub-surface operations. The gravity of this impact is recognised in the NSW *Threatened Species Conservation Act 1995*¸ which identifies 'Alteration of habitat following subsidence due to longwall mining' as a Key Threatening Process.

For the purposes of this Audit, a **worsening** trend is defined as increasing threats to wetlands, or loss or damage of wetlands in the Catchment.

**Data and method**
Few data were received for this Audit that differ from previous audits. Three main themes are addressed below: wetland extent (same data as previous audit); long wall mining impacts (recent information) and local council programs that do not include any site-specific monitoring to determine wetland health (i.e. condition over time). For this audit period, few management activities have been undertaken to improve the condition of wetlands (based on accessible information to this Audit).

**Wetland extent**
A total of 32,505 ha of wetlands are recognised in the study area (**Figure 29**). Of these, 21% of the wetland surface area is located in the Lake Burragorang sub-catchment, 20% in Upper Nepean River, 13% in Mulwaree River and 13% in Kangaroo River. The remaining sub-catchments have six or less hectares of wetland surface area each. The previous audit provides a description of a selection of important wetlands in the study area, including information from the DIWA and conceptual models of each ecosystem: Wingecarribee Swamp; Long, Hanging Rock, Mundego and Stingray Swamps (Paddys River Swamps); Boyd Plateau Bogs; Budderoo National Park Heath Swamp; Lake Bathurst and the Morass Wetlands; Thirlmere Lakes; and Blue Mountains Swamps.

As there is no documented change in wetland extent (spatial dataset), there is no basis for repeating the description of each wetland provided in previous audits. However, there are continued records of longwall mining impacts to wetlands that potentially reduce wetland extent in the long term, thus representing a worsening trend.

**Wetland impacts from mining**
Longwall mining occurs in several parts of the study area, often intersecting with wetland hydrology (upland swamps and creeks). WaterNSW has been working for a number of years to develop a sound understanding of surface and groundwater impacts from longwall mining[3] .

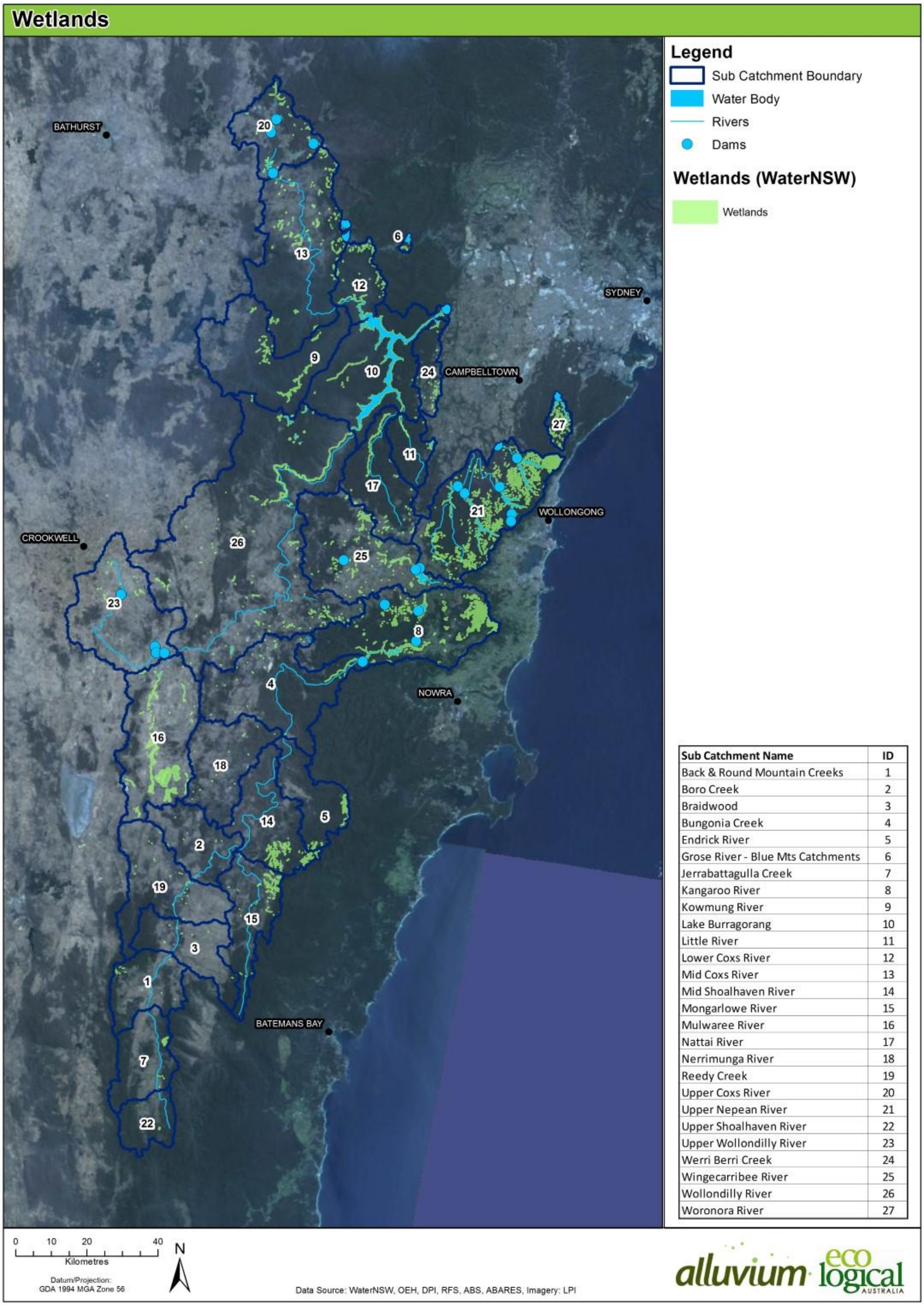
A number of factors influence the vulnerability of upland swamps to impacts from longwall mining, such as geomorphology and hydrology that determines the retention of water within the swamp itself, but also the direction of flow. DoP (2008) identifies specific threats to upland swamps as a direct result of longwall mining:

- cracking of base-rock
- increased drainage
- change in the water table level
- creation of nick points
- change in surface topography (and subsequent hydrology)
- flushing and erosion of sediment (leading to changes in water quality and impacts to flora and fauna).

The irreversibility of impacts to these wetlands, including Endangered Ecological Communities (EECs), are an important consideration for OEH. For example, if the relatively impermeable base of the Newnes Plateau Shrub Swamps or Hanging Swamps is fractured, then any perched aquifer is likely to drain downwards into the fracture network, thereby altering natural groundwater levels within the swamp and leading to increased desiccation. Desiccation of swamps can lead to increased oxidation and subsidence of peat deposits; increased drying potential and a consequent increase in fire risk, changes in hydraulic conductivity and a loss of recharge potential (the swamp peat loses some of its absorption capacity), 'flashier' flooding during storm events, and an increased tendency for the catchment valley to dry up faster in post rainfall periods, that is an increase in the number of cease to flow days (see references in OEH 2014).

Site specific impacts are detailed in the 2013 audit, which states 'swamps in the Special Areas have already been impacted, and it is possible that further swamps may be impacted by current (or future) mining operations'. This 2016 Audit reviewed annual reports, their independent reviews and other investigations related to seven mines (Angus Place, Berrima, Dendrobium, Metropolitan, Russel Vale, Springvale and Wongawilli).

[3] see publications: http://www.waternsw.com.au/water-quality/catchment/mining/research/longwall




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
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| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 29. Wetlands in the Catchment (WaterNSW 2017)**

The following points describe impacts that have been published since the previous audit:

- **Angus Place (also see Springvale)** – During the 2014 reporting period there was no secondary extraction beneath Newnes Plateau Shrub Swamps or Newnes Plateau Hanging Swamps. Groundwater monitoring activities continue to show that areas that have been undermined continue to exhibit pre-mining behaviour, with the groundwater levels responding to the prevailing climatic conditions. The monitoring results showed no abnormal trends or movements in the groundwater levels which could be attributed to mining during the reporting period and as such are consistent with the initial predictions made in the 2006 Environmental Assessment (Centennial Coal 2014).
- **Berrima** – On 23 October 2013, Boral announced the transition of the Colliery to a 'care and maintenance' mode, suspending coal extraction. On 1 July 2014, Boral announced it would seek approval from the State Government to permanently close the site. Boral (2015) concluded that a proposed Final Closure Plan approach is likely to have a neutral long term impact on the Wingecarribee River.
- **Dendrobium** (Area 3B Longwall 11 - End of Panel Report) – There were no observed impacts to Wongawilli or Donalds Castle Creek resulting from Longwall 11. Multiple fractures, uplift and displacement occurred within WC21 (a tributary of Wongawilli Creek), in Rockbar 27 and upstream of Pool 30. There was surface water diversion and loss of flow in the impacted areas. Impacts to the first and second order streams SC10C, WC17, DC13, WC21 and the upper reaches of Donalds Castle Creek has resulted in a reduction of aquatic and stream pool habitat which has resulted in a number of Trigger Action Response Plan (TARP) items. Fracturing of bedrock and reductions in pool water levels and flow associated with the extraction of Longwalls 9 and 10 were observed in WC21 from December 2013. This represents a direct loss of aquatic habitat and biota. During field visits for their aquatic ecology study, the only water present at the WC21 monitoring sites was at Site X2 which consisted of a few small, shallow, disconnected pools. In Donalds Castle Creek similar, but less extensive physical mining impacts and loss of aquatic habitat were observed at Site X1 in September 2013 and in 2015 (Illawarra Coal 2016).
- **Dendrobium** (Area 3B - Report to Government) – Most mining-related impacts have not caused significant environmental harm. However, the impacts at WC21 are significant. The extent of the subsidence impacts at WC21 has exceeded the predictions of Illawarra Coal and its specialist advisers. While the impacts on upland swamps have been in accordance with predictions and are not considered at this stage to be in breach of the mine's performance measures, it is more difficult to determine their long-term significance. This is because the timeframes for impacts to swamp vegetation communities and long-term soil stability are likely to be much longer than the less than three years since mining commenced in Area 3B. Level 2 fracturing in rockbars has been observed in WC21. Since undermining of Longwalls 9 and 10, complete loss of flow has been observed in this watercourse in the area overlying the mined panels, this length being some 600 m. The bed of the stream is sufficiently cracked that it seems incapable of containing significant runoff flows for more than a few days. It was agreed that remediation action by Illawarra Coal is required at WC21. Remediation of cracking within watercourses has been successfully undertaken at a number of sites. Remediation of swamps damaged by subsidence has not yet been proven to be viable (DPE 2015).
- **Dendrobium** (Area 3B - Hydrology of Upland Swamps) - The *Hydrology of Upland Swamps* Project has clearly demonstrated impacts to the Coastal Upland Swamp (CUS) endangered ecological community as a result of longwall mining. This has included impacts to perched aquifer levels within Swamp 1b, soil moisture levels within Swamp 1b, and loss of flow to the Donalds Castle Creek tributary downstream of Swamp 1b. Together with other monitoring data on upland swamps, the overall effect of longwall mining has been a loss of the consistent perched aquifer within the undermined swamp, a slower saturation of swamp sediments in response to rainfall when it occurs and faster recession rates for soil moisture levels post rainfall events (increased desiccation of the swamp), together with a reduced delivery of water to the downstream catchment. This has major implications for the long term persistence of the swamp community above areas impacted by longwall mining and their delivery of water to the downstream catchment, which in this case forms part of Sydney's drinking water supply (Krogh 2016).
- **Metropolitan** – During the 2015 monitoring period, there were negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet, or at least 70% the Eastern

Tributary, between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 and 26, respectively (HEC 2015). The performance indicator for upland swamp groundwater levels continues to be exceeded for Swamp 20. During the last quarter of 2012, the swamp substrate piezometer changed character from being permanently waterlogged to being periodically waterlogged and now the groundwater levels regularly drop below the -2σ limit. This change appears to coincide with the passage of Longwall 21 past the site in April 2012. The water levels have fluctuated since then between the top and bottom of the hole. The passing of Longwall 22B alongside the monitoring site (September 2013) seems to have had no additional effect. Similarly, no obvious effect was observed for the closest approach of Longwall 23B (September 2014) or Longwall 24 (April 2015). There appears to be a mining effect in the sandstone groundwater levels beneath Swamp 25, but there is no evidence for groundwater level impacts within the swamp substrate. The performance indicator for upland swamp groundwater levels has not been exceeded for Swamps 25, 28, 30, 33 or 35 (HydroSimulations 2015). The upland swamp performance indicator 'The vegetation in upland swamps is not expected to experience changes significantly different to changes in control swamps' has not been exceeded. Visual inspections of riparian vegetation identified vegetation dieback greater than 50 cm from the Waratah Rivulet/Eastern Tributary at sites MRIP02, and between sites MRIP05 and MRIP09. As a result the performance indicator has been exceeded. In accordance with the Metropolitan Coal Biodiversity Management Plan, further assessment has been commissioned (Eco Logical Australia 2015).

- **Russel Vale** (Longwall 5 - End of Panel Report) - Lowering of the piezometric surface has been observed in association with low rainfall periods, although no observable adverse effect on swamp water levels has been caused in swamps overlying the LW4, LW5 20 mm subsidence zone. However, a TARP is operative due to the GW1 (VWP) and GW1A water levels in the shallow strata that have not yet recovered (Wollongong Coal 2014a).
- **Springvale** (Mine Extension Project – Review Report in response to EIS) – The Commission is aware that 39 swamps have previously been undermined at the Springvale and Angus Place mines, including 13 shrub and 26 hanging swamps. Of these 39 swamps, impacts have been observed at four, including Narrow North, Narrow South, East Wolgan and Junction Swamps. The Commission agrees with the Department that two of the eleven swamps (Sunnyside Swamp and Nine Mile Swamp), are located outside the predicted subsidence zone of the proposed longwalls and are unlikely to experience any significant fracturing. However, due to the compressive strains of up to 15mm/m resulting from valley closure, the remaining nine swamps are likely to experience some level of fracturing. The Commission acknowledges that there is a considerable lack of certainty around swamps, including a general lack of available distribution and condition data, difficulties in accurately predicting the extent and timing of swamp impacts, and uncertainty about the possibility of remediation measures. The Commission also agrees with OEH that there is currently very little evidence to suggest that rehabilitation of previously damaged swamps is effective. Given that all these uncertainties and complexities exist, the NSW Government is seeking to develop an offsets policy to deal with swamp impacts. However, OEH has raised concerns that more than 1,100 hectares of like-for-like offsets could be required, which may not be available (PAC 2015).
- **Springvale** (Mine Extension Project – response to EIS) – OEH has consistently stated that it does not support the direct undermining of Newnes Plateau Shrub Swamp (NPSS) Endangered Ecological Community (EEC) using the longwall mining technique unless there has been a modification to the mining techniques that will ensure that impacts will be prevented. This is because of the direct and long-term damage that has already occurred. Desiccation of swamps is a demonstrated impact caused by Centennial's longwall operations at both Springvale and Angus Place mines. As a result of the apparent omissions and factual errors in the History of Mining beneath Swamps section, OEH is not confident that MSEC's historical review of swamp impacts is either rigorous or reflective of what will likely occur if these swamps are directly mined beneath by 261 m or 360 m wide longwalls. In addition, the past impacts to swamps located over lineaments identify a significant potential for further irreversible impacts to NPSS EECs where they lie above mapped lineaments such as the Deanes Creek lineament. This risk is especially acute for swamps in the Carne Creek catchment. OEH is not aware of any evidence that demonstrates that Australian streams naturally 'self-remediate' after mining induced fracturing and that all water diverted to the subsurface fracture network actually 're-emerges further downstream'. There are many areas in the Southern and Western coalfields where this has not been found to have occurred despite decadal periods of time since mining impacts were first recognised (OEH 2014).

- **Wongawilli** (Longwall N2 - End of Panel Report) – No upland swamps are located in the vicinity of Longwall N2; no observable changes to vegetation composition in Wattle Tree Creek or Little Wattle Tree Creek; no observable changes to frog populations in Wattle Tree Creek or Little Wattle Tree Creek (Wollongong Coal 2014b).

**Local council programs**
Most information received from councils focused on riparian vegetation, and has been presented in **Section 4.3** of this audit. Although riparian zones are associated with wetlands (flowing streams), the list in **Table 32** refers to non-flowing wetlands, or floodplains connected to flowing streams.

**Table 32. Local Council wetland management programs**

| Council | Regeneration or rehabilitation | Weed management |
|---|---|---|
| Blue Mountains City Council | >50 Bushcare and Landcare groups operate in the Blue Mountains | >50 Bushcare and Landcare groups operate in the Blue Mountains |
| Goulburn Mulwaree Council | Eastgrove Wetlands – Completed by FROGS (Friends and Residents of Goulburn's Swamplands) Landcare Inc. This group has established a wetlands from an old brick pit. This project has been going for about 3 years. | |
| Wingecarribee Shire Council | Mittagong Creek Rehabilitation project, and Rivercare (Bushcare) Group – includes revegetation works post weed removal, and approximately 6,000 native plants for native grassland and wetland habitat. | Likely as part of regeneration works |

**Conclusion**
The available data indicates that there has been a decline in the extent and condition of wetlands in some areas of the Catchment, and efforts to rehabilitate wetlands that were impacted by longwall mining have been unsuccessful to date. However, community groups have been working to regenerate and rehabilitate wetlands in some areas in the Blue Mountains, Goulburn Mulwaree and Wingecarribee Council areas.

## 4.7 Watercourse physical form

**Definition and context**

Physical form describes the geomorphic complexity of a river. An understanding of the physical form and underlying physical processes occurring within a river system can be used to predict the likely trajectory of a waterway (with and/or without management interventions) and target areas for investment. Furthermore, an understanding of geomorphic processes is fundamental to understanding the likely water quality conditions that will arise within the Catchment, due to the strong interdependency of fine sediment loads and nutrient loads.

One system for assessing physical form is provided by the Riverstyles® framework. Riverstyles is a geomorphic approach for examining river character, behaviour, condition and recovery potential (Brierley and Fryirs 2005). The Riverstyles framework has been applied extensively throughout NSW to capture data at a river reach scale on the geomorphic character, behaviour, condition and expected recovery potential. The Riverstyles assessments undertaken across NSW provide the only widespread, systematic and reach-scale evaluation of the geomorphic character and condition of waterways, so are therefore the primary dataset of interest for the physical form indicator.

As such, the 2013 Audit's consideration of physical form drew heavily upon the following Riverstyles assessments previously undertaken across the catchments:

- A 2012 RiverStyles assessment across the Hawkesbury Nepean CMA region (GHD 2012a), which itself built upon earlier assessments of the major streams from 2001 (ID&A 2001). This dataset covers the Warragamba, Blue Mountains and Upper Nepean SCA catchments i.e. the majority of the study region.
- A 2012 RiverStyles assessment across the Southern Rivers CMA region (GHD 2012b). This dataset covers the Shoalhaven SCA catchment i.e. a large portion of the study region.

In reviewing the 2013 Audit it is apparent that this failed to include the 2007 RiverStyles assessment from the Sydney Metropolitan CMA region (Earth Tech 2007), which covers the Woronora SCA catchment. Fortunately the exclusion of the Woronora assessments from the 2013 Audit had little impact on the audit results - almost all streams of the Woronora catchment were assessed as being in good condition[4] and are therefore not detrimentally impacting Catchment health.

**Data**

Since the 2013 audit no further additions or updates have been made to Riverstyles assessments within the catchments (pers. comm., Department Primary Industries, December 2016). In the absence of updates to the RiverStyles mapping since 2012, the systematic understanding of geomorphic river condition across the Catchment has not substantially advanced since the previous audit.

With this context in mind, the 2016 Audit has not sought to reproduce the Riverstyles assessments documented in the 2013 Audit report – the findings of the 2013 Audit still represent the most current systematic knowledge on physical form across the catchments.

However, the 2016 Audit identified the opportunity to re-analyse the Riverstyles data to provide a more direct measure of the likely impact on water quality arising from fluvial geomorphic processes throughout the catchments. Specifically, while the Riverstyle data presented in the 2013 Audit provides a thorough description of the form and condition of waterways, what is more directly relevant to water quality management is an understanding of high risk areas for ongoing bank/bed erosion of fine sediments (associated with high nutrient load generation). The 2016 Audit has therefore involved a re-analysis of the Riverstyles data to provide an improved understanding of the risk for sediment and nutrient delivery to downstream. This re-analysis is presented below.

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[4] Several short headwater reaches in Darkes Forest were in moderate condition, but assessed as having high recovery potential, so are unlikely to pose a threat to overall catchment condition.

**Method**
In the context of the Riverstyle assessment data, the relative risk that a given waterway will produce and deliver sediment to downstream reaches is a function of the:

- Riverstyle classification e.g. some styles are more prone to channel adjustments such as incision (deepening and widening), meander migration (lateral movement) and avulsion, and styles with fine bed and bank sediments will produce higher rates of nutrient delivery than those with sand/gravel sediments.
- Condition of the reach e.g. degraded waterways of a given Riverstyle will produce and export more sediment than waterways in intact/good condition.

These components of the Riverstyle assessments were translated to provide a rating of the sediment/nutrient generation risk for each reach. The matrix shown in **Table 33** was developed to provide risk ratings between 1 and 10, where higher numbers represent a greater risk of sediment/nutrient generation.

**Table 33. Risk rating assigned based on Riverstyle classification and geomorphic condition**

| Riverstyle | Good | Moderate | Poor | Condition not assigned |
|---|---|---|---|---|
| *CVS - Floodplain pockets, sand* | 2 | 2 | 2 | (no reaches) |
| *CVS - Floodplain pockets, gravel* | 2 | 2 | 2 | (no reaches) |
| *CVS - Headwater* | 1 | 1 | 1 | (no reaches) |
| *CVS - Gorge* | 1 | 1 | 1 | (no reaches) |
| *CVS - Terrace Gorge* | (no reaches) | 1 | (no reaches) | (no reaches) |
| *CVS T - Sinking ** | 1 | (no reaches) | (no reaches) | (no reaches) |
| *SMG - Chain of ponds* | 4 | 8 | 9 | (no reaches) |
| *SMG - Valley fill, fine grained* | 4 | 8 | 9 | (no reaches) |
| *SMG - Valley fill, sand* | 4 | 6 | 7 | (no reaches) |
| *LUV CC - Channelised fill* | 6 | 8 | 9 | (no reaches) |
| *LUV CC - Low sinuosity, fine grained* | 6 | 8 | 9 | (no reaches) |
| *LUV CC - Low sinuosity, sand* | 5 | 5 | 7 | (no reaches) |
| *LUV CC - Low sinuosity, gravel* | 5 | 5 | 7 | (no reaches) |
| *LUV CC - Meandering, fine grained* | 6 | 8 | (no reaches) | (no reaches) |
| *LUV CC - Tidal ** | 4 | | (no reaches) | (no reaches) |
| *PCVS - Bedrock controlled, fine grained* | (no reaches) | 7 | 8 | (no reaches) |
| *PCVS - Bedrock controlled, gravel* | 3 | 3 | 5 | (no reaches) |
| *PCVS - Bedrock controlled, sand* | 3 | 3 | 5 | (no reaches) |
| *PCVS - Planform controlled, low sinuosity, fine grained* | 5 | 7 | 8 | (no reaches) |
| *PCVS - Planform controlled, low sinuosity, gravel* | 3 | 3 | 5 | (no reaches) |
| *PCVS - Planform controlled, meandering, fine grained* | 5 | (no reaches) | (no reaches) | (no reaches) |
| *PCVS - Planform controlled, low sinuosity, sand* | 3 | 3 | 5 | (no reaches) |
| *Not assessed (within reserve in HNCMA region)* | (no reaches) | (no reaches) | (no reaches) | 3 |
| *Urban Stream - Highly Modified* | 1 | 1 | 1 | 1 |
| *Water storage - dam or weir pool* | 0 | 0 | 0 | (no reaches) |

* The 'CVS T – Sinking' and 'LUV CC – Tidal' Riverstyles are clearly erroneous assessments as there are no tidal reaches within the study area. The reaches with these classifications total 790 m and 1,223 m respectively across the study area so are of little consequence to the overall understanding of geomorphic condition and trajectory.

Mapping the risk ratings across the study area identified that the spatial distribution of risk across the catchments generally aligns with the spatial distribution of geomorphic condition (i.e. comparing **Figure 30** with Figure 6.10 of the 2013 Audit).

However, when examined at a sub-catchment level there are some stark differences in the percentage of streams in poor/moderate condition and the percentage of streams at high risk of sediment/nutrient generation (**Figure 31** and **Figure 32**). Of particular note from this analysis is that:

- The Braidwood, Mulwaree River and Upper Wollondilly River sub-catchments stand out as having by far the highest proportion of high risk streams (more than 50% of their stream length was categorised as risk level 8 or 9). This is despite their condition ratings being similar to many other sub-catchments.

- The Boro Creek, Nerrimunga River, Upper Cox River and Wingecarribee River sub-catchments represent the next most at risk sub-catchments (up to one-third of their stream length was categorised as risk level 8 or 9).

The above results considered the proportion of stream length within each catchment that was in each condition and risk category, which is consistent with the way results were analysed for the 2013 Audit. While this is helpful to provide a sense of the sub-catchments more/less degraded, it does not account for the relative size of the sub-catchment (i.e. its actual length of stream). Therefore **Figure 33** presents the total length of streams in poor/moderate condition and total length of streams at high risk of sediment/nutrient generation for each sub-catchment. This analysis demonstrates that:

- The Wollondilly River sub-catchment has by far the greatest length of high risk waterways (having 343 km of stream categorised as risk level 8 or 9). Given its large size this sub-catchment was not otherwise identified through the proportional statistics presented above.
- The Mulwaree River and Upper Wollondilly River sub-catchments have the second greatest length of at risk streams (having 245 km and 207 km respectively categorised as risk level 8 or 9). Being smaller catchments than the Wollondilly River, these two may be suitable for a more intensive river rehabilitation program than the Wollondilly River sub-catchment.
- The remaining sub-catchments with a high proportion of high risk streams (e.g. Boro Creek, Braidwood, Nerrimunga River, Upper Coxs River, Wingecarribee River) have much smaller total lengths of high risk streams (owning to their relatively small sub-catchment size) and may therefore be a lesser focus for rehabilitation than those mentioned above.

**Conclusion**
The findings above indicate that the greatest risk of sediment/nutrient generation through fluvial geomorphic processes is expected to arise from the Wollondilly region, including the Wollondilly sub-catchment itself and its two major tributaries sub-catchments the Mulwaree and Upper Wollondilly. Sediment and nutrient generation in this region will have a direct impact on the downstream receiving waterbody of Lake Burragorang. Further investigation and planning of a targeted stream restoration program in this region would provide greater protection to Sydney's water supply catchments.

The Riverstyles datasets forming the basis of this assessment have not been updated since 2012. This prevented the 2016 Audit from examining the temporal trends in physical form since the previous audit. As a result the 2016 Audit focused on a re-analysis of the spatial trends in physical form.

Past experience undertaking fluvial geomorphology investigations in south-east Australia would suggest that geomorphic characteristics are likely to remain relatively consistent at a catchment-scale over a four-year period, though there will be changes at a reach and sub-catchment scale. Consequently there is a moderate level of confidence that the results from the Riverstyles assessments of 2012 are still representative of the general conditions occurring at this point in time.

Future reviews and updates of the Riverstyles assessments will be required to identify changes in geomorphic character and condition over time and to inform future catchment audits.

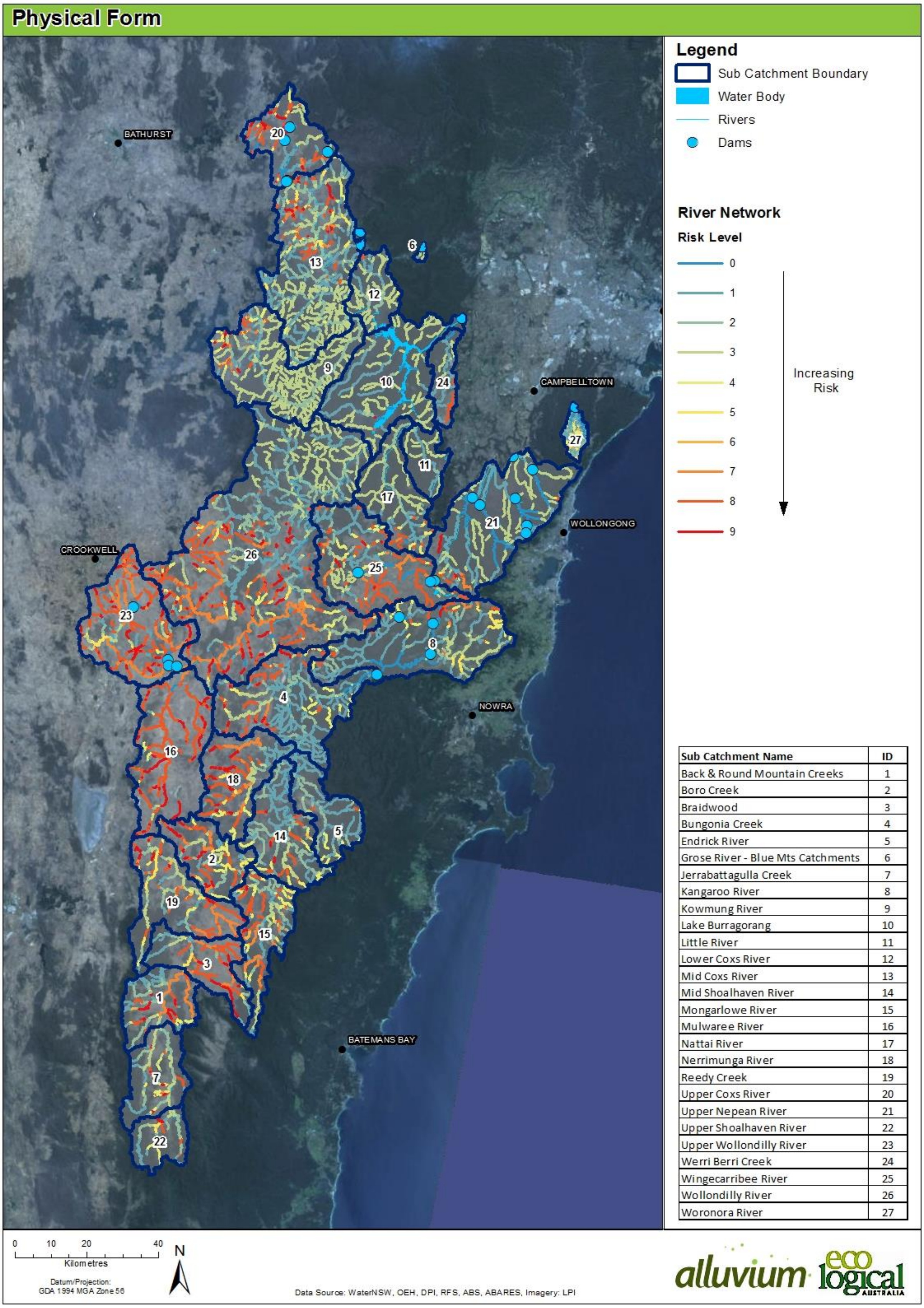



**Figure 30. Ratings of the relative risk of sediment / nutrient generation from each reach**

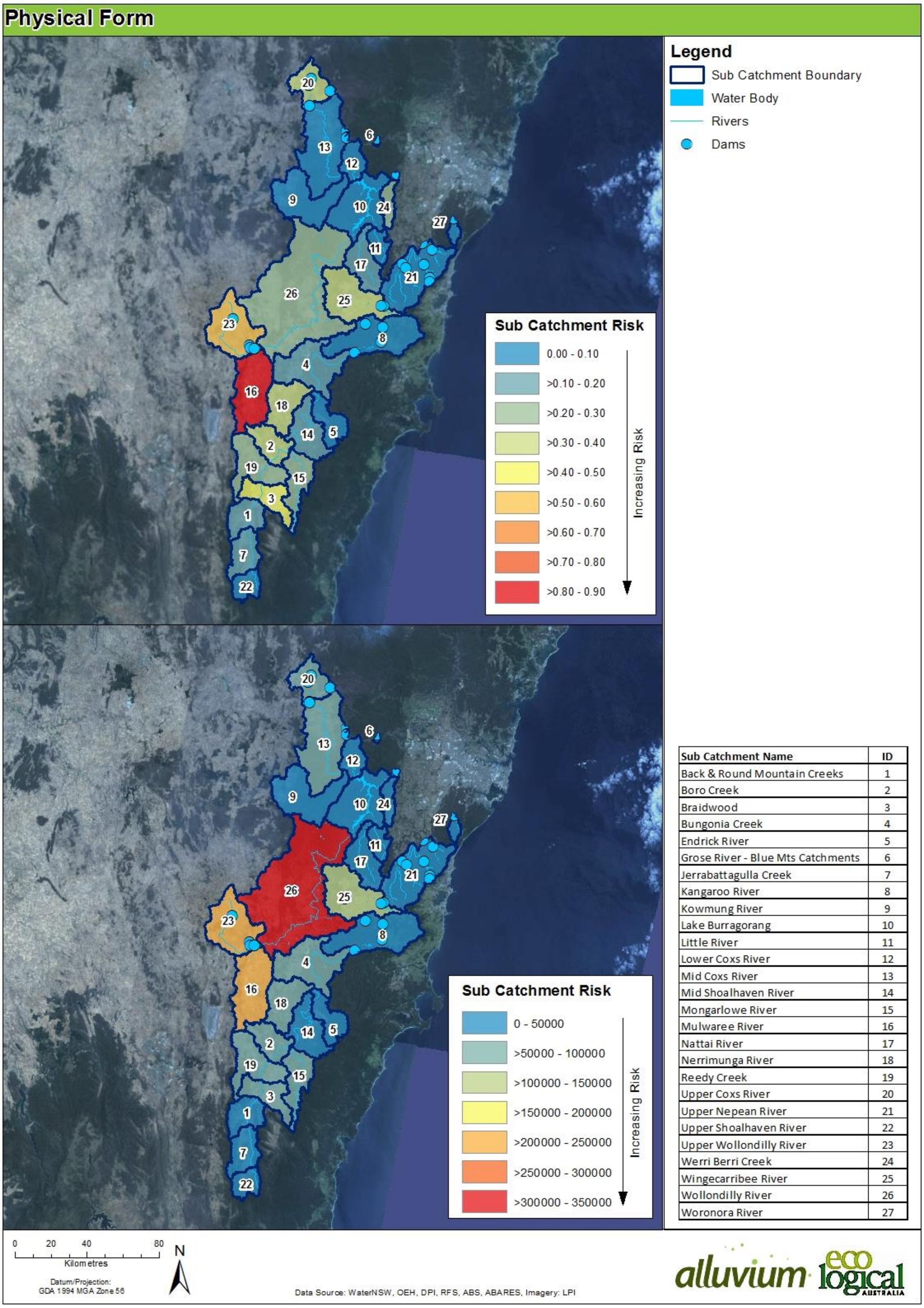



**Figure 31. Stream length in each sub-catchment with a risk score of ≥8 shown as a proportion of total sub-catchment length (top) and as absolute length in metres (bottom)**

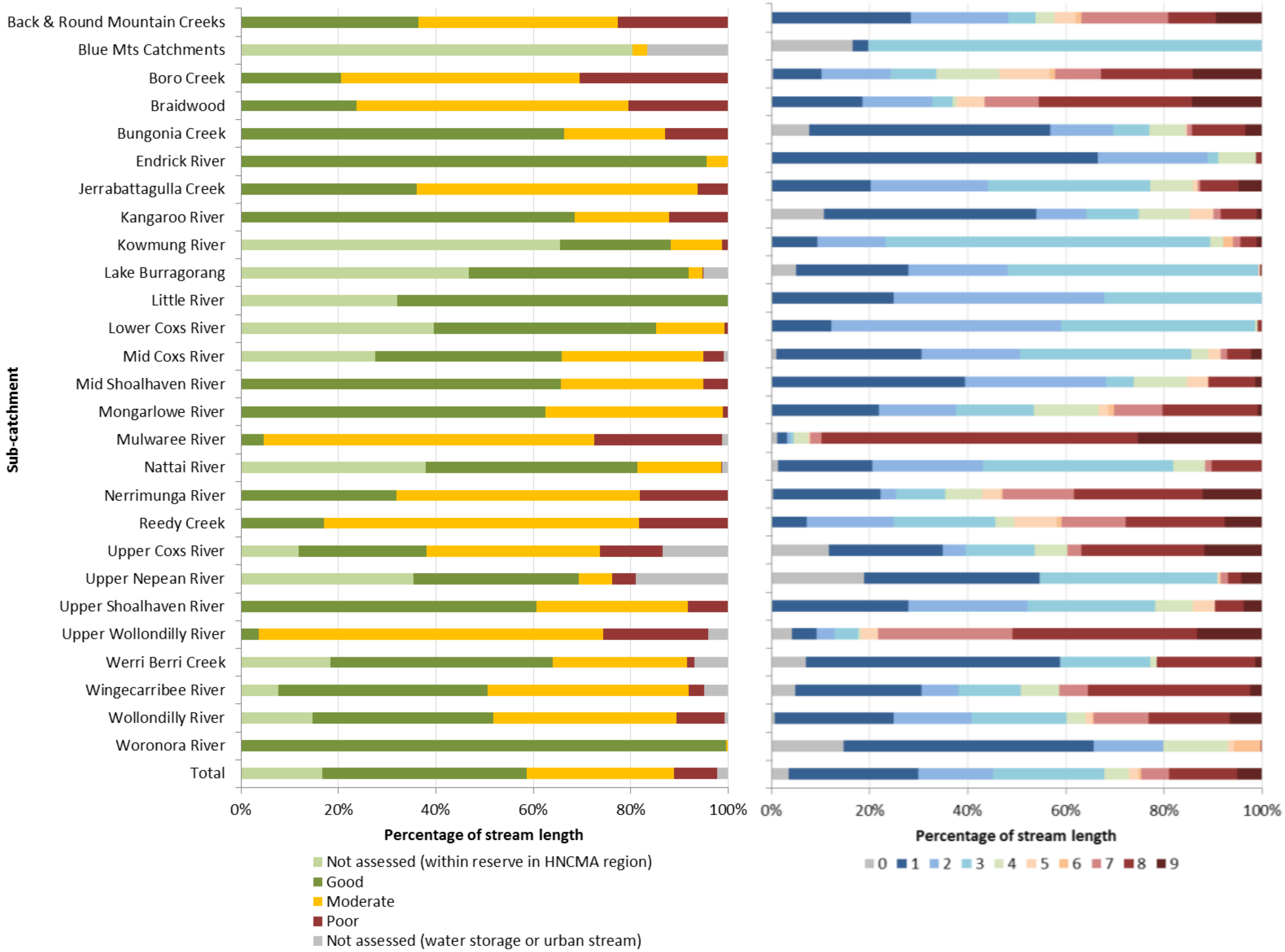



**Figure 32. Percentage of stream length in each sub-catchment in each condition category (left) and with each risk rating (right)**

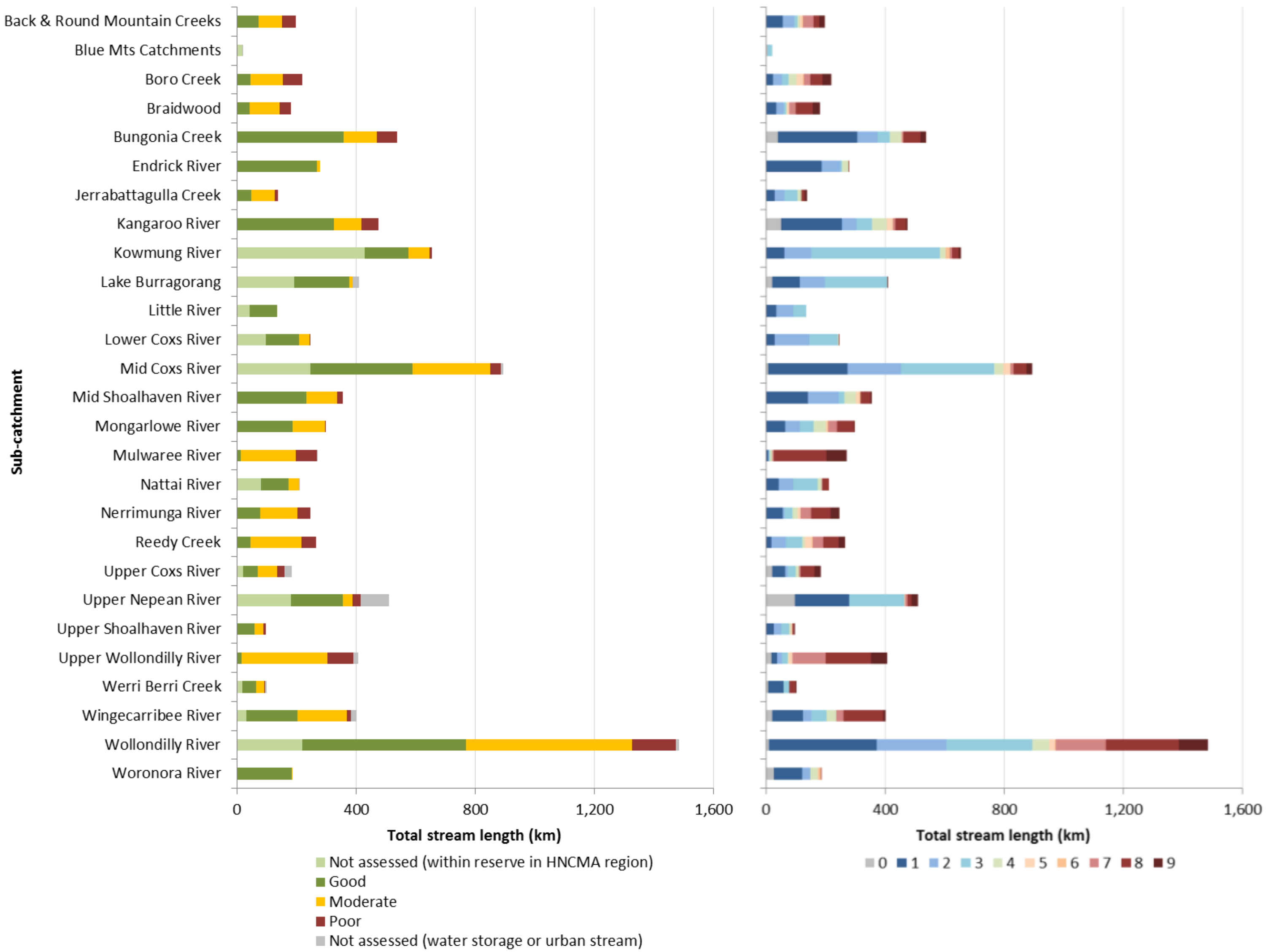



**Figure 33. Total stream length in each sub-catchment in each condition category (left) and with each risk rating (right)**

# 5 Environmental pressures

## 5.1 Land use

**Definition and context**

The land use indicator focuses on spatial and quantitative changes in land use across the Catchment. This indicator indirectly provides an understanding of the possible sources of pollution, and the potential risks to catchment water quality arising from them (DWE 2008). The indicator also assists with evaluating where land use changes may have potentially eased threats to catchment water quality.

The criteria for this indicator include:

- the type and extent of land uses across the catchment
- land use changes since the previous audit
- the number and type of development applications
- the area under mining lease.

Under the multi-barrier approach to catchment management, increasing development will increase risks to drinking water supply (ie. **worsening** trend). Conversely, an increasing area of land managed for conservation purposes should reduce risks to supply (ie. **improving** trend).

**Land use data**

Land use mapping data for the Catchment was provided by WaterNSW. The 2016 land uses were mapped by WaterNSW based on the Australian Land Use and Management (ALUM version 7) classification system. Land use data were also sourced from the previous catchment audit (GHD 2013) for 2010 and 2012. The land use data were reviewed to quantify and map changes in land use that have occurred since the previous 2013 audit.

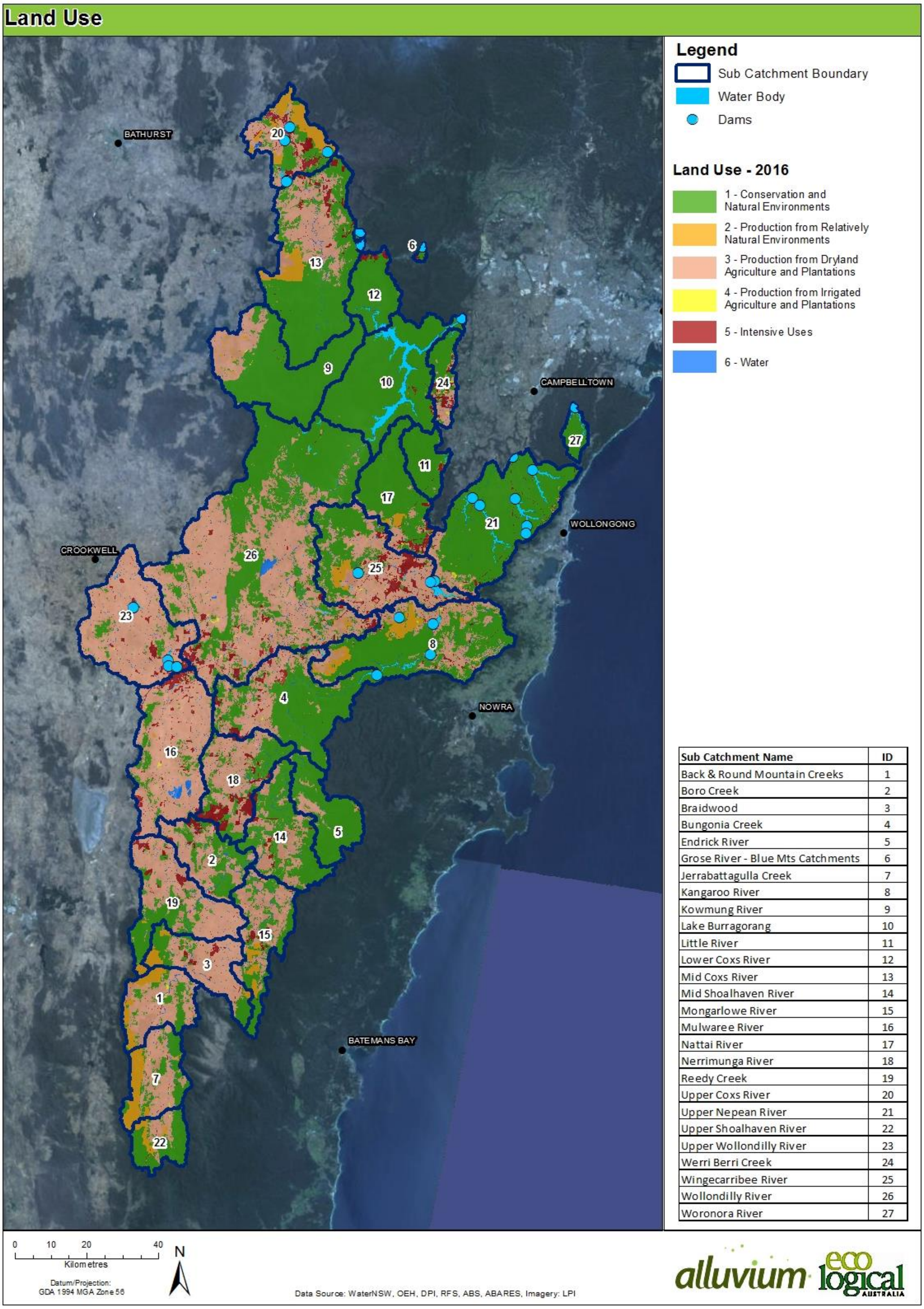
Data on the number and type of development applications were provided by WaterNSW and sourced from the NSW Planning and Environment (DPE) for the audit period. WaterNSW provided data on development applications referred by consent authorities for concurrence under the *Water NSW Act 2014*. The number of approved development applications for individual local government areas (LGAs) in the Catchment was sourced from DPE (http://datareporting.planning.nsw.gov.au). The sourced data provided details on development applications considered during the audit period in the following categories:

- Development applications that were reviewed internally and solely by individual councils
- New development applications forwarded to Water NSW by individual councils for consideration and concurrence under the Water NSW Act 2014
- State Significant Development, State Significant Infrastructure and Part 3A approvals
- Minor modifications to existing development consents under s96 of the *Environmental Planning and Assessment Act 1979*
- Major amendments to existing development consents.

Spatial data showing details and extents of mining, mineral and petroleum leases were sourced from the NSW Department of Industry, Resources and Energy (http://minview.minerals.nsw.gov.au/). The data includes details on areas that are actively mined or under exploration.

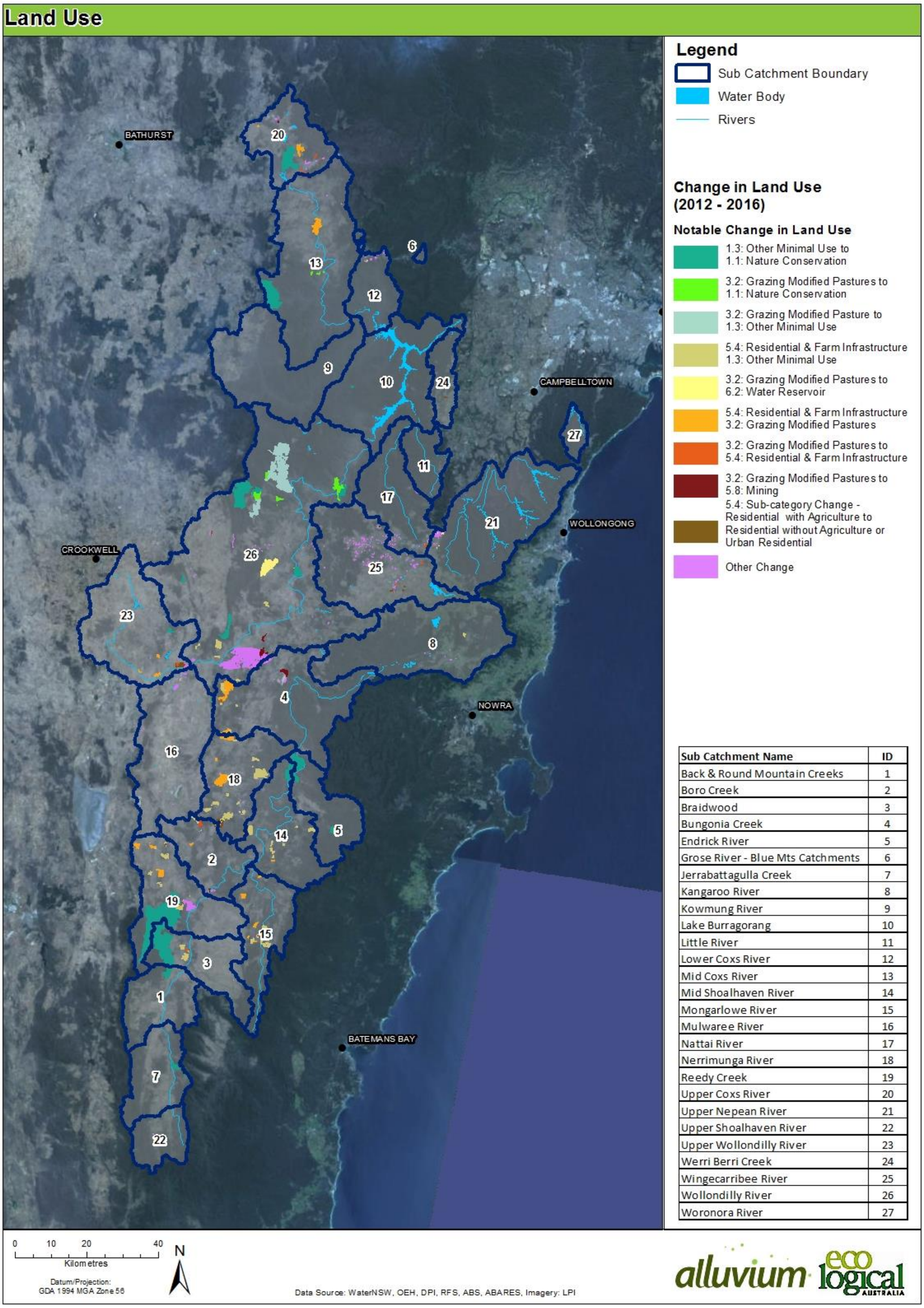
**Changes in land use**

Mapping of the 2016 ALUM 7 land use categories is shown on **Figure 34**. ALUM 7 categories where the total land use area has changed considerably (assumed to be more than 100 ha across the Catchment) between 2012 and 2016 are mapped separately on **Figure 35**. Total land use areas across the Catchment for each ALUM category in 2010, 2012 and 2016 are presented in **Table 34**.




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 34. Land use categories 2016**




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 35. Significant land use changes 2012-16 (excluding changes to underground mining)**

**Table 34. Total land use areas**

| ALUM 7 Class Code | ALUM 7 Major Category / Sub-category Description | 2010 (ha) (GHD 2013) | 2012 (ha) (GHD 2013) | 2016 (ha) | % change 2013 to 2016 |
|---|---|---|---|---|---|
| 1 | **Conservation and Natural Environments** | **785,480** | **785,551** | **796,540** | **1%** |
| 1.1 | Nature conservation | 414,501 | 414,487 | 442,321 | 7% |
| 1.2 | Managed resource protection | 109,238 | 109,223 | 109,206 | 0% |
| 1.3 | Other minimal use | 261,741 | 261,840 | 245,013 | -6% |
| 2 | **Production from Relatively Natural Environments** | **53,348** | **53,340** | **53,315** | **0%** |
| 2.1 | Grazing native vegetation | 138 | 138 | 138 | 0% |
| 2.2 | Production forestry | 53,210 | 53,201 | 53,176 | 0% |
| 3 | **Production from Dryland Agriculture and Plantations** | **620,545** | **617,373** | **613,411** | **-0.6%** |
| 3.1 | Plantation forestry | 35,533 | 35,497 | 35,498 | 0% |
| 3.2 | Grazing modified pastures | 567,389 | 564,174 | 560,194 | -0.7% |
| 3.3 | Cropping | 943 | 919 | 1,011 | 10% |
| 3.4 | Perennial horticulture | 198 | 316 | 316 | 0% |
| 3.5 | Seasonal horticulture | 305 | 330 | 330 | 0% |
| 3.6 | Land in transition | 16,177 | 16,138 | 16,062 | -0.5% |
| 4 | **Production from Irrigated Agriculture and Plantations** | **2,777** | **2,811** | **2,718** | **-3%** |
| 4.1 | Irrigated plantation forestry | 18 | 17 | 17 | 0% |
| 4.2 | Grazing irrigated modified pastures | 1,499 | 1,477 | 1,385 | -6% |
| 4.3 | Irrigated cropping | 0 | 6 | 6 | 0% |
| 4.4 | Irrigated perennial horticulture | 1,050 | 1,059 | 1,059 | 0% |
| 4.5 | Irrigated seasonal horticulture | 209 | 249 | 249 | 0% |
| 4.6 | Irrigated land in transition | 1 | 1 | 1 | 0% |
| 5 | **Intensive Uses** | **76,956** | **76,316** | **68,227** | **-11%** |
| 5.1 | Intensive horticulture | 56 | 55 | 56 | 2% |
| 5.2 | Intensive animal husbandry | 3,187 | 3,185 | 3,195 | 0% |
| 5.3 | Manufacturing and industrial | 292 | 286 | 286 | 0% |
| 5.4 | Residential and farm infrastructure | 51,740 | 51,084 | 42,483 | -17% |
| 5.5 | Services | 5,914 | 5,900 | 5,848 | -1% |
| 5.6 | Utilities | 2,227 | 2,218 | 2,221 | 0.1% |
| 5.7 | Transport and communication | 10,140 | 10,132 | 10,151 | 0.2% |
| 5.8 | Mining | 2,915 | 2,986 | 3,517 | 18% |
| 5.9 | Waste treatment and disposal | 485 | 470 | 470 | 0% |
| 6 | **Water** | **26,261** | **29,977** | **31,155** | **4%** |
| 6.1 | Lake | 1,342 | 1,331 | 1,331 | 0% |
| 6.2 | Reservoir | 14,911 | 18,667 | 19,844 | 6% |
| 6.3 | River | 9,146 | 9,138 | 9,138 | 0% |
| 6.4 | Channel/aqueduct | 1 | 1 | 1 | 0% |
| 6.5 | Marsh/wetland | 861 | 839 | 839 | 0% |
| | | | | | |
| | | 1,565,367 | 1,565,368 | 1,565,366 | |

Major changes in land use are summarised below with changes in specific sub-catchments summarised in **Table 35**. **Table 34** and **Figure 35** indicate there were considerable increases in nature conservation, mining and reservoir land use areas between 2012 and 2016.

Nature conservation areas have increased by over 24,000 ha (7%) across the catchments. This increase is primarily associated with land previously categorised as residual native cover or grazing modified pastures land transitioning to nature conservation area (either national park or protected landscapes).

The area of mining (including mines, quarries, tailings and disused extractive industries) has increased by approximately 530 ha (18%) across the catchments. The increased mining area is primarily associated with expansion of two quarries near the town of Marulan and one near the adjacent town of Brayton in the Wollondilly River and Bungonia Creek sub-catchments. Expansion of mining areas near Blackmans Flat and Lidsdale in the Upper Coxs River sub-catchment have also occurred since the previous audit.

The current mining and mineral leases in the catchment were sourced from the NSW Department of Industry, Resources and Energy (http://minview.minerals.nsw.gov.au/). The data is separated into areas that are currently mined or under exploration (refer to **Figure 36** and **Figure 37**). A hold was put on Petroleum Exploration Licences and coal seam gas activities in the Catchment Special Areas during the Audit period as an outcome from the NSW Gas Plan.

**Table 34** indicates there have been significant reductions in other minimal use, grazing modified pastures, and residential and farm infrastructure land use areas between 2012 and 2016.

In the central to southern parts of the Catchment, previously rural residential land (without agriculture) is now actively being grazed and used for agriculture. Other rural residential land in this area is now residual native cover (other minimal use). There are also localised areas throughout the catchments where previous grazing land has transitioned to urban residential development.

The other minimal use category land has reduced by over 16,800 ha (-6%) and this reduction is primarily associated with the transition of residual native cover land into the nature conservation category (national park and protected landscapes).

The grazing modified pastures category includes areas with greater than 50% exotic pasture grasses (i.e. less than 50% native vegetation) and woody fodder plants for livestock grazing. The 2016 mapping indicates this category has decreased by 4,000 ha (-0.7%) since the previous audit. The grazing modified pastures changes are primarily associated with changes in land use to mining, urban residential, rural residential with agriculture, residual native cover areas and reservoir.

The residential and farm infrastructure category includes urban residential, rural residential (including small hobby farms), remote communities and farm buildings/infrastructure (footprint of infrastructure only). The area of residential and farm infrastructure has reduced by over 8,600 ha (-17%). The reductions in residential and farm infrastructure land use areas are primarily associated with rural residential without agriculture land transitioning to grazing, residual native cover or urban residential land.

**Table 35. Summary of sub-catchments with notable land use changes**

| ID | Sub-catchment | Notable land use changes |
|---|---|---|
| 3 | Braidwood | • Additional area of national park (nature conservation) in the forested area near Tallaganda in the western section of the sub-catchment that was previously residual native cover (other minimal use).<br>• Additional residual native cover (other minimal use) land previously rural residential without agriculture land (residential and farm infrastructure). |
| 4 | Bungonia Creek | • Two large land parcels in the west of the sub-catchment, mapped rural residential without agriculture (residential and farm infrastructure) in previous audit now grazing on modified pastures. Parts of these sites also transitioned from rural residential (residential and farm infrastructure) to residual native cover (other minimal use).<br>• New mine (quarry) on land east of Marulan previously mapped as grazing modified pastures. |
| 5 | Endrick River | • Large areas in the sub-catchment transitioned to national park (nature conservation) from previously mapped residual native cover (other minimal use). |
| 13 | Mid Coxs River | • Area of land just north of Jenolan Caves transitioned to national park (nature conservation) from previously mapped residual native cover (other minimal use).<br>• Central area in the sub-catchment transitioned from residential and rural residential without agriculture land (residential and farm infrastructure) to grazing modified pastures. |
| 18 | Nerrimunga River | • A number of areas distributed throughout the sub-catchment where land use has transitioned from rural residential without agriculture (residential and farm infrastructure) to residual native cover (other minimal use).<br>• Area in the south of the sub-catchment transitioned from rural residential without agriculture (residential and farm infrastructure) to rural residential with agriculture (residential and farm infrastructure).<br>• Large area in the central and northern parts of the sub-catchment transitioned from rural residential without agriculture (residential and farm infrastructure) to grazing modified pastures. |
| 19 | Reedy Creek | • Additional area of national park (nature conservation) land in the forested area near Tallaganda (continuous area from adjacent Sub-catchment 3) in the upper reaches of the sub-catchment previously residual native cover.<br>• Large areas in the central northern parts of the sub-catchment transitioned from rural residential without agriculture (residential and farm infrastructure) to grazing modified pastures.<br>• Several areas distributed throughout the sub-catchment where land use has transitioned from rural residential without agriculture to residual native cover (other minimal use).<br>• Area where land use has transitioned from grazing modified pastures to rural residential with agriculture. |
| 20 | Upper Coxs River | • Expansion of mining near Blackmans Flat and Lidsdale in areas mapped land under rehabilitation (land in transition) or grazing modified pastures in the previous audit.<br>• A large proportion of the Marrangaroo National Park has transitioned from residual native cover (other minimal use) to national park (nature conservation).<br>• Large area of land east of Lithgow Golf Club transitioned from rural residential without agriculture to grazing modified pasture. |

| ID | Sub-catchment | Notable land use changes |
|---|---|---|
| | | • A number of land parcels adjacent to the Lithgow urban area transitioned from rural residential or grazing modified pasture to urban residential. |
| 26 | Wollondilly River | • In northern parts of the sub-catchment, large areas of land use have transitioned from grazing to residual native cover (other minimal use) or from residual native cover (other minimal use) to protected landscape or national park (both nature conservation).<br>• Expanded mining land use (quarries) at two locations in the upper catchment area near the adjacent towns of Brayton and Marulan that have transitioned from previous grazing modified pastures land use. |

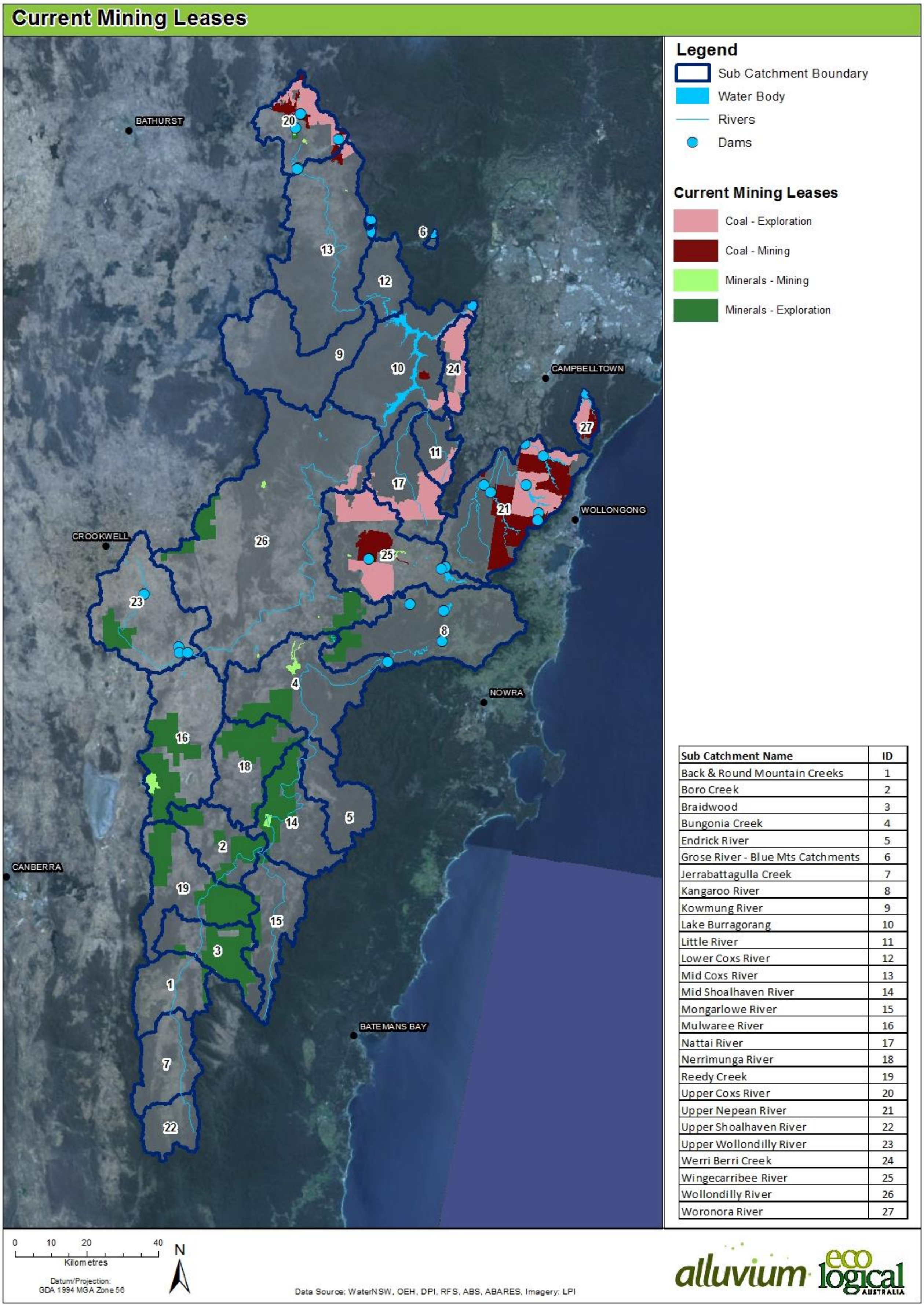



**Figure 36. Current mining leases**

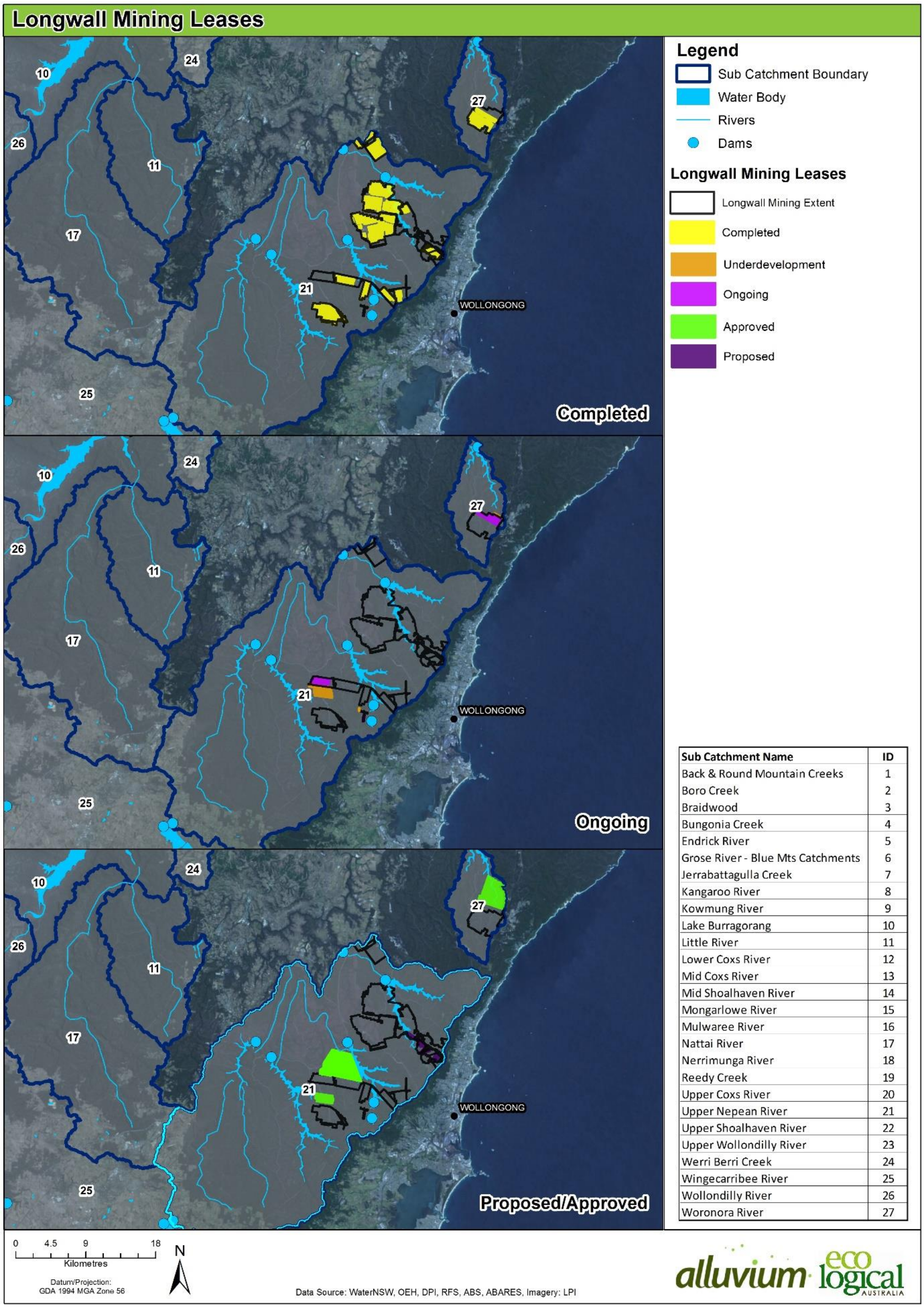



**Figure 37. Longwall mining leases in the Woronora and Upper Nepean sub-catchments**

### Development applications

***All development applications***

The average annual number of development applications approved by each Council in the Catchment are summarised for the current and previous audit periods in **Table 36**. The percentage change in the average annual number of development applications is also mapped for each LGA on **Figure 38**. Complete data were only available for 2013-15 and therefore averages in the current audit period are based on two year's data.

**Table 36. Average annual number of development applications approved by councils**

| Council name | 2010-2013 | 2013-2015 | Change in average annual DA's |
|---|---|---|---|
| Blue Mountains City Council | 694 | 750 | +8.0% |
| City of Lithgow Council | 228 | 259 | +13.8% |
| Goulburn Mulwaree Council | 355 | 370 | +4.3% |
| Kiama Council | 283 | 268 | -5.4% |
| Oberon Council | 72 | 99 | +36.2% |
| Palerang Council | 312 | 260 | -16.6% |
| Shoalhaven City Council | 1473 | 1511 | +2.6% |
| Upper Lachlan Shire Council | 135 | 112 | -17.4% |
| Wingecarribee Shire Council | 713 | 684 | -4.1% |
| Wollondilly Shire Council | 723 | 776 | +7.4% |
| Wollongong City Council | 1366 | 1398 | +2.3% |

Source: http://datareporting.planning.nsw.gov.au/ldpm-download-data

**Table 36** shows that development approvals have increased in most LGAs within the catchments. Development approvals have increased in most of the more populated LGA's (i.e. Wollondilly, Blue Mountains, Wollongong, Shoalhaven). Development application approvals reduced in the Wingecarribee, Kiama, Upper Lachlan and Palerang LGAs and were relatively steady in Goulburn-Mulwaree. It is envisaged that many of the development approvals in the coastal LGA's (i.e. Wollongong, Kiama and Shoalhaven) are in areas that drain to the coast outside the catchments. Similarly, development in the more inland LGA's (e.g. Upper Lachlan) may also be occurring in areas that drain to inland rivers outside the catchments. The available development application data for each LGA does not define if the development is located within the catchments.

**Figure 38** indicates that the percentage change in development applications was highest in the northern part of the catchments closest to the Special Areas. Overall, the development application data indicates (compared to the previous audit) that pressures on natural resources in individual sub-catchments may be increasing more significantly from approved developments in the Wollondilly, Blue Mountains, Lithgow and Oberon LGAs.

The total number of DAs referred to WaterNSW for concurrence reduced by an average of approximately 20% across the LGA's. In the Blue Mountains and Palerang LGA's the reduction exceeded 50%. Whilst the number of referred DA's was lower, the total number of DA's increased in many LGA's. The reduction in the number of referred DA's was potentially due to DA's with only a minor potential for water quality impacts no longer being referred to WaterNSW.

WaterNSW provided data on the number of State Significant Development (SSD) and State Significant Infrastructure (SSI) developments reviewed by WaterNSW during the audit period. The data showed that less SDD and SSI developments were reviewed compared to the previous audit period. Consistent with the previous audit, SSD applications were primarily for mining and extractive industry developments.

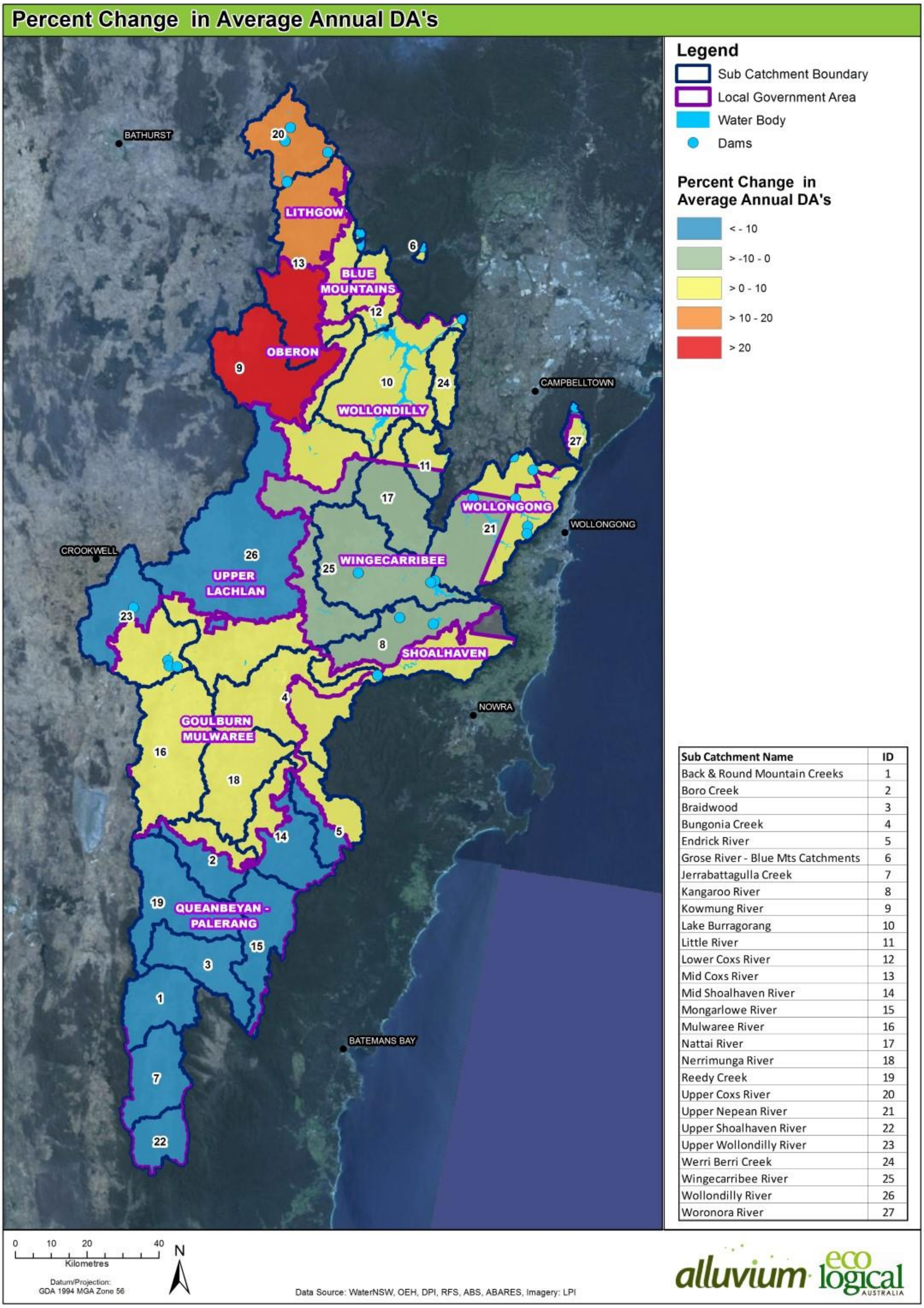



**Figure 38. Percentage change in average annual development applications**

***Referred development applications***
State Environmental Planning Policy (Sydney Drinking Water Catchments) 2011 requires that any development proposed in the catchments shall incorporate WaterNSW's current recommended practices and standards, or achieve outcomes that exceed these practices. Currently, development applicants are required to demonstrate that their development would have a neutral or beneficial effect on water quality.

In accordance with the *Water NSW Act 2014*, consent authorities (primarily councils) are required to achieve concurrence with WaterNSW prior to approving development in the catchments, except in circumstances where the Minister is the consent authority or the consent authority is satisfied that the development would have no identifiable impact on water quality.

Development applications that were referred by councils to WaterNSW for concurrence in the audit period are summarised in **Table 37.** **Table 37** also includes development application totals from the previous audit.

**Table 37. Development applications requiring WaterNSW concurrence between 2013 and 2016**

| | **Referred DAs 2013 - 2016** | | | | | | | **Referred DAs 2010-2013** |
|---|---|---|---|---|---|---|---|---|
| **LGA** | **Rural Dwelling / Dual Occupancy** | **Urban Subdivision / Multi-dwelling sewered** | **Rural Subdivision** | **Commercial / Industrial** | **Tourism/ Recreation/ Cultural** | **Other** | **Total** | **Total (GHD 2013)** |
| Blue Mountains | 4 | 4 | 0 | 4 | 4 | 3 | 19 | 40 |
| Goulburn Mulwaree | 13 | 23 | 13 | 16 | 13 | 21 | 99 | 108 |
| Kiama | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Lithgow | 24 | 6 | 14 | 16 | 8 | 22 | 90 | 112 |
| Oberon | 1 | 0 | 2 | 0 | 0 | 0 | 3 | 1 |
| Palerang | 9 | 3 | 3 | 2 | 0 | 7 | 24 | 52 |
| Shoalhaven | 5 | 1 | 1 | 1 | 13 | 2 | 23 | 37 |
| Upper Lachlan | 9 | 2 | 0 | 0 | 1 | 4 | 16 | 21 |
| Wingecarribee | 11 | 82 | 25 | 42 | 47 | 44 | 251 | 276 |
| Wollondilly | 9 | 3 | 3 | 4 | 0 | 8 | 27 | 36 |
| Wollongong | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 |
| Totals | 85 | 124 | 61 | 85 | 87 | 112 | 554 | 686 |

Source: WaterNSW

**Table 37** indicates that the total number of referred development applications reduced by an average of approximately 20% across the catchments, compared to the previous audit period. In the Blue Mountains and Palerang LGA's the reduction exceeded 50%. Whilst the number of referred DA's was lower, the total number of DA's increased in many LGA's. The reduction in the number of referred DA's was potentially due to increased experience of Council development assessment officers, resulting in less DA's with only minor potential for impacts on water quality being referred to WaterNSW. An increasing number of DA's are also likely to be categorised as exempt of complying developments and would no longer require a DA to be prepared.

In addition to processing DA's requiring concurrence, WaterNSW reviewed 171 approved developments that were seeking modified consent of minor changes under s96 of the *Environmental Planning and Assessment Act 1979*. An additional 72 approved DA's seeking amended approvals due to major changes to the original consent were also reviewed.

***State Significant Development and Infrastructure***

State Environmental Planning Policy (State and Regional Development) 2011 introduced State Significant Development (SSD) and State Significant Infrastructure (SSI) development categories. SSD is development that is of a particular type, size or value where it is deemed to be significant from the perspective of the state. SSD also includes development within specific identified sites that are considered important from a whole-of-state perspective. SSI is infrastructure that is considered to have a particular strategic value to the state. SSI includes development such as large port, wharf and boating facilities, large rail infrastructure, large water storage and treatment facilities, pipelines, submarine telecommunication cables and large projects in National Parks.

WaterNSW provided data on the number of proposed SDD and SSI developments reviewed by WaterNSW during the audit period. This data along with those from the previous audit are summarised in **Table 38.** The data shows that less SDD and SSI developments were reviewed during the audit period when compared to the previous audit period. Consistent with the previous audit, SSD applications during the audit period were primarily for mining and extractive industry developments.

**Table 38. State significant developments and infrastructure**

| State significant development type | 2010-13 (GHD 2013) | 2013-16 |
|---|---|---|
| Agriculture, timber, food and related industries | | 1 |
| Other manufacturing industries, distribution and storage facilities | 4 | |
| Mining, petroleum production, extractive industries and related industries | 29 | 22 |
| Tourism and recreational facilities | 3 | |
| Transport, communications, energy and water infrastructure | 9 | 1 |
| Resource and waste related industries | 1 | 1 |
| State significant sites | | 1 |

Source: WaterNSW

Details of the SSDs reviewed during the audit period and the status of these projects are summarised in **Table 39.**

**Table 39. State Significant Developments in the catchments reviewed by WaterNSW 2013 to 2016**

| Development type | Development name | Status |
|---|---|---|
| Mining | Angus Place Mine - Development Continuity Modification Mod 4 | Approved 27/10/14 |
| Mining | Springvale Coal - Centennial Western Coal Services Project | Approved 4/4/14 |
| Mining | Angus Place Mine Extension Project - Centennial Coal - Angus Place Colliery | Under assessment |
| Mining | Springvale Colliery Modification - Coal Production Increase | Approved 5/12/13 |
| Mining | Springvale Colliery - Springvale Mine Extension Project | Approved 23/9/15 |
| Mining | Springvale Colliery - Springvale Mine Extension Project - Production Increase Modification | Collating submissions |
| Mining | Springvale Water Treatment Project | Application received |
| Mining | Angus Place – Neubeck Coal Project | Approved 21/9/15 |
| Mining | NRE No. 1 Mine Underground Expansion Project - Gujarat, Cnr Princes Highway & Bellambi Lane, Russell Vale | Under assessment |
| Mining | Russell Vale Colliery (Wollongong Coal Limited) previously known as NRE Colliery -Gujarat NRE FCGL Pty Ltd, Fairy Meadows | Proponent reviewing submissions |
| Mining | Dargues Reef Gold Project, MOD 3 Majors Creek | Recommendations made |
| Mining | Hume Coal - Sutton Forest | Preparing DGRs |
| Mining | Berrima Rail Project | Preparing SEARs |
| Extractive | Site Access Modification 1 - Ardmore Park Quarry – Multiquip | Approved 8/10/10 |
| Extractive | New Berrima Clay / Shale Quarry, The Austral Brick Company, Berrima | EA received |
| Extractive | Gunlake Hard Rock Quarry Marulan - Gunlake Quarries, Marulan | Proponent reviewing submissions |
| Extractive | Woodlawn Zinc-copper mine project - Tri Origin Minerals Ltd, Collector Road, Tarago | EA received |
| Extractive | Austen Quarry Hartley - Extension - Stage 2 (Adelaide Brighton) | Approved 15/7/15 |
| Extractive | Marulan South Limestone Mine Continuation Project - Boral Cement Limited (BCL) | Preparing SEARs |
| Petroleum (oil, gas and coal seam gas) | Marulan South Hard Rock Quarry - Peppertree Quarry | On exhibition |
| Petroleum (oil, gas and coal seam gas) | Lynwood Mod 4 - Marulan Hard Rock quarry | Approved 18/05/16 |
| Electricity generation | Jupiter Wind Farm | SEARs issued |
| Resources and waste related industries | Woodlawn Bioreactor Expansion Project, Woodlawn Waste Facility - Veolia Environmental Services P/L, Woodlawn - Mod 1 | Approved 16/3/12 |

Source: WaterNSW

**Conclusion**

Development for mining and other land uses continued during the audit period, placing additional pressure on the health of the Catchment.

## 5.2 Pollution and potential contamination

**Definition and context**
Pollution and contamination sites in the catchment area are predominantly anthropogenic. Criteria relevant to this indicator are:

- assessments of the number and magnitude of sites of pollution and potential contamination
- regulatory performance of sites and activities
- progress of improvement programs.

Information for this section was sourced from the EPA's Public Register.

**Pollution sources and regulation**

***NSW EPA regulation***
The EPA has regulatory authority under the *Protection of the Environment Operations Act 1997* (POEO) for licensed premises and the *Contaminated Land Management Act 1997* in relation to environmental management and water quality. The POEO is the key piece of environment protection legislation administered by the EPA. The EPA has responsibility for reviewing all annual returns provided by license operators, as required by each Environment Protection Licences (EPL). There are 55 recorded EPL sites in the catchment area.

The EPA, SCA, and Local Councils also have compliance and enforcement powers under the POEO in relation to environmental management and water quality and conduct targeted inspections of priority risk activities or in response to pollution incidents. Under the POEO, non-licensed premises are regulated by Local Councils. EPA licenced premises in the Catchment relate to the following pollution sources:

- 4 Intensive animal production
- 19 Mines and quarries
- 6 Landfills
- 7 Sewage treatment plants
- 18 Industry

Some of these pollution sources are discussed below.

*Underground Coal Mines*

Mine water discharges have been a focus of EPA regulation under conditions in environment protection licences. This includes limit, monitoring and reporting conditions. It also includes pollution reduction programs. Full details of these requirements can be accessed on the EPA Public Register for each respective licence. These include the following underground coal mines:

- South 32
    - South 32's Westcliff mine currently discharges to the Georges River under Environment Protection Licence no 2504.
    - The mine has proposed to increase the capacity of its reverse osmosis wastewater treatment plant at Appin West for underground re-use and this would remove the need for mine water discharges to the Georges River. Reverse osmosis treated water could be discharged to the Nepean River via Allens Creek near Douglas Park.

- Tahmoor Mine
    - Tahmoor mine (Glencore) discharges underground mine water to the Bargo and Nepean Rivers under Environment Protection Licence Number 1389. The EPA has attached licence conditions in relation to water treatment upgrades.

- Berrima Colliery
    - Berrima Colliery discharges groundwater to Wingecarribee River. The mine was closed in July 2014 and long term management options are being examined for the discharge under a mine closure plan.

*Wingecarribee Shire Council - Sewage Treatment Plants*

In November 2016, Wingecarribee Council committed to investigations and improvement work on sewerage infrastructure and associated sewage treatment plants (STPs) at Berrima, Bowral, Bundanoon, Mittagong and Moss Vale townships under new Environment Improvement Plans attached to their environment protection licences and agreed to with the EPA. The plans include various investigations to reduce unwanted flows of stormwater and groundwater into the sewerage system. Other environmental improvement plans will look closer at existing measures used to treat sewage and the management of sewage during high inflows such as storm events. The programs are expected to be completed by July 2018. The outcomes of these programs will inform further improvement works for these sewage treatment systems.

*Contaminated sites*

There are 25 sites in the catchment area on the NSW Contaminated Land Public Record. Two notices were issued in the audit period under Part 3 of the NSW *Contaminated Land Management Act 1997* (CLM Act).

- Former Goulburn Gasworks
- Mobil Service Station Goulburn

***Regulation by WaterNSW***

Over the audit period WaterNSW continued the focus on prevention of unauthorised access to restricted areas through the strategic use of barriers, fencing, gates, surveillance, public communications and signage. WaterNSW carries out surveillance using cameras and regular weekend patrols. Regular weekend surveillance activities in Special and Controlled Areas are conducted on most weekends and public holidays by teams of WaterNSW Authorised Officers. While delivering other outcomes, they provide a level of visibility resulting in a general deterrent in the surrounding community and act on detections of illegal activity. This supports enforcement actions such as official cautions, penalty infringement notices and prosecutions.

During the period WaterNSW conducted 11 joint compliance operations in cooperation with OEH (NPWS), DPI (Fisheries), NSW Police and the Illawarra Regional Illegal Dumping Squad. Joint agency operations pool the resources of WaterNSW, NSW Police, Council RID squads, NSW Fisheries and NPWS officers and are conducted 3 or 4 times per year. They are planned, tasked and coordinated by WaterNSW. They provide an intense, high visibility presence targeted at illegal activity in and around Special and Controlled Areas. Compared with regular surveillance, joint agency operations generally involve more officers and possibly helicopter, boat and Police trail bike support. This level of resourcing means that when illegal activity is taking place there is greater potential to detect offenders compared to regular weekend surveillance. In most cases detections result in a PIN or an official caution letter. Refer to Table 3 under the Compliance and Investigations section for WaterNSW notices issued and actions taken.

WaterNSW continues to use a range of media to inform the community about access restrictions to the Special Areas. The Special Area brochure about access restrictions and 'What you can and can't do in Special Areas' was revised and reprinted in 2016, and is available at WaterNSW, NPWS offices, tourist information centres, on the WaterNSW website and is distributed by WaterNSW and NPWS field officers.

***Regulation by Department of Industry***

Derelict mines are abandoned mining sites where no individual or company can be held responsible for their ongoing management or rehabilitation. The NSW Department of Industry (DoI) is responsible for public health and safety issues posed by declared derelict mines in NSW.

In 2009 WaterNSW partnered with DoI to remediate sites that held safety and water quality concerns. Rehabilitation of the Yerranderie silver field, Oakdale no.2 colliery, Black Bobs Creek colliery, Mulloon Creek copper mine, and Tolwong and Tuglow copper mine sites was concluded on 30 June 2016. Joadja and Hartley Vale oil shale mines are stable and will continue to be monitored to ensure they do not become a source of contaminants.

WaterNSW has carried out follow up inspections of all rehabilitated derelict mine sites six, 12 and 24 months after the conclusion of works. Where necessary, remedial works have been maintained or upgraded. WaterNSW has also carried out inspections of the Mulloon Creek and Yerranderie sites more than five years post remediation. All major controls employed at the sites are intact and were functioning as desired.

At the conclusion of the remediation program for high priority derelict mine sites WaterNSW identified 22 second tier derelict mine sites and carried out inspections to determine whether any of these sites had deteriorated to a point where remedial action was warranted. Three sites were identified that warranted further assessment - Steelworks Mine at Lithgow and the Old Timberlight and Lucky Hit Prospect Sites.

The Lucky Hit Prospect (Site 2) has been assessed as not being of sufficient risk to warrant further work. DoI has agreed to rehabilitate the Old Timberlight Mine (works pending).

The Steelworks Coal Mine became unstable following a major bushfire in October 2013 and heavy rains in February/March 2014 mobilized a significant volume of sediments affecting private residences. The site was rehabilitated between December 2014 and February 2015. Re-inspection of the site in April 2016 confirmed the site has been stabilised.

***Regulation by other Agencies***
Local Councils are generally responsible for leading compliance and enforcement action for areas outside of the Special Areas. POEO water-related notices issued by councils in the audit period are as follows:

- 7 - Goulburn Mulwaree Council
- 6 - Wingecarribee Council
- 4 - Queanbeyan Pallerang Council

**Pollution risk**
WaterNSW uses the Pollution Source Assessment Tool (PSAT) to assess levels of potential risks from identified sources across the Catchment and prioritise catchment actions under the Healthy Catchments Strategy. The PSAT is a spatial decision support system that currently incorporates 14 types of significant pollution sources in the Catchment; identified as 'modules' in **Table 40**. The PSAT modules are progressively updated to incorporate new data, changes to existing information and advances in scientific modelling and knowledge.

**Table 40. Pollution Source Assessment Tool modules**

| PSAT module name | Pollution source type |
|---|---|
| Intensive animal production | Point |
| Horticulture | Diffuse |
| Mines and quarries | Point |
| Grazing | Diffuse |
| Landfills | Point |
| Urban stormwater | Diffuse |
| Onsite sewage systems | Point |
| Sewage treatment plants | Point |
| Industry | Point |
| Roads | Diffuse |
| Forests | Diffuse |
| Gully erosion | Diffuse |

In 2012-15, all of the PSAT modules were updated to incorporate new data, changes to existing information and advances in scientific modelling. The only exception was streambank (gully) erosion, which is unlikely to have changed since previous iterations of the PSAT and was therefore not re-analysed. For the first time the PSAT outputs were scaled so that they can be reported by any set of spatial units and can be compared between modules. The PSAT was also used to explore two scenarios of catchment intervention work in grazing lands: fencing of un-fenced riparian areas and improvement in groundcover to that of the median of the best six years in satellite records.

In 2016, the PSAT identified the highest risk areas and land uses to target catchment programs under the 2016-2020 Healthy Catchments Strategy. The 2016 PSAT found the highest risk priorities for the four pollutants (nitrogen, phosphorous, pathogens and suspended solids) are:

1. Grazing has the potential to contribute the greatest pollutant loads in Sydney's declared catchment.
2. Intensive animal production (particularly dairies) remains high risk in the eastern Wingecarribee and Kangaroo valley areas.
3. Forests with a high risk rating occur in areas with high slope, high soil erodibility and high fire susceptibility, however these results are generally an inherent (rather than human induced) risk scattered across large areas.
4. Urban Stormwater in urban areas such as the upper Blue Mountains and Mittagong
5. Other urban landuses such as industry and landfills in scattered high risk sites around the urban fringe, particularly in the Southern Highlands, the upper Blue Mountains and Lithgow.

A summary of the risk, combined across all modules and aggregated by drainage unit, is shown in **Figure 39**. Reasons for result changes include:

- The 2016 results show an increased dominance by Grazing in drainage unit results and the inclusion for the first time of two modules, gully erosion and forests, which are not sources of pathogens. This reflects a focus in program activities over the past 8 years on reducing the risk of pathogen sources in the catchments, most notably sewage treatment plants, dairies, and onsite sewage.
- Risk from Sewage Treatment Plants reduced significantly between 2008 and 2012, remaining out of the top 5 priority modules from 2012 onwards. This is the result of a sewage treatment plant upgrade program prior to 2012, resulting in a reduction in assessed risk for that module. However, results from this audit regarding water quality and population growth indicate that Moss Vale, Mittagong, Bowral and Berrima STPs in Wingecarribee Shire require upgrading. This information should be incorporated in future PSAT modelling.
- Onsite wastewater management was highlighted as a priority by the 2012 PSAT run. Sewering programs and other work with councils have since been carried out to address this assessed risk (for example sewering of Robertson, Kangaroo Valley and Taralga) and as a result it is no longer a priority for 2016.
- There has been gradual expansion of urban areas, particularly around the Southern Highlands, Lithgow and Goulburn, and councils continue to minimise spending on stormwater treatment in existing urban areas. This has resulted in Urban Stormwater remaining a high priority in PSAT 2016. New developments are generally assessed as low risk due to stormwater controls implemented under the Neutral or Beneficial Effect (NoRBE) test developed and administered by WaterNSW.
- For the first time, PSAT results include comprehensive mapping of gully erosion in the catchments. Gully erosion risk remains widespread, hence its appearance in the top 5 priorities. However, it should be noted that it is only considered a significant risk for suspended solids, which is generally considered to be a lower priority pollutant in comparison with pathogens, nitrogen and phosphorus.
- The risk associated with forests has been assessed for the first time in the 2016 run. The sheer scale of native forest in the DWC, plus the combination of risk factors for pollutant runoff from forests

(such as slope and susceptibility to fire) in some areas, has resulted in this module ranking in the top five. However, it should be noted that high risk areas make up only a small portion of total forested land in the catchments.

**Compliance and enforcement**

WaterNSW, the EPA and local councils each have compliance and enforcement powers across the catchments under the *Protection of the Environment Operations Act 1997* in relation to environmental management and water quality. All these bodies may conduct targeted inspections of priority risk activities or in response to urgent pollution incidents.

WaterNSW liaises closely with councils and the EPA to determine appropriate responses to water quality risks and incidents. WaterNSW focuses most of its compliance activities on the Special Areas (see following section on Compliance in Special Areas), where it has additional powers under the *Water NSW Act 2014* and the Water NSW Regulation 2013. Outside the Special Areas, either councils or the EPA generally lead compliance and enforcement action. However, WaterNSW can and does lead such action where it has been agreed between the agencies, or where WaterNSW perceives reluctance by those agencies to act on a matter.

WaterNSW also undertakes inspections to collect updated information on sites that pose the greatest risks to water quality. This assists WaterNSW to detect and respond to non-compliant behaviours through further investigation and regulatory action.

**Table 41** lists notices and non-compliance actions taken by WaterNSW during the audit period.

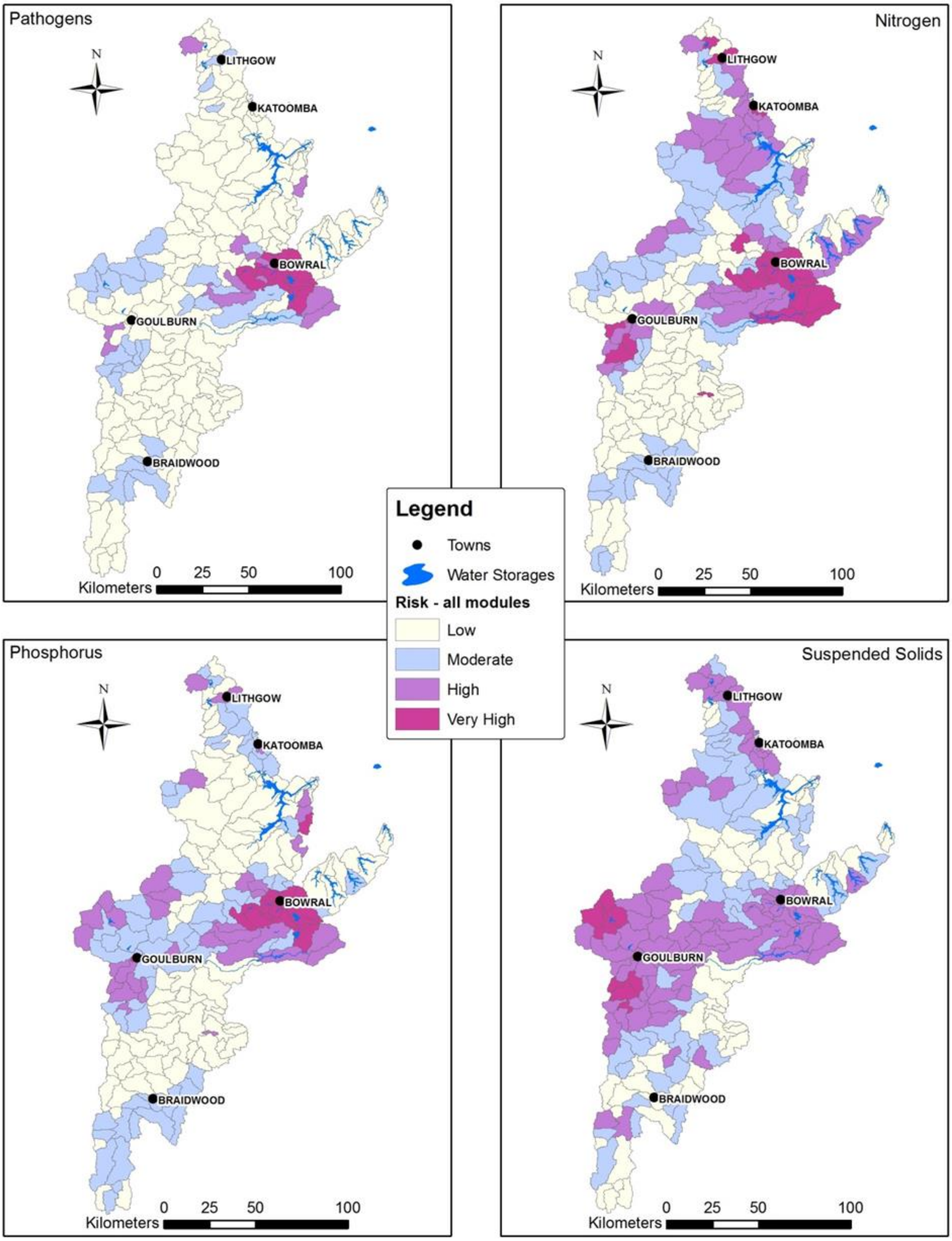



**Figure 39. PSAT 2016 risk by drainage unit for all modules combined (WaterNSW)**

**Table 41. WaterNSW notices or actions in response to non-compliance 2013-16**

| Regulatory Notice or Action | 2013-14 | 2014-15 | 2015-16 |
|---|---|---|---|
| ***Water NSW Act 2014* (previously the Sydney Water Catchment Management Act 1998) and Water NSW Regulation 2013 (previously the Sydney Water Catchment Management Regulation 2013)** | | | |
| Notices requiring information/records (62v/62s/71/74) | 9 | 3 | 4 |
| Notice to attend and answer questions (s62R/70) | 1 | 4 | - |
| Catchment Correction Notices (s62B/77) | 1 | 1 | - |
| Catchment Protection Notices (s62F/81) | - | - | - |
| Penalty infringement notices | 6 | 38 | 15 |
| Official Caution Letters | 19 | 47 | 39 |
| Prosecutions commenced | - | 1[5] | 2[6] |
| ***Protection of the Environment Operations Act 1997*** | | | |
| Clean-up notices (s91) | 4 | 2 | 1 |
| Prevention notices (s96) | 4 | 5 | - |
| Compliance cost notices (s104) | 1 | - | - |
| Notices requiring information/records (s192) | 6 | 1 | 3 |
| Notice to attend and answer questions (s203) | 1 | 0 | - |
| Penalty infringement notices | - | 2 | - |
| Official Caution Letters | 1 | 5 | - |
| Prosecutions commenced | - | 1 | - |

**Pollution Source Improvement Programs**

The WaterNSW Healthy Catchments Strategy (HCS) 2012-2016 outlines initiatives to reduce the key catchment risks to water quality. The Healthy Catchments Program delivers annually on this strategy and is implemented in partnership with the Local Land Services, Department of Planning and Environment, the Department of Primary Industries, the Office of Environment and Heritage, local councils, landowners and the community.

The HCS addresses diffuse and point sources of water pollution identified as priorities for additional action by the PSAT. Sewage, urban stormwater and rural lands, including grazing and agriculture, are high risk pollution sources identified by PSAT. These are addressed by the Rural Landscape and Priority Pollutant Programs. A summary of program expenditure is included below.

[5] FAULKNER prosecution in 2014/2015 involved offences under both the Sydney Water Catchment Management Regulation 2008 and the *Protection of the Environment Operations Act 1997.* Therefore it is reported in both the Water NSW Regulation and Protection of the Environment Operations Act sections of Table 3.

[6] 1 x court elect by HOUGH for a penalty notice issued by Water NSW and 1 x Veolia prosecution.

**Table 42. Program expenditure**

| Initiative | 2013-14 | 2014-15 | 2015-16 |
|---|---|---|---|
| Rural Landscape Program | $1.725M | $2.084M | $1.535M |
| Priority Pollutant Program | $1.427M | $1.922M | $0.533M* |

* Expenditure on sewage and stormwater grants was $350,000 lower than budgeted as early milestones were achieved in June 2015, reducing the funds required in 2015/16. Structural changes resulted in salary expenditure being underspent by $300,000

***Rural Landscape Program***

In 2013 WaterNSW developed its Rural Landscape Program (RLP) in partnership with the South East Local Land Service (SE LLS). The RLP provides incentives to graziers to develop infrastructure to better manage grazing primarily through fencing stock out of waterways (and providing supplementary water), grazing of land according to its inherent land capability, repairing serious erosion and providing education and training. This holistic program replaced the Sustainable Grazing Program, Riparian Management Assistance Program, the Catchment Protection Scheme and the Grazier Incentives Program.

The RLP provides an integrated program for addressing water quality risks arising from gully erosion, grazing, and uncontrolled stock access to waterways. The program is delivered as a partnership between WaterNSW and SE LLS, and enables the SE LLS to leverage funding sources and integrate a full range of natural resource management objectives (i.e. weed control, biodiversity conservation) into the landholder agreements.

Between 2013 and 2016, WaterNSW focused its funding on 52 Priority Drainage Units (PDUs) identified through the grazing and erosion modules of the Pollution Source Assessment Tool (PSAT). The Rural Landscape Program awarded 215 grants to landholders that: protected 9,814 ha of downstream waterways from upstream gully and streambank erosion; ensured 5,210 ha of grazing land was managed to best practice standards; and protected 263 km of riparian streambank from uncontrolled stock access. WaterNSW funding was leveraged with contributions from SE LLS and each landholder.

The WaterNSW – NSW DPI Sustainable Grazing Program was finalised in June 2014. Over the seven-year life of the Sustainable Grazing Program, 220 courses were delivered that provided education on sustainable grazing management practices to 3,862 landholders. This represents about 22% of the 17,600 rural properties larger than 2 ha. Since June 2014 grazier education has been delivered through the RLP.

***Priority Pollutant Program***

*Intensive Livestock industries*

There are 21 dairies in Sydney's Declared Catchment area. All have dairy effluent management systems in place. Most dairy operators have participated in the education and training programs offered by WaterNSW.

In 2012-13, WaterNSW collaborated with Dairy NSW and predecessors of the SE LLS to develop dairy effluent application plans and assist dairy farmers to remove solids from dairy treatment ponds. In 2013-14, dairy effluent ponds on eight dairy farms were cleaned with 10.6ML of solids being removed and field applied. This equated to reuse of 21.2 tonnes of nitrogen, 6.6 tonnes of phosphorus, and 9.3 tonnes of potassium. The project encouraged independent action from two dairy farmers to clean their dairy effluent ponds and one dairy farmer to purchase a vacuum tanker to manage dairy effluent.

In 2014-15, WaterNSW partnered with Dairy Australia, SE LLS, NSW DPI (Agriculture) and Western Sydney University (WSU) to test a new technique to agitate and irrigate dairy effluent whilst preventing build-up of solids. The project is aiming to improve the reuse of nutrients in dairy effluent and simultaneously simplify and reduce the cost of management of dairy effluent ponds. The project is due for completion in June 2017.

*Sewage Treatment Infrastructure*

Sewage treatment plants (STP) in the Catchment constructed or upgraded prior to the current audit period are listed below. The Goulburn STP is currently under construction in accordance with the Pollution Reduction

Program. STPs in the Wingecarribee LGA are scheduled for upgrades to cope with increasing populations and aged infrastructure.

- Bowral - September 2006 upgrade
- Goulburn - October 2007 upgrade
- Bundanoon - March 2010 upgrade
- Braidwood - August 2010 upgrade
- Taralga - January 2011 new
- Lithgow - November 2011 upgrade
- Wallerawang - May 2012 upgrade
- Kangaroo Valley - June 2013 new
- Robertson - June 2013 new

At the conclusion of the Accelerated Sewerage Program (ASP) in June 2013, all STPs in Sydney's Declared Catchments (**Table 2**) were operating in accordance with EPA Licences. WaterNSW's assessment at the conclusion of the ASP was that the major sewerage infrastructure within Sydney's Declared Catchments was up to contemporary standards. WaterNSW carried out a statistical analysis of instream water quality before and after the upgrade of the Lithgow and Braidwood STPs. Statistically significant differences before and after the Lithgow STP upgrade were found for total and filterable phosphorus. There were statistically significant decreases in total nitrogen and total phosphorus at the Braidwood STP following the upgrade.

Having previously invested heavily in the ASP to bring STPs up to contemporary standards WaterNSW's focus from 2013 forward has been in supporting capacity building and upskilling of council staff.

The WaterNSW 2014 Infrastructure Grants Program was developed to reduce the discharge of nitrogen, phosphorus and pathogens to catchment waterways. Three sewerage grants were awarded through this program:

- Wingecarribee Shire Council received $825,000 towards the refurbishment of sewers in Bowral to prevent stormwater inflow and infiltration. This project will prevent the discharge of 20.1 tonnes of nutrients from entering waterways over the next 20 years.
- Goulburn Mulwaree Council received $825,000 towards the upgrade of the Bradley Street pumping station project to help eliminate sewage overflows from the sewage pumping station. This project will prevent the discharge of 1.2 tonnes of nutrients from entering waterways over the next 20 years.
- Palerang Shire Council received $275,550 for the West Braidwood Sewer Extension Project to connect 27 light industrial and residential properties to sewer. This project will prevent the discharge of 1.1 tonnes of nutrients from entering waterways over the next 20 years.

Performance of sewage treatment systems in the audit period is as follows:

**Table 43. Performance of sewage treatment systems**

| LGA/Area | Sewerage System Incidents | 2013-14 | 2014-15 | 2015-16 |
|---|---|---|---|---|
| Wingecarribee | Reticulation/pumping station overflows | 4 | 28 | 32 |
| | Sewage Treatment Plant – bypasses/overflows | 23 | 7 | 6 |
| Blue Mountains (Sydney Water) | Reticulation/pumping station overflows | 9 | 8 | 16 |
| Shoalhaven (Kangaroo Valley system) | Reticulation/pumping station overflows | 9 | 11 | 9 |
| | Sewage Treatment Plant – bypasses/overflows | | | 1 |

*On-site systems*

There are approximately 13,319[7] on-site sewage management systems (OSSMs) in Sydney's Declared Catchments. By June 2016, 10,964 (82%) on-site systems had been inspected and licensed through a grants program run by WaterNSW with local councils.

WaterNSW has conducted an On-Site Sewage Management Network Group since 2013, where council staff and consultants have been invited to attend conferences, workshops and seminars. Between 2013 and 2016 WaterNSW has delivered more than 52 events. Overall the events have been very well received always rating strongly on participant evaluation.

WaterNSW also has a role in assessing the potential water quality impacts of sewage treatment plants and on-site sewage management systems within the Declared Catchment, particularly given their potential to contribute significant amounts of nutrients and pathogens to local waterways if not designed and managed appropriately. Catchment councils use the wastewater effluent model within the online NorBE Assessment Tool to determine whether OSSMs for dwellings in unsewered areas can achieve a neutral or beneficial effect on water quality. During the audit period, WaterNSW assessed more than 260 development applications with an on-site sewage management component. Developments included standard dwellings, tourist facilities, horse stables and rural subdivisions.

*Urban Stormwater*

Local councils are responsible for planning and regulating urban stormwater management systems. WaterNSW consults with and assists councils and developers in pursuing best-practice stormwater management in existing urban areas and for new developments in the catchment.

WaterNSW's main activities in relation to stormwater management over the 2013-2016 period were aimed at assisting councils in understanding stormwater impacts and implementing best practice stormwater management. WaterNSW awarded $526,902 in stormwater infrastructure grants:

- Blue Mountains City Council (BMCC) received $164,450 towards the Leura Falls Creek Catchment Management Project designed to reduce over 6 tonnes of nutrients over 20 years
- BMCC received $215,876 for the Upper Jamison Creek Stormwater Drainage and Treatment Project expected to reduce about 1.5 tonnes of nutrients over 20 years
- BMCC received $146,576 for the Streets to Creeks - Lower Jamison Creek Stormwater Treatment Project expected to reduce about 12.5 tonnes of nutrients over 20 years

WaterNSW established a Stormwater Management Network Group in 2013, where council staff and consultants were invited to attend conferences, workshops and seminars. From 2013 to 2016, WaterNSW has delivered more than 50 events focussed on sewage and stormwater to council staff (including four one-day conferences). Many of these events were conducted with industry partners such as Stormwater Industry Association, Local and State Government, included consultants, or were specifically aimed at developing specific council partnerships.

**Conclusion**

PSAT continues to be a valuable risk management tool for prioritising responses in the Catchment. Priorities identified by the 2016 PSAT are generally consistent with the findings of this Audit.

There has been a reduced risk to catchment health from sewerage infrastructure and urban stormwater due to infrastructure improvements. Water quality impacts associated with wildfire in forested areas is an emerging risk to the Catchment.

[7] WaterNSW On-Site Inspection Program

## 5.3 Soil erosion

**Definition and context**

Soil erosion is one of the contributing components that increases risk to water quality within the Catchment. The water quality risk arises from the strong interdependency of fine sediment and nutrient loads i.e. nutrients are chemically bound to fine sediments, so liberation of sediment also results in liberation of nutrients. The liberation of nutrients from the soil profile can encourage excessive growth of algae and in-stream vegetation.

A Catchment Protection Scheme (CPS) has been in place for over 50 years to specifically address soil erosion[8]. While there are numerous types of soil erosion, gully and streambank erosion are the main contributors in the Sydney Catchment (GHD 2013). Since 1984 gully erosion has been the focus of the CPS (many gully erosion sites pre-date 1979), while streambank erosion has tended to been addressed through other programs (Bickmore 2012). Gully erosion is the focus of this section of the Audit, whereas the impact of streambank erosion is considered in **Section 4.7** physical form.

**Method**

The understanding and quantification of gully erosion within the Catchment has advanced substantially since previous audits. In particular:

- The 2010 Audit quantified gully erosion using 1986 aerial photography (Emery 1986) and data from the 2005 Water Quality Risk Management Framework (SCA 2005). This provided an estimate of the total area of active gully erosion across the catchments (7.8 $km^2$).
- The 2013 Audit had no new quantitative gully erosion data available from across the Catchment and again relied upon the 1986 and 2005 datasets for the catchment-wide discussion. However, it did report on outcomes from the Gully Erosion Evaluation Trial (GEET) that was initiated in 2011 to develop techniques to map the location, extent, and severity of gully erosion across the Catchment. By the time of the 2013 Audit the GEET had been implemented across three drainage units (Dixons Creek, Eden Forest and Oallen Ford) only.
- This 2016 audit is now supported by results from implementation of the GEET method across an additional 42 priority drainage units (i.e. a total of 45 drainage units). The 45 drainage units were identified multiple government agencies as those units most likely to be experiencing gully erosion. The GEET implementation covers a significant portion of the non-forested catchment area (**Figure 40**) and is (anecdotally) said to encompass the vast majority of areas within the Catchment likely to be prone to gully erosion (pers. comm., WaterNSW, January 2017).

The GEET implementation provides a recent and comprehensive analysis of gully erosion, with more attributes and indicators of gullying than was available in previous work. For the purposes of this audit, the status of gullying has been examined by quantifying the length of active vs. stable gullies across the Catchment.

The data from implementation of GEET which formed the basis of this assessment is not directly comparable with data used in previous audits. This prevented the 2016 Audit from specifically examining the temporal trends in gully erosion since the previous audit. As a result the 2016 Audit has not provided an assessment of the spatial trends in gully erosion.

Though the spatial quantitative gully data itself is not directly comparable over time, there has been a heavy focus on monitoring of gullying in recent years and works undertaken to address gullying. This suggests that the status of gully erosion in the Catchment continues to improve, though there is a low level of confidence in this assessment. Future gully monitoring would be well placed to use the GEET method (although this could be complemented by other approaches if appropriate), to enable direct assessments of the change in gully erosion over time that can inform future audits.

[8] In 2013 WaterNSW developed its Rural Landscape Program (RLP) in partnership with the South East Local Land Service to support better management of grazing from a land and soil health perspective. This holistic program replaced the Sustainable Grazing Program, Riparian Management Assistance Program, Catchment Protection Scheme and the Grazier Incentives Program.

The roll-out of the GEET method since the 2013 audit provides numerous metrics that could be used to examine the status of gully erosion across the Catchment over time. For example, possible metrics that can be calculated from this data are the:

- Length of active vs. stable gullies (expressed as either total km, % length or km/km$^2$)
- Length of treated vs. untreated gullies (expressed as above)
- Length of gully prioritised for works vs. prioritised for monitoring vs. not at risk (expressed as above)
- Number of active vs. stable gully heads (expressed as either total no., % or no./km$^2$)
- Number of treated vs. untreated gully heads (expressed as above)
- Rate of gully head progression (expressed as m/yr)

However, while the GEET roll-out provides an excellent baseline for consistent monitoring of gully erosion into the future, unfortunately GEET outcomes cannot be directly compared to the previous catchment-wide gully data (e.g. Emery 1986 and SCA 2005). There are two reasons for this:

- The GEET method has much higher detection ability than the 1980s mapping due to use of newer technology and higher resolution data - only 58% of gullies mapped through the GEET were previously mapped in 1984 (Bickmore 2012). As a result, increases in the extent of mapped gullies are likely to result from both changes in the method and on-ground change, but the relative influence of these two drivers is not quantifiable.
- The potential metrics from the GEET data (refer above) are not directly comparable to the metric used previously (i.e. a total area of gullying of 7.8 km$^2$).

**Length and density of active gullies**
The analysis indicated that by far the longest length of actively ongoing eroding gullies is found in the Wollondilly sub-catchment. The next longest length of active gullies occurs in the sub-catchments of the mid-Shoalhaven region (specifically in descending order, they are Reedy Creek, Nerrimunga River, Boro Creek, Mongarlowe River and Mid Shoalhaven River).

These sub-catchments collectively also have the greatest density of active gullies (measured in metres of active gully per ha of catchment). Of these the Mongarlowe River has the densest active gully network, followed (in descending order) by Reedy Creek, Wollondilly River, Boro Creek, Nerrimunga River and Mid Shoalhaven River. Gully erosion in the mid-Wollondilly and mid-Shoalhaven regions is therefore seen as contributing the greatest soil erosion related risk to the water quality of downstream receiving waterbodies in the Catchment.

**Erosion management on WaterNSW lands**
In addition to the quantified knowledge of gullying through the GEET implementation, WaterNSW have a direct understanding on changes in gullying through the management of erosion on their lands. Their landholdings include significant portions of Special Area lands and 23,547 ha of cleared land in the Braidwood area. Soil erosion due to historical broad-scale clearing for agriculture or mining is an issue that requires ongoing management on the Braidwood lands in particular.

WaterNSW has in place soil conservation plans for specific properties and sites, and natural remediation methods have stabilised erosion in many areas. Since the 2013 audit, WaterNSW have actively managed gullying on their lands through (WaterNSW 2016):

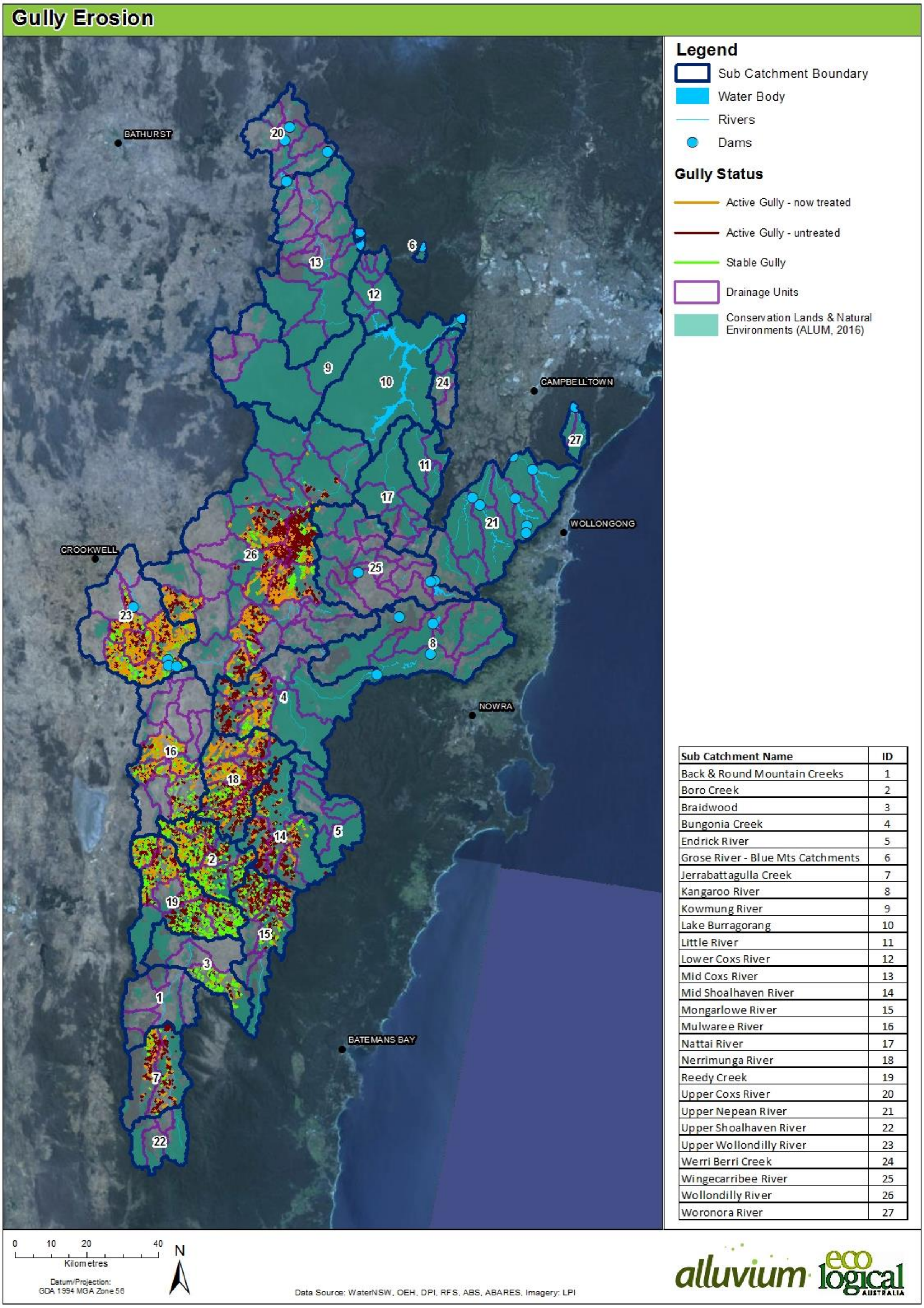
- using the results of the GEET implementation to review soil erosion control programs and priorities across WaterNSW properties in the Braidwood area and
- updating the Pollution Source Assessment Tool (PSAT), including the gully erosion module, to incorporate new data, changes to existing information and advances in scientific modelling*
- developing and implementing an erosion control program for leased and unleased lands in Braidwood, including specifically treating 11 sites through reshaping, drainage control and installation of structures (such as flumes and dams)
- awarding 215 grants to landholders through the Rural Landscape Program that protected 9,814 ha of downstream waterways from upstream gully and streambank erosion and ensured 5,210 ha of

grazing land was managed to best practice standards. WaterNSW funding was leveraged with contributions from South East Local Land Service and each landholder.

*For the first time, 2016 PSAT results include comprehensive mapping of gully erosion in the catchments. Gully erosion risk remains widespread, hence its appearance in the top five PSAT priorities. However, it is only a significant risk for suspended solids, which is generally considered to be a lower priority pollutant in comparison with pathogens, nitrogen and phosphorus.

**Conclusion**

The overall status of gully erosion in the Catchment continues to improve, though there is a low level of confidence in this assessment. Future gully monitoring would be well placed to use the GEET method (although this could be complemented by other approaches if appropriate), to enable direct assessments of the change in gully erosion over time that can inform future catchment audits.




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
| Kowmung River | 9 |
| Lake Burragorang | 10 |
| Little River | 11 |
| Lower Coxs River | 12 |
| Mid Coxs River | 13 |
| Mid Shoalhaven River | 14 |
| Mongarlowe River | 15 |
| Mulwaree River | 16 |
| Nattai River | 17 |
| Nerrimunga River | 18 |
| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 40. Distribution of gully mapping from implementation of the GEET method**

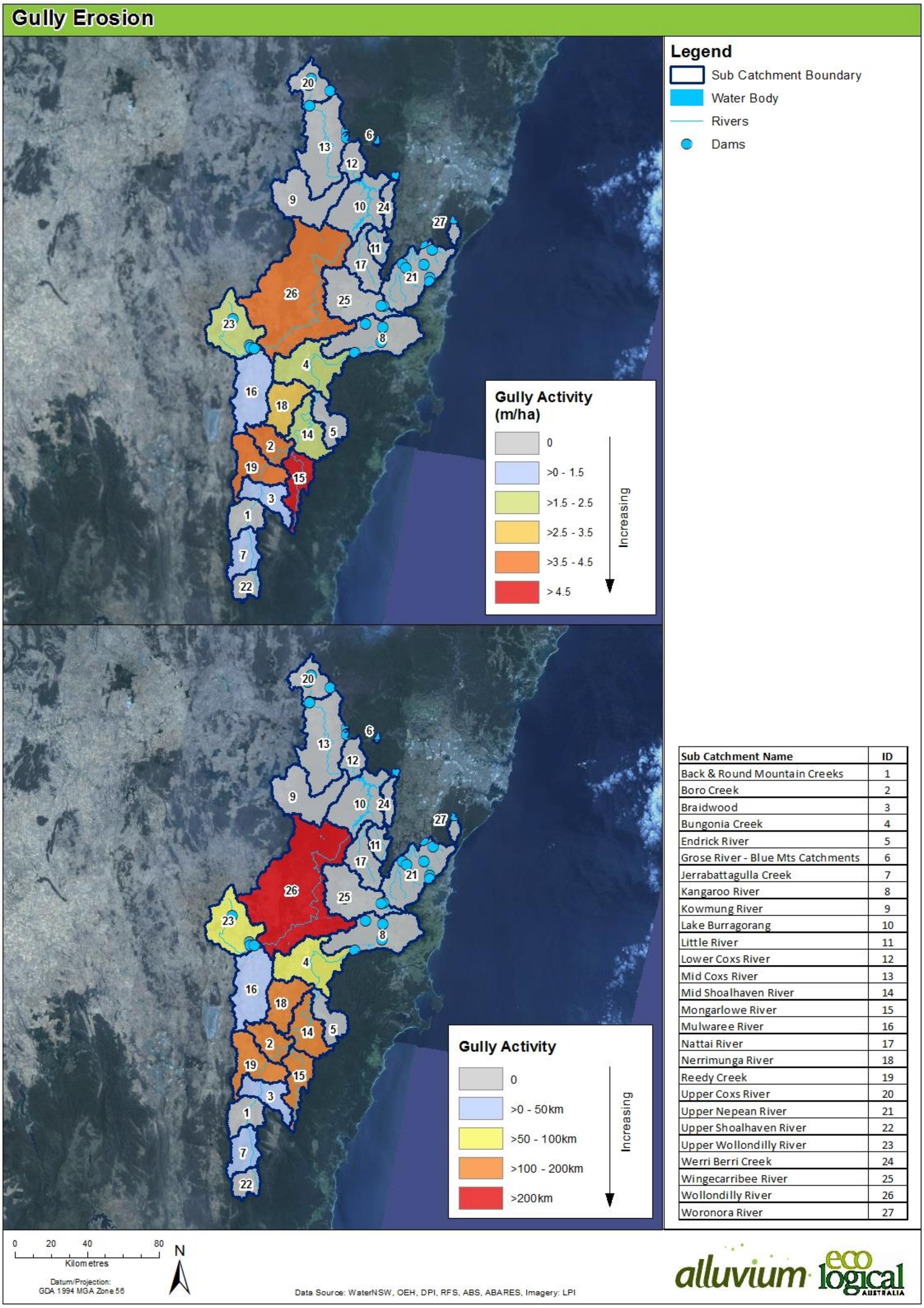



**Figure 41. Length of active untreated gullies in each sub-catchment shown as a proportion of the assessed area (top) and as absolute length (bottom) – grey areas had no assessment of their gullying**

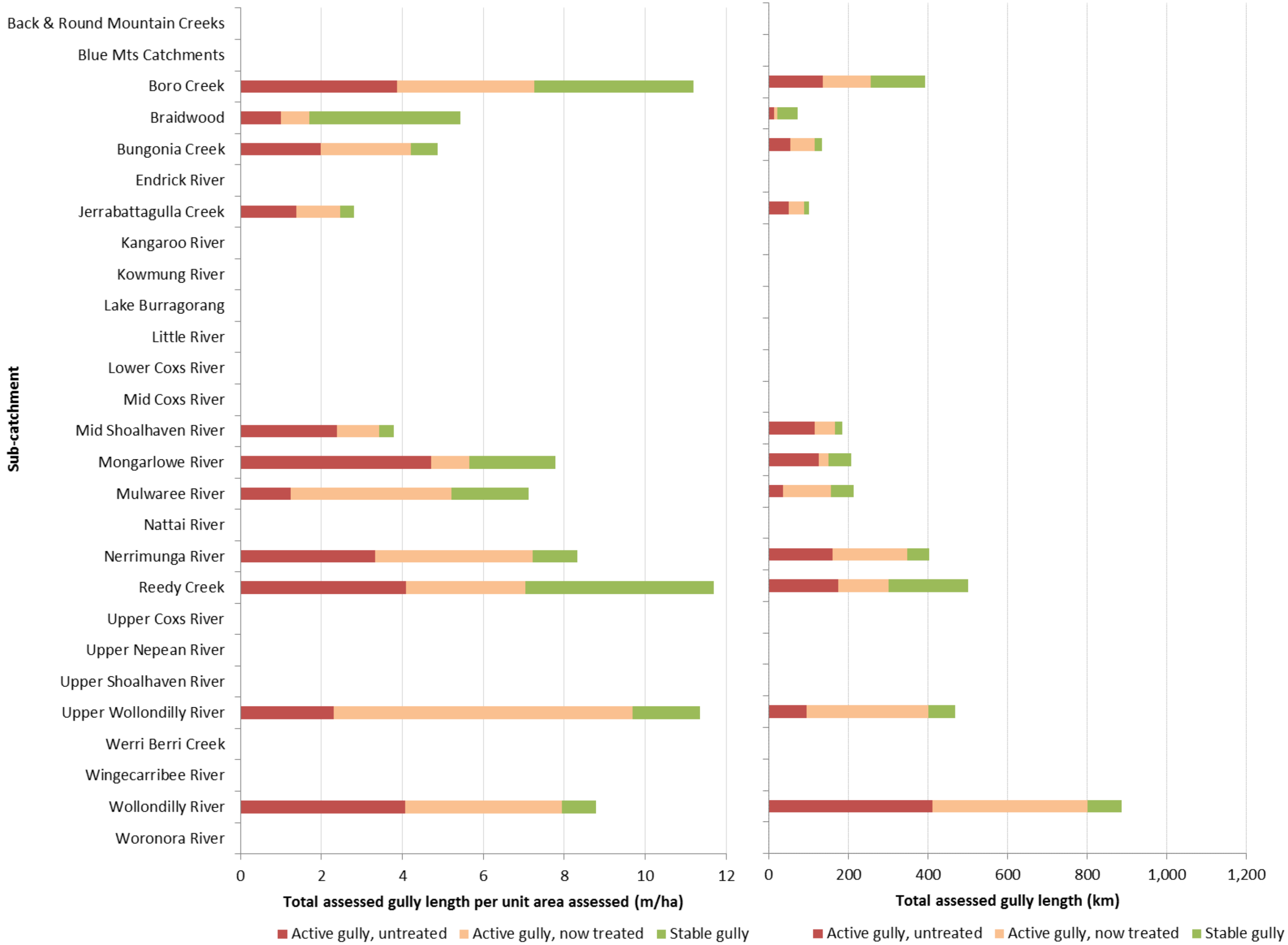



**Figure 42. Total assessed gully length in each sub-catchment shown as a proportion of the assessed area (left) and as absolute length (right)**

## 5.4 Population settlements and patterns

**Definition and context**

The population settlements and patterns indicator provides information on the number and distribution of people living within the Catchment. Increasing population has potential implications for water quality and places increased pressure on the water resources required to sustain the population. Assessment criteria include:

- average annual population growth rate
- increase in population density.

Threats to water quality and quantity associated with population are likely to be most closely associated with the expansion and consolidation of urban and village areas and particularly the land use changes that accompany population increases.

**Population data**

The estimated resident population (ERP) is the official estimate of the Australian population. ERP links people to a usual place of residence within Australia. Usual place of residence data is collected by the Australian Bureau of Statistics (ABS) every five years during the census. The latest available ABS census data is from the 2011 Census, which was presented in the 2013 catchment audit (GHD 2013). An ABS census was held in 2016, however his data will not be available until later in 2017.

Whilst 2016 Census data was unavailable, the ABS updates residential population estimates at 30 June each year between censuses. The estimates for all years between censuses are refined and finalised after the following census results have been compiled. For this audit, ABS final population estimates are available for 2011, with revised estimates for 2012 to 2014, and preliminary estimates for 2015 (http://www.abs.gov.au).

In Australia, Statistical Areas Level 2 (SA2) are the base spatial unit used to collect and disseminate statistics. SA2s are based on officially gazetted suburbs and localities. LGA populations are estimated as at 30 June each year from SA2 estimates. For post-census years, population is estimated using a mathematical model which is based on historical relationships between population and related indicator data. During census years, smaller 'mesh block' areas are used to provide detailed estimates of the spatial distribution of the population based on usual place of residence counts.

Data for ABS Category No. 3218.0 (Regional Population Growth, Australia) was adopted for this audit for the purposes of analysing changes in population that have occurred across the catchments. Data for ABS Category No. 1270.0.55.004 (Significant Urban Areas, Urban Centres and Localities) was adopted for the purpose of analysing the distribution of the population across the catchments and particularly areas where the population is concentrated.

Additional NSW population projections for the 2011 to 2036 period were sourced from the NSW Department of Planning and Environment (DPE) (http://www.planning.nsw.gov.au/Research-and-Demography/Demography/Population-projections) for each LGA. Whilst similarly based on the 2011 ABS Census data, different assumptions have been adopted by DPE to estimate population growth.

**Analysis limitations**

The latest ABS census data available for the audit was from 2011 and therefore the population analysis for the entire audit period is based on estimates only. These estimates will only be confirmed following release of the 2016 Census data. The census data is from mesh block areas that are considerably smaller than SA2 areas that the total population estimates between censuses are based upon. These two factors limit the accuracy of the population estimates and evaluation of changes to the distribution of the population for the current audit.

Whilst the accuracy of the population estimates during the audit period is somewhat limited by the absence of recent census data, it is expected that the mathematical models applied to estimate population changes between censuses using other indicator data should be satisfactory for predicting overall trends in population changes.

**Population growth rate**

The estimated total residential population (number of persons) for each LGA in the catchments is summarised in **Table 44** along with calculated population change rates (% change/year) for the current and recent audit periods.

**Table 44. Estimated residential population (persons) by LGA**

| Council name | Total estimated population | | | | Annual population growth rate (%/yr) | | |
|---|---|---|---|---|---|---|---|
| | 2007 | 2010 | 2013 | 2015 | 2007 to 2010 | 2010 to 2013 | 2013 to 2015 |
| Blue Mountains City Council | 76,198 | 78,227 | 79,165 | 79,812 | 0.9% | 0.4% | 0.4% |
| City of Lithgow Council | 20,277 | 20,732 | 21,109 | 21,416 | 0.7% | 0.6% | 0.7% |
| Goulburn Mulwaree Council | 26,803 | 28,083 | 29,214 | 29,550 | 1.6% | 1.3% | 0.6% |
| Kiama Council | 19,809 | 20,522 | 21,058 | 21,505 | 1.2% | 0.9% | 1.1% |
| Oberon Council | 5,166 | 5,207 | 5,260 | 5,318 | 0.3% | 0.3% | 0.6% |
| Palerang Council | 13,291 | 14,591 | 15,276 | 15,897 | 3.3% | 1.6% | 2.0% |
| Shoalhaven City Council | 91,497 | 95,154 | 97,617 | 100,147 | 1.3% | 0.9% | 1.3% |
| Upper Lachlan Shire Council | 7,229 | 7,379 | 7,596 | 7,876 | 0.7% | 1.0% | 1.8% |
| Wingecarribee Shire Council | 44,054 | 45,761 | 46,991 | 48,028 | 1.3% | 0.9% | 1.1% |
| Wollondilly Shire Council | 41,589 | 43,828 | 46,281 | 47,997 | 1.8% | 1.9% | 1.9% |
| Wollongong City Council | 192,770 | 200,468 | 205,157 | 208,875 | 1.3% | 0.8% | 0.9% |
| Total residential population | 538,683 | 559,952 | 574,724 | 586,421 | 1.3% | 0.9% | 0.7% |

Source: Australia Bureau of Statistics, 3218.0 Regional Population Growth, Australia

The total population within the catchment was estimated to be 113,042 in 2011 based on ABS Census data (GHD 2013). The previous audit provided population estimates to the 2011 Census. Based on ABS total residential population estimates for 2010 and 2015 summarised in **Table 44**, it is estimated that the population across all LGA's has increased by 4.9% between the 2011 Census and 30 June 2016, and by 3.0% between 1 July 2013 and 30 June 2016. Assuming that catchment population growth was similar to the total LGA population growth, it is estimated that the catchment population was 115,100 and 118,600 at 1 July 2013 and 30 June 2016 respectively. This represents an estimated catchment population growth of 3,500 people within the audit period.

**Table 44** indicates that the population has increased across all LGA's in the catchments since the previous audit. The population growth rate across most LGA's is similar to the previous audit period with several exceptions. In Goulburn-Mulwaree the annual population growth rate has reduced by more than 50%. In Oberon and Upper Lachlan the annual population growth rate has more than doubled, although the increase in total number of residents is low compared to the other LGAs (refer **Table 46**).

Similar population projections by NSW Planning & Environment (DPE) are outlined in Table 45. Due to different assumptions adopted by DPE the projected populations differ somewhat from those estimated by the ABS. DPE is currently projecting that the population will reduce between 2011 and 2036 in the Lithgow, Oberon and Upper Lachlan LGA's. This suggests that the estimated higher recent growth rates in the Oberon and Upper Lachlan LGA's will reverse in the next couple of decades.

**Table 45. New South Wales State and Local Government Area Population Projections**

| Council name | Total estimated population | | | 2011 to 2036 | | |
|---|---|---|---|---|---|---|
| | 2011 | 2016 | 2036 | Total Change | Total % Change | % change / year |
| Blue Mountains City Council | 78,550 | 82,000 | 90,400 | 11,850 | 15.1% | 0.60% |
| City of Lithgow Council | 20,850 | 21,100 | 20,450 | -400 | -2.0% | -0.08% |
| Goulburn Mulwaree Council | 28,350 | 29,750 | 34,400 | 6,050 | 21.4% | 0.86% |
| Kiama Council | 20,800 | 22,150 | 27,100 | 6,300 | 30.3% | 1.21% |
| Oberon Council | 5,200 | 5,250 | 4,900 | -300 | -5.6% | -0.22% |
| Palerang Council | 54,850 | 61,150 | 86,200 | 31,350 | 57.2% | 2.29% |
| Shoalhaven City Council | 96,200 | 99,600 | 109,700 | 13,500 | 14.0% | 0.56% |
| Upper Lachlan Shire Council | 7,400 | 7,500 | 7,400 | 0 | -0.2% | -0.01% |
| Wingecarribee Shire Council | 46,150 | 47,750 | 51,800 | 5,650 | 12.3% | 0.49% |
| Wollondilly Shire Council | 44,600 | 49,350 | 72,600 | 28,000 | 62.8% | 2.51% |
| Wollongong City Council | 202,050 | 211,750 | 244,400 | 42,350 | 20.9% | 0.84% |
| Total Population | 605,000 | 637,350 | 749,350 | 144,350 | 23.9% | 0.96% |

Source: NSW Planning & Environment (2016)

**Population density**

**Table 46** indicates that population density is highest in the Wollongong, Kiama, Blue Mountains and Shoalhaven LGAs. Although, it is estimated that a high proportion of the population in these LGAs is located closer to the coastline and outside the catchments (refer **Table 47**). It is these LGAs where the population density has also increased at a higher rate since the previous audit. Within the catchments, it is apparent the population has increased at a greater rate in the Wingecarribee LGA since the previous audit.

**Table 46. Estimated annual residential population growth rates by LGA**

| Council name | Annual population growth rate (residents/yr) | | | LGA size (km²) | Population density (p/km²) | Increase in population density (p/km²/yr) | |
|---|---|---|---|---|---|---|---|
| | 2007 to 2010 | 2010 to 2013 | 2013 to 2015 | | 2015 | 2010 to 2013 | 2013 to 2015 |
| Blue Mountains City Council | 676 | 313 | 324 | 1431 | 55.8 | 0.22 | 0.23 |
| City of Lithgow Council | 152 | 126 | 154 | 4512 | 4.7 | 0.03 | 0.03 |
| Goulburn Mulwaree Council | 427 | 377 | 168 | 3220 | 9.2 | 0.12 | 0.05 |
| Kiama Council | 238 | 179 | 224 | 258 | 83.4 | 0.69 | 0.87 |
| Oberon Council | 14 | 18 | 29 | 3627 | 1.5 | 0.00 | 0.01 |
| Palerang Council | 433 | 228 | 311 | 5147 | 3.1 | 0.04 | 0.06 |
| Shoalhaven City Council | 1219 | 821 | 1265 | 4567 | 21.9 | 0.18 | 0.28 |
| Upper Lachlan Shire Council | 50 | 72 | 140 | 7128 | 1.1 | 0.01 | 0.02 |
| Wingecarribee Shire Council | 569 | 410 | 519 | 2688 | 17.9 | 0.15 | 0.19 |
| Wollondilly Shire Council | 746 | 818 | 858 | 2556 | 18.8 | 0.32 | 0.34 |
| Wollongong City Council | 2566 | 1563 | 1859 | 684 | 305.4 | 2.29 | 2.72 |

Source: Australia Bureau of Statistics, Catalogue No. 3218.0 Regional Population Growth, Australia

The ABS population estimates summarised in **Table 44** are for the entire LGAs including areas inside and outside the catchments. What is most relevant for assessing risks to the catchments is the population residing inside the catchments. In the absence of 2016 Census mesh block data, the 2011 Census mesh block data was reviewed to estimate the proportion of the population in each LGA that is located within the catchments.

These estimates are summarised in **Table 47** and suggest that the largest residential populations inside the catchments are in the Wingecarribee, Goulburn-Mulwaree, Lithgow and Blue Mountains LGAs.

**Table 47. Estimated proportion of the 2011 population in each LGA residing in the catchments**

| LGA | Estimated proportion of total LGA population in the catchments 2011 | Estimated LGA population residing in the catchments 2011 |
|---|---|---|
| Blue Mountains City Council | 18% | 13800 |
| City of Lithgow Council | 81% | 17001 |
| Goulburn Mulwaree Council | 98% | 28671 |
| Kiama Council | 1% | 233 |
| Oberon Council | 4% | 236 |
| Palerang Council | 20% | 3200 |
| Shoalhaven City Council | 2% | 1534 |
| Upper Lachlan Shire Council | 25% | 2329 |
| Wingecarribee Shire Council | 91% | 41830 |
| Wollondilly Shire Council | 13% | 5862 |
| Wollongong City Council | 0.1% | 178 |

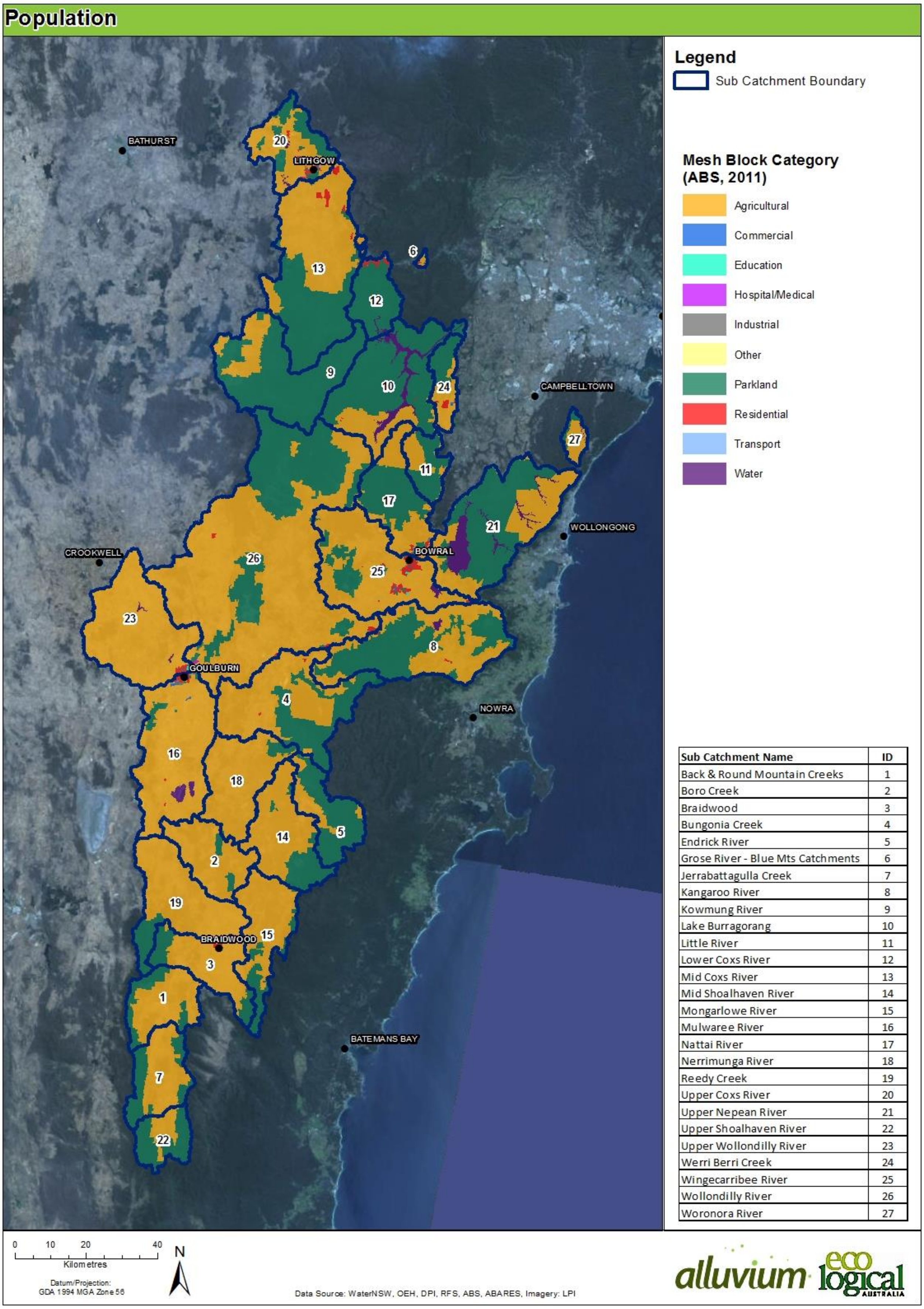
The population in the catchments is also not evenly distributed, with the population typically being concentrated in key towns and urban areas. Data from the 2011 Census was utilised by ABS to delineate the locations of urban areas and smaller villages across Australia. The locations of urban areas where the population is concentrated are shown in **Figure 43**. The 2011 Census data indicates that approximately 80% of the population in the catchments is concentrated in urban areas and villages. The remainder of the population is more widely distributed across agricultural areas of the catchment.

**Conclusion**

Data from the Australian Bureau of Statistics suggests that the Catchment population increased by 3,500 to 118,600 between 1 July 2013 and 30 June 2016. The population has increased within all Catchment LGAs and the population growth rates are similar to the previous audit period. The pressure from population growth across the Catchment therefore shows a worsening trend from the perspective of catchment health. An exception to this is the Goulburn-Mulwaree LGA where the average annual population growth rate has reduced from 1.3% to 0.6%.

Current estimates of population growth by NSW Planning and Environment (DPE) suggest that the total population will increase by 18% between 2016 and 2036 across the catchment LGAs. Although DPE has projected a decreasing population over this period in localised areas of the catchments including the Lithgow, Oberon and Upper Lachlan LGAs.

Results from the 2016 ABS Census are currently unavailable to assist with confirming population estimates made since the 2011 Census. The 2011 Census data indicates that the LGAs with the highest population residing in the catchments include Wingecarribee, Goulburn-Mulwaree, Lithgow and the Blue Mountains. This data also indicates that the population is not evenly distributed throughout the catchments, with approximately 80% of the population residing in urban areas and villages with a population exceeding 200 people. The remaining 20% of the population is distributed throughout rural and agricultural areas. Whilst data from the 2016 Census would be required to analyse any changes in population distribution between urban and rural areas, it is expected that the trend for the population to be concentrated in urban areas and villages throughout the Catchment will remain.




| Sub Catchment Name | ID |
|---|---|
| Back & Round Mountain Creeks | 1 |
| Boro Creek | 2 |
| Braidwood | 3 |
| Bungonia Creek | 4 |
| Endrick River | 5 |
| Grose River - Blue Mts Catchments | 6 |
| Jerrabattagulla Creek | 7 |
| Kangaroo River | 8 |
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| Reedy Creek | 19 |
| Upper Coxs River | 20 |
| Upper Nepean River | 21 |
| Upper Shoalhaven River | 22 |
| Upper Wollondilly River | 23 |
| Werri Berri Creek | 24 |
| Wingecarribee River | 25 |
| Wollondilly River | 26 |
| Woronora River | 27 |

**Figure 43. Urban area and village locations in the catchments (ABS, 2011)**

## 5.5 Community attitudes, aspirations and engagement

**Definition and context**
Knowledge of how the community can participate in catchment management assists with setting catchment health objectives and appropriate management actions to achieve them (DWE 2008). This indicator aims to gauge the attitude of the community living within the Sydney Drinking Water Catchment towards maintaining and improving catchment health, and the level of engagement within the community to achieve this.

The attitude of the community towards maintaining and improving catchment health could be measured through controlled surveys of a sufficient sample of the community. Changes in the community's attitude could then be evaluated by repeating the survey and comparing the results with previous audit surveys. However, no catchment-wide surveys focusing on community attitudes to catchment health have been completed.

In lieu of survey data, the attitude of the community to maintaining and improving catchment health was measured by:

- participation in community natural resource management organisations, where levels of participation are **improving**, **stable** or **reducing** compared to the previous audit period
- review of community strategic plans (CSPs) that were current during the audit period.

The community's attitude can also be assessed through their participation in education programs. Whilst participation in education will increase the ability of the community to contribute to improving catchment health, additional motivation is necessary to take following steps to develop skills and become directly involved in activities to maintain and improve catchment health.

**Community natural resource management organisations**
The level of engagement within the community was measured in previous audits by the number of community natural resource management organisations operating within the catchment, and the number of landholders engaged in on-ground improvement works. The same approach is adopted for this audit focusing on the data held by NSW Local Land Services (LLS).

The accuracy of the analysis relies primarily on data provided by LLS on the number of community natural resource management organisations and number of landholders engaged in improvement works within the catchment. The key limitation is that the LLS databases are not configured to enable these numbers to be extracted for the specific catchments being audited. The required data is categorised based on LLS region and does not currently include an identifier for the catchments. This requires LLS staff to complete additional searches through the databases to extract the figures required and results in some uncertainty with the estimated figures.

The available data indicates that community involvement in active on-ground works and natural resource management advocacy remains strong in the catchments. There are more than 105 community organisations involved in natural resource management across the Catchment. The data provided by LLS also indicates that more than 40 Landcare groups are engaged in on ground works throughout the Catchment. Data provided for the audit by each LLS is summarised in **Volume 3**.

The previous audit indicated that there were more than 360 community based organisations active in the HNCMA and SRCMA catchments (GHD 2013). This includes community organisation operating both inside and outside the catchments and is therefore not directly comparable with the data provided for this audit.

***LLS funding of community initiatives***
The Central Tablelands, South East and Greater Sydney LLS organisations provided data on the number of landholder works funded by LLS within the catchments for the 2013-2016 period as summarised below.

Central Tablelands LLS provided data on the number of projects where on-ground works have been funded for landholders in the drinking water catchments. The provided data was extracted from the Office of Environment and Heritage Land Management Database.

The previous audit indicated that the total number of landholder projects funded by LLS for the 2010 to 2013 period exceeded 390 across the former HNCMA and SRCMA catchments (GHD 2013). This data included landholders outside the catchments and excluded projects located in the catchment within the former Sydney Metropolitan CMA area. Data supplied by LLS for the current audit is specifically for projects located within the catchments, and the total funded projects reported for the 2013 to 2016 period was 295. Whilst the data for each audit is not directly comparable, it suggests that the number of landholder projects funded by the LLS within the Catchment is similar to the 2013 audit.

Central Tablelands LLS advised that 67 on-ground landholder projects were funded in the catchments from 2013 to 2016 (35 projects in 2013-14, 16 projects in 2014-15 and 16 projects in 2015-16).

The nature of the works funded in the Central Tablelands LLS were typically general natural resource management activities including fencing, waterway fencing, revegetation, weed control and pest animal control. Some minor erosion control works were also completed. Specific details on individual works funded were unavailable. In previous years, large scale engineering works were completed in the Central Tablelands LLS area to manage erosion. During the audit period, no similar large scale engineering works were completed.

South East LLS provided data on the number of projects where on-ground works have been funded for landholders in the catchments. South East LLS advised that 188 on-ground landholder projects were funded in the catchments from 2013 to 2016 (65 projects in 2013-14, 69 projects in 2014-15 and 54 projects in 2015-16). Greater Sydney LLS advised that 40 on-ground landholder projects were funded by LLS in the catchments between 2013 and 2016.

The previous audit indicated that the total number of landholder funded projects for the 2010 to 2013 period exceeded 390 across the former HNCMA and SRCMA catchments (GHD, 2013). The previous audit reported total CMA funded projects (including areas outside the catchment) and excluded works in parts of the catchment located within the former Sydney Metropolitan CMA catchment. Data supplied by LLS for the current audit was specifically for projects located within the catchments and the total funded projects reported for the 2013 to 2016 period was 295. The available data suggests that within the catchment, the number of land manager projects funded is likely to be similar for each audit period.

***WaterNSW funding of community initiatives***

The Healthy Catchments Strategy 2012-16 details WaterNSW's actions in the Sydney declared catchment area aimed at reducing risks to water quality (Sydney Catchment Authority 2013). The Healthy Catchments Strategy has seven integrated management initiatives that each addresses a catchment risk to water quality. The main initiative relevant to community engagement is the Active Communities initiative. Whilst details of the projects and sites funded vary from year to year, the actual level of funding provides an indication of the extent of community engagement activities completed each year.

Annual catchment management reports detail the level of funding for the Active Communities initiative and these figures are summarised in **Figure 44.** **Figure 44** shows that the budget for community initiatives has increased in the current audit period when compared to the previous audit period. Typically, the budgeted funds are not exhausted each year, with actual funds spent lower than budgeted. Whilst the actual funds spent on community initiatives has increased in the current audit period, the unspent funds (i.e. the difference between budgeted and actual) has also increased. This indicates that there may be capacity constraints that are limiting delivery of parts of the Active Communities initiative.

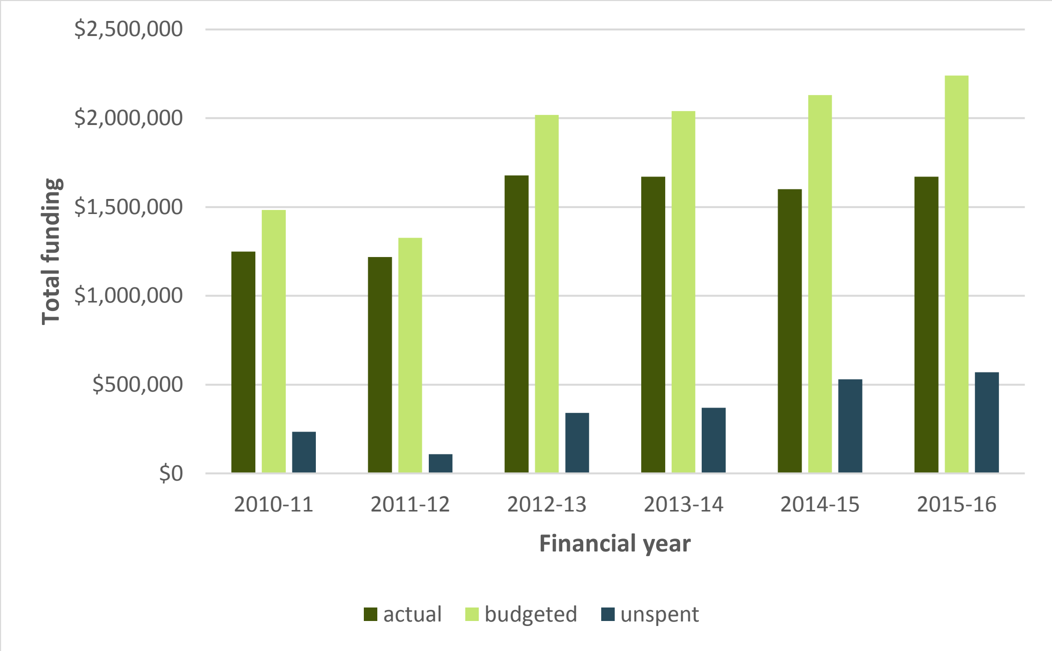


**Figure 44. WaterNSW funding of Active Communities initiative (WaterNSW 2016 & 2015, SCA 2014, 2013, 2012 & 2011)**

**Community Strategic Plans**

The *Local Government Act 1993* requires that a Community Strategic Plan (CSP) is prepared for each local government area and endorsed by Council. A CSP identifies the main priorities and aspirations of the community for their local government area. The CSPs apply for a minimum 10-year period after endorsement of the plan by Council. Whilst Councils have the responsibility to prepare and maintain these plans, responsibility for implementing the plans is shared by state agencies, community groups and individuals within the community. Although preparation and updating of the plans does not align with the three-year audit period, the plans provide a good snapshot of local community priorities on a range of issues including water management.

CSPs were available for all local government areas across the catchments. Most of the CSPs were prepared prior to the 2013 audit, although being long-term plans all remain current for this audit. Each CSP was reviewed to ascertain the community's priorities for water management. The context that the word 'water' was used on each occasion in each CSP was evaluated, and then classified into one of three priority categories:

- Water supply and sewerage (community health)
- Drainage and flooding (community safety)
- Catchment and waterway protection (catchment health).

Applying this approach, it was found that communities in different LGAs across the catchments have different water management priorities. Based on this review, the current dominant water management priority was identified for each LGA. The dominant water management priority was where more than 60% of the mentions of 'water' in the CSP related to a category. The water management priorities based on the CSPs are shown on **Figure 45.** Key themes in each CSP that are relevant to water management are summarised in **Volume 3**.

It was found that there is a general trend of catchment and waterway protection being a dominant priority for communities located near the dams and within designated special areas. Communities located outside the Special Areas and more inland appear to have a greater focus on water supply security, water conservation and sewerage. It is likely that many of the inland communities were more impacted by recent droughts, and this is likely to have influenced their water management priorities. None of the CSPs indicate that drainage and flooding was a dominant water management issue for any of the communities. Although, communities where drainage and flooding was identified as a concern typically aligned with those where catchment and waterway protection was the dominant priority.

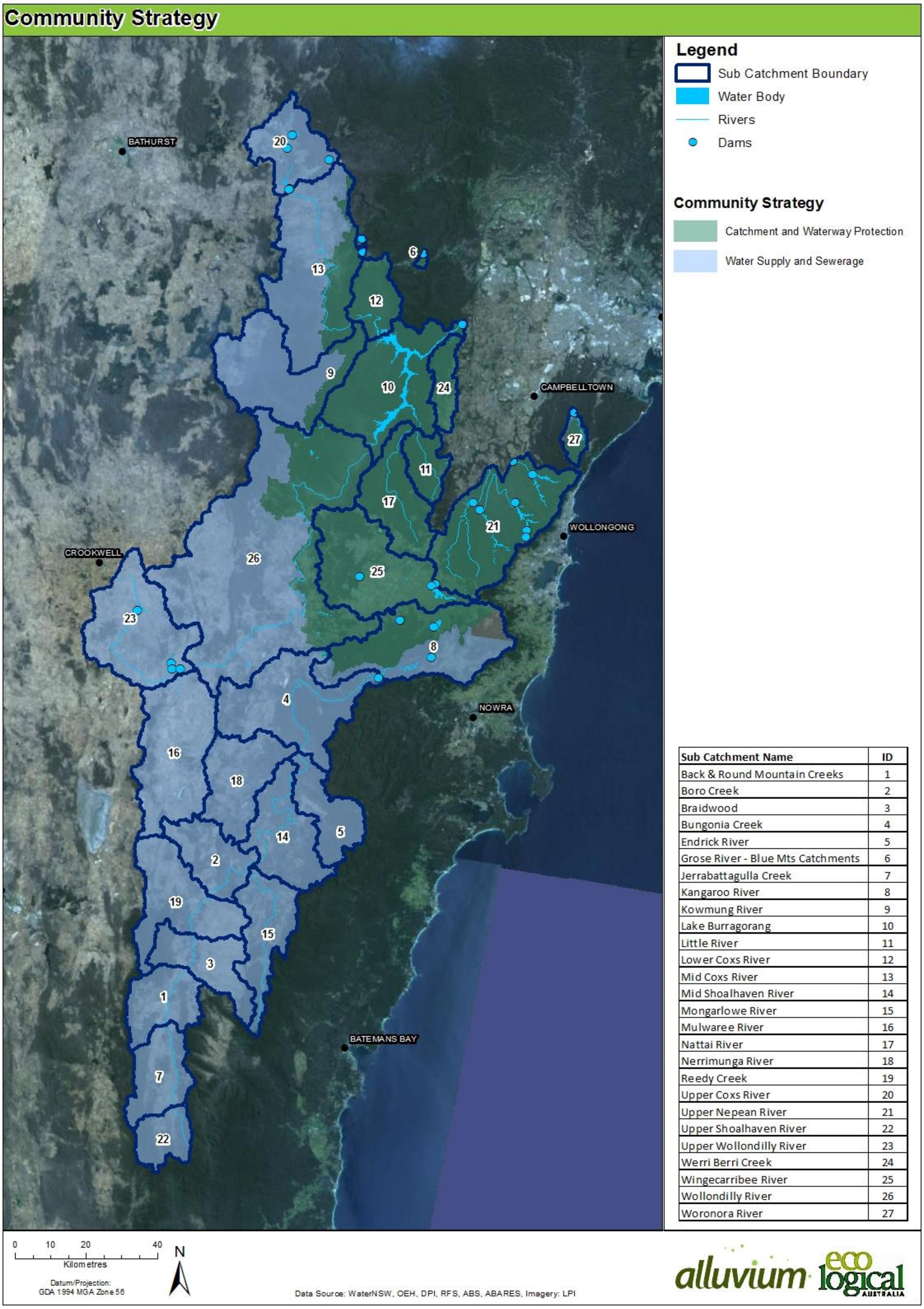


**Figure 45. Community Strategic Plan water management focus**

**Community submissions to the audit**
Submissions to the audit outlining key concerns in the catchment were provided by representatives of the Nature Conservation Council, The Colong Foundation for Wilderness, Lithgow Environment Group Inc and the Blue Mountains Conservation Society.

Concerns raised by these community groups were primarily associated with existing and future impacts on the catchments from mining. These groups raised concerns that the impacts of mining may be more widespread than previously estimated. Concerns were also raised regarding the impact of recent Land and Environment Court interpretations of the neutral or beneficial effect criteria. There were also concerns that insufficient funds are currently being set aside for future rehabilitation on mine closure and that rehabilitation may not be feasible.

Within the catchments, the community has raised concerns with specific sites. These are listed below and addressed in **Volume 1**.

- Thirlmere Lakes – Increased frequency of draining and drying of the lakes.
- Newnes Plateau hanging swamps – Subsidence and surface cracking leading to draining of the swamps and diversion of surface water underground.
- Springvale Mine extension – Increased salinity in the Coxs River and subsidence impacts on hanging swamps.
- Wallerawang power station – Impacts of closure resulting in cooling water previously diverted from Springvale Mine now being directed to Sawyer's Swamp Creek (Coxs River tributary).
- Lake Wallace and Lake Lyell on the Upper Coxs River – Water quality impacts of more regular lake spilling due to increased flow as a result of the Wallerawang power station closure.
- Springvale Delta Water Transfer Scheme – Proposal to transfer mine water from Springvale Colliery to the Mount Piper Power Station generally supported.
- Illawarra Coal Mine – Methane rising in the Nepean River
- Russell Vale Colliery extension – Impacts on the environment
- Angus Place Colliery – Seepage into Lambs Creek
- Pine Dale Mine and Neueck Creek project – Acid mine drainage and future impacts
- Dendrobium mine – Impacts on Cordeaux Dam draining to Nepean River

Available data also indicates that the number of cases in the Land and Environment Court relating to sites in the catchments has increased when compared to the previous audit.

**Conclusion**
The available data indicates that community involvement in on-ground works and natural resource management advocacy remains strong in the catchments. Overall funding of community programs for on-ground works has been similar or slightly more than during the previous audit period. Special interest groups continue to raise concerns about environmental pressures from mining and power stations in the northern part of the Catchment.

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