



Sydney Catchment Authority

Annual Water Quality Monitoring Report

2012-13

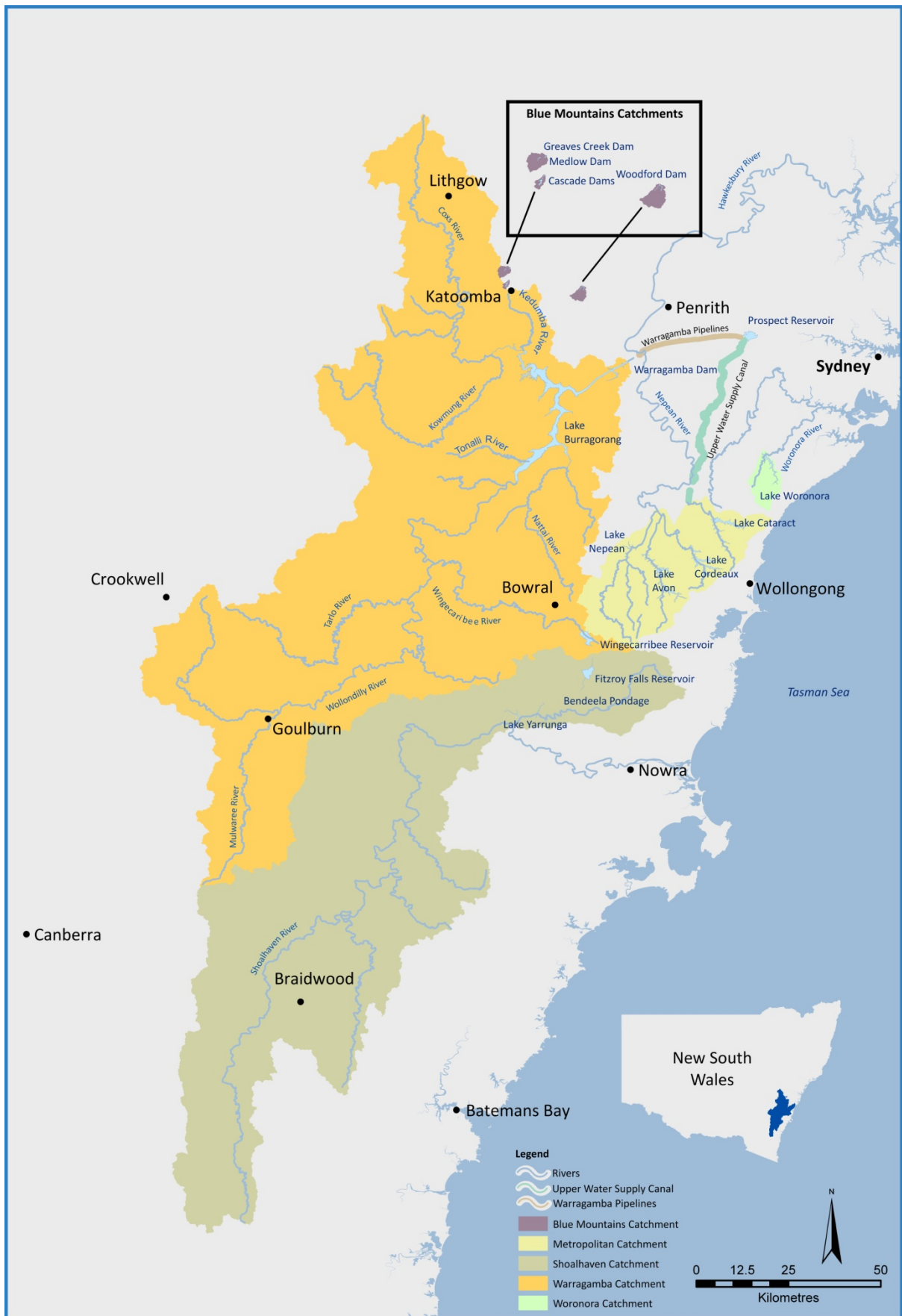


Figure 1 Sydney's drinking water catchments

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Executive Summary

Introduction

Under Section 14(1) of the *Sydney Water Catchment Management Act 1999* a principal objective of the SCA is 'to ensure that water supplied complies with appropriate standards of water quality'. The **SCA Water Monitoring Program (WMP)** details a comprehensive and integrated monitoring plan covering catchments, reservoirs, intakes to water filtration plants, picnic area sites and downstream sites. The WMP has been developed in collaboration with NSW Health, Sydney Water and other wholesale customers. The program, endorsed by NSW Health, incorporates locations, frequency, benchmarks or guideline values for more than 200 characteristics. The WMP involves routine, event, algal, pathogen and hydrometric monitoring; employing field, laboratory and telemetered 'real-time' sampling. The WMP provides timely water quality data and information to inform operational decisions.

The Australian Drinking Water Guidelines' framework for the management of water supplies covers the whole supply chain from source to the consumer to ensure safe drinking water. The SCA is responsible for managing part of this supply chain (catchments, storages and raw water supply system) working closely with upstream stakeholders through to downstream customers so as to ensure the raw water supplied for treatment is of appropriate quality. Raw water is treated by the customers who report on drinking water quality. Monitoring of the water quality through this supply chain provides essential information with regards to the short and long term water quality risks.

This report describes the results of the water quality monitoring undertaken by the SCA during 2012-13. The report is provided to meet the SCA's statutory obligations in addition to providing stakeholders, students, researchers and the general public with water quality information for waters managed by the SCA.

Highlights

The 2012-13 reporting period experienced above average inflows, with total storage volume rising from 96.7% in July 2012 to 98.1% in July 2013. Inflow events in February 2013 and June 2013 saw storages operate at near full capacity for the entire reporting period.

Effective incident response, including the tracking of inflows in storages and proactive depth and source selection resulted in the continued supply of raw water which was able to be successfully treated by our customers to comply with Australian Drinking Water Guidelines. The real time monitoring network combined with modelling capability for Warragamba were used effectively for incident response.

As can be expected, nitrogen, phosphorus and chlorophyll-*a* were higher than ANZECC benchmarks at those **catchment sites** with significant agricultural or urban development (e.g. Wollondilly and Kangaroo rivers). Water quality in native catchments (e.g. Upper Nepean rivers) was better and highlights the important role Special Areas play in protecting water quality. Turbidity remained well below ANZECC benchmarks despite a number of significant inflow events.

Wet weather monitoring via auto-samplers was undertaken at 26 sites in the catchments, with a total of 669 samples taken. Wet weather monitoring is an important tool in understanding catchment behaviour and identifying water quality threats from inflows.

Macroinvertebrate monitoring was undertaken in the spring of 2012 at 60 sites across 27 sub-catchments. With reference to the AUSRIVAS ecological indicator, ecological health has slightly improved since the 2011 survey.

Similarly, in a number of **storages** (e.g. Lake Yarrunga and Lake Burragorang), nitrogen, phosphorus and chlorophyll-*a* were above ANZECC benchmarks. Cyanobacteria counts and toxins remained below guideline values. Total aluminium was above ANZECC benchmarks at a number of storages (e.g. Lake Woronora and Lake Cataract) and is related to inflow events which can bring in aluminium-rich sediments. These elevated results didn't present any issues and the raw water supplied was successfully treated to within drinking water guidelines.

Seasonal algal monitoring was undertaken at a number of SCA storages with a history of algal activity. While a number of storages did exceed the alert trigger for chlorophyll-*a*, no exceedances of toxic algal cells or algal toxins were found. Algal monitoring at water filtration plants also had no exceedances.

Water quality conformance for 2012-13 with regards to
Raw Water Supply Agreements and Australian Drinking Water Guidelines
was 99.4% and 100% respectively.

Water supplied to **water filtration plants** maintained very high compliance with raw water supply agreements. Heavy metals, pesticides and synthetic organic compounds remained below ADWG at all water filtration plant sites with very few detections.

Picnic tap monitoring indicated that residual chlorine was occasionally higher than aesthetic guidelines as specified in the WMP. However, concentrations were well below levels considered detrimental to consumer health. Total iron at Lake Cataract picnic tap was higher than aesthetic guidelines but did not pose a significant health threat.

Monitoring **downstream** of SCA storages is undertaken as part of the requirements of the Water Licences and Approvals package issued by the NSW Office of Water. Given the extent of agricultural and urban encroachment, water quality at downstream sites was good compared to ANZECC benchmarks. Nitrogen and chlorophyll-*a* were above ANZECC benchmarks however potentially toxic cyanobacterial counts and toxins were well below guidelines indicating no threat to recreational users.

Guided by the Science Strategic Plan, the SCA has continued and initiated a number of **scientific research projects** through internal and external collaborative arrangements. Notable research projects with a direct influence on water quality included:

- Validation of the grazing evaluation model
- Impact of mining on reservoir sediments
- Sewage treatment plant evaluation study

- On-Site Sewage Disposal Evaluation Study
- Effect of chlorination on *Giardia* in the Upper Canal
- Sources of taste and odour producing compounds in Prospect Reservoir.

Guided by the SCA's Raw Water Quality Incident Response Plan, the SCA successfully managed two **water quality incidents** in the reporting period:

- Elevated metals at Orchard Hills water filtration plant
- Elevated algal biomass at Kangaroo Valley water filtration plant.

The SCA kept abreast of emerging water quality issues in close liaison with NSW Health and Sydney Water. No new issues impacting raw water were identified during the year.

Trend analysis was undertaken at a number of catchment, storage, water filtration plant and downstream sites, agreed to by NSW Health and Office of Water, for the ten years' (2003-2013) of monitoring data.

Generally, catchment sites showed a decreasing trend in total nitrogen and turbidity while iron and manganese tended to increase. Storages tended to show increasing trends in true colour, iron and aluminium. Decreasing trends in total nitrogen and chlorophyll-*a* were observed at most storages except Lake Burragorang where total nitrogen and chlorophyll-*a* increased at all sites. Following on from storages, iron and aluminium were found to increase at the inlet to most water filtration plants, yet have generally remained below raw water supply agreements' thresholds. Water filtration plants also experienced decreasing trends in hardness and alkalinity as expected with frequent rain events in the latter years.

1 Introduction

Section 14(1) of the *Sydney Water Catchment Management Act 1998* (the Act) states that a principal objective of the SCA is 'to ensure that water supplied by it complies with appropriate standards of water quality'. The SCA undertakes extensive monitoring within its catchments, storages and raw water supply system and in rivers downstream of storages to meet this objective.

The SCA's Water Monitoring Program 2010–2015 sets out the location, frequency and analytes monitored. The monitoring program includes specific and health-related characteristics as determined in consultation with major customers and endorsed by NSW Health. Monitoring for operations and planning helps the SCA understand the threats to water quality throughout the supply system, including rivers, reservoirs and the delivery system. This information helps the SCA to select the best source water for our customers.

The SCA's water monitoring program is informed by pollution source assessment undertaken by the SCA for pathogens, nutrients (phosphorus and nitrogen) and suspended solids. Catchment-to-tap water quality risk assessments are also undertaken for each supply system in conjunction with NSW Health and customers, and inform the program to a large extent. These assessments assist in prioritising monitoring as well as actions to rectify existing threats to water quality within drinking water catchments.

The SCA uses the data collected by its water monitoring program to:

- provide early detection of possible contaminants in the water to help protect the health of more than four million consumers
- ensure that the raw water delivered to its wholesale customers meets agreed standards and can be treated to meet the Australian Drinking Water Guidelines
- identify and target possible contamination sources in the catchments and storages
- identify emerging water quality issues and address them in forward planning.

The SCA's compliance monitoring activities are governed by three key drivers:

- operating licence granted by the Governor of NSW and administered by Independent Pricing and Regulatory Tribunal
- Water Licences and Approvals package granted by the Water Administration Ministerial Corporation and administered by the NSW Office of Water (NOW)
- raw water supply agreements between the SCA and its wholesale customers.

1.1 This report

This report describes the results of water quality monitoring undertaken by the SCA during 2012-13, through the Water Monitoring Program 2010-2015 in accordance with Section 2.2.2 of the Reporting Manual for Sydney Catchment Authority (IPART, 2013). The report also discusses monitoring of flows and temperatures as required under the Water Licences and Approvals package. As well as meeting the SCA's statutory obligations, the report aims to provide the community with information on water quality.

More specifically, this report aims to:

- interpret the results of the collected water quality data
- where relevant water quality criteria are available, detail how the system has performed relative to the criteria (benchmarks)
- provide information on the integrity of the data reported
- report on research activities
- report on measures planned or taken to manage water quality incidents.

In accordance with the Reporting Manual, this year's report also includes an analysis of trends in water quality over the previous 10 years. The trend analysis is conducted at the inflows to the water filtration plants, at locations within SCA's water storages, and at other specific locations within the area of operations as endorsed by NSW Health and NSW Office of Water.

2 Overview of the water supply network

The SCA collects water from river catchments to the south and west of Sydney and stores it in lakes and reservoirs to supply more than four million people in the Greater Sydney region.

It is transported via a network of rivers, pipes and canals to water filtration plants, where it is treated for consumers in Sydney, Illawarra, the Shoalhaven, Goulburn, Blue Mountains and the Southern Highlands. Water is also released from storages as environmental flows to maintain the health of the downstream river systems.

The catchments cover an area of approximately 16,000 square kilometres (sq km)—extending from the headwaters of the Cocks River north of Lithgow, south to the source of the Shoalhaven River near Cooma, and from Woronora in the east to the source of the Wollondilly River near Crookwell in the west (Figure 1).

Raw water is collected from the river systems of five major catchments:

- Warragamba
- Upper Nepean
- Woronora
- Shoalhaven
- Blue Mountains.

The characteristics of each system are summarised in Table 2.1, including the supply zone and approximate number of people supplied by that part of the system. The transfer routes for water around the system are shown in the schematic water supply system (Figure 2.1).

Australian Drinking Water Guidelines' framework for management of water supplies covers the whole supply chain from source to the consumer to ensure safe drinking water. The SCA is responsible for managing part of this supply chain (catchment, storages and raw water supply system) but recognises the importance of this approach and works closely with upstream stakeholders and downstream customers to ensure raw water supplied for treatment is of appropriate quality. Raw water is treated by the customers who report on drinking water quality. Monitoring of water quality provides useful information about water quality risks.

Greater Sydney's Water Supply System

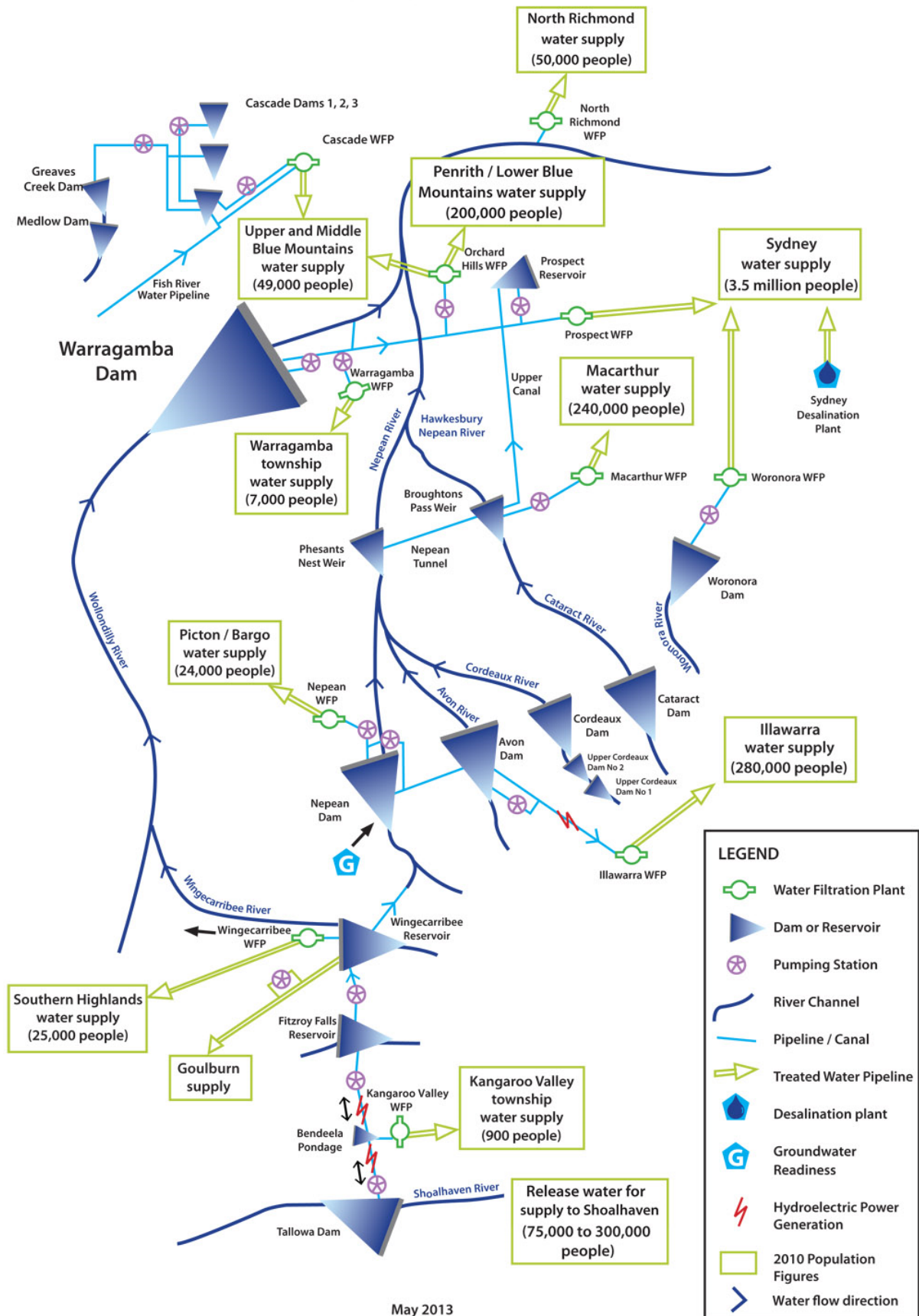


Figure 2.1 Schematic of the water supply system

Table 2.1 Characteristics of the SCA's major delivery systems

Delivery System	Major Storages	Total Capacity (ML)	Operating Capacity* (ML)	Catchment Area (km ²)
Warragamba	Burraborang	2,031,000	2,027,000	9,051
	Prospect	48,200	33,330	10
Upper Nepean	Cataract	97,370	97,190	130
	Cordeaux	93,640	93,640	91
	Upper Cordeaux 1	775	Nil	Included in Cordeaux
	Upper Cordeaux 2	1,180	Nil	Included in Cordeaux
	Avon	214,360	146,700	142
	Nepean	68,100	67,730	320
Woronora	Woronora	71,790	71,790	75
Shoalhaven	Yarrunga	85,500	7500	5,750
	Bendeela	1,200	900	Included in Shoalhaven
	Fitzroy Falls	22,920	9,950	31
	Wingecarribee	25,880	24130	40
Blue Mountains	Lower Cascade	305	305	3
	Middle Cascade	167	167	2
	Upper Cascade	1,791	1,791	2
	Medlow	326	326	5
	Greaves	301	301	7

* The total capacity of a reservoir is the amount of water it can hold when full. Operational restrictions may reduce the amount of useable water that the SCA can supply to its customers.

2.1 Warragamba system

The Warragamba delivery system consists of two large diameter pipes which transport water by gravity from Lake Burraborang to water filtration plants (WFP) at Warragamba, Orchard Hills and Prospect. Prospect Reservoir can supply directly to Prospect WFP. Water from the Upper Nepean system is also supplied to Prospect via the Upper Canal.

Lake Burraborang, which sits behind Warragamba Dam, is the SCA's largest reservoir with a total capacity of more than two million megalitres (ML). It has the capacity to supply up to 80% of Sydney's water.

The Warragamba catchment covers 9,051 sq km, with Lake Burraborang covering 75 sq km when full. One quarter of the catchment is a declared Special Area, where public access is restricted to protect water quality, the land here is mostly natural bushland. The rest of the catchment has eight local council areas with several different types of land use.

2.2 Upper Nepean system

The Upper Nepean system is fed by four dams - Nepean, Avon, Cordeaux and Cataract. These dams collect water from rivers on the Illawarra Plateau to provide an additional supply of water for Sydney via Broughtons Pass Weir and the Upper Canal.

Lake Nepean has the largest catchment (320 sq km) of the four reservoirs, comprising mostly natural bushland or land used for grazing and cropping. Forestry, intensive agriculture and mining also occur within this catchment. The lake supplies water to the Nepean, Macarthur and Prospect WFPs. The Nepean WFP supplies drinking water to the surrounding rural area and the local townships of Bargo, Thirlmere, Picton and The Oaks.

Lake Avon, with a catchment area of 142 sq km, supplies the Illawarra region and comprises mostly highly protected bushland. Water is transported from the upper reaches of Lake Avon by gravity or by pumping to the Illawarra WFP for supply to the Illawarra region. Water from Lake Nepean can also be transferred via a tunnel to Avon Dam to supplement supply to the Illawarra region.

Lake Cordeaux and Lake Cataract have catchments of 91 and 130 sq km respectively. These catchments are mostly Special Areas, containing largely unspoilt bushland. The Cataract and Cordeaux lakes supply water to the Macarthur and Prospect WFPs.

The Macarthur WFP supplies drinking water sourced from the Upper Canal delivery system at Broughtons Pass Weir to the Camden, Campbelltown and Wollondilly local government areas.

2.3 Woronora system

The Woronora system delivers water via a pipe system from Lake Woronora to Woronora WFP, which supplies approximately 100,000 residents of Helensburgh, Engadine and parts of Sutherland Shire. The Woronora catchment covers 75 sq km of native bushland. Lake Woronora is located on the southern outskirts of Sydney on the western side of Heathcote National Park.

2.4 Blue Mountains system

The Blue Mountains delivery system is a complex network of pipes that can deliver water from both within and outside the Blue Mountains catchments - a small group of bushland valleys covering a combined area of 19 sq km.

The system provides water to residents of the middle and upper Blue Mountains from Lake Greaves, Medlow and the three Cascade lakes at Katoomba (five of the smallest reservoirs managed by the SCA).

All five lakes contribute to the supply of water to the Cascade WFP, which can also be supplemented with water transferred from Lake Oberon on the Fish River or from the Duckmaloi River at Duckmaloi Weir (both west of the Great Dividing Range).

Water from Warragamba Dam (treated at the Orchard Hills WFP) is pumped up the mountains to supplement the system, supplying water to residents of the lower to middle Blue Mountains.

2.5 Shoalhaven system

The Shoalhaven system is a network of dams, pumps, canals and pipelines that transfers water from the catchments of the Shoalhaven River to either the Warragamba or the Upper Nepean systems to supply Sydney and the Illawarra region during times of drought.

It is also used by Eraring Energy to generate electricity. Power generation involves the regular exchange of stored waters between Lake Yarrunga, Bendeela Pondage and Fitzroy Falls Reservoir.

The SCA releases water from Lake Yarrunga downstream into the Shoalhaven River for the Shoalhaven City Council to supply its customers. Environmental flows are also released to maintain the health of the river.

The major storage is Lake Yarrunga, which covers 8.3 sq km at the junction of the Kangaroo and Shoalhaven Rivers. The Shoalhaven catchment covers an area of 5,750 sq km and has a variety of land uses, including bushland, dairy farming, beef and sheep production, and rural residential.

Bendeela Pondage is a very small impoundment in the delivery system between Lake Yarrunga and Fitzroy Falls Reservoir. Raw water is treated at the Kangaroo Valley WFP operated by Shoalhaven City Council to supply drinking water for the residents of Kangaroo Valley.

Wingecarribee Reservoir supplies water to Wingecarribee WFP, operated by Wingecarribee Shire Council to supply drinking water for consumers in the Southern Highlands. Wingecarribee Reservoir can also transfer raw water to Goulburn Mulwaree Council to supplement storage levels in Goulburn Mulwaree's water supply dams if required.

2.6 Hawkesbury-Nepean River

The Hawkesbury–Nepean River sits below the major storage reservoirs in the Warragamba and Nepean catchments. It is sustained by:

- flows from local catchments
- flows of treated effluent from Sydney Water's waste water and recycled water treatment plants
- spills from the SCA storages
- environmental flow and other releases from the SCA storages which help maintain and improve the ecological health of the river
- highly treated recycled water from Sydney Water.

The NSW Office of Water licenses various water extractors along the length of the Hawkesbury–Nepean River for agricultural and some industrial use. Sydney Water also draws and treats water from the river at North Richmond to supply consumers in that area.

3 SCA's water monitoring program

The SCA's water monitoring program (WMP) covers routine, targeted, investigative and event-based monitoring over its area of operations.

The program covers catchments, storages, inlets to water filtration plants, picnic taps, transfer canals and pipelines, as well as rivers downstream of water supply dams and weirs. Monitoring includes physical, chemical, biological, radiological, hydrological and meteorological parameters through on-line, field sampling and laboratory analysis. A key feature of the WMP is an agreed list of water quality characteristics. The list contains:

- those characteristics (not modified/removed by conventional treatment) for which Australian Drinking Water Guidelines (ADWG) must not be exceeded
- those characteristics for which ADWG exist but these are not applicable to raw water, where the SCA must endeavour to supply the best quality so that it can be treated to meet the ADWG.

The SCA is subject to a range of statutory requirements and standards set by regulatory agencies. The SCA is also benchmarked against other raw water suppliers to maintain best practice service standards.

The principal documents outlining requirements on the SCA with respect to water monitoring are:

- SCA Operating Licence, *Sydney Water Catchment Management Act 1998* (Part 3)
- SCA's Water Licences and Approvals Package under *Water Management Act 2000* (Part 4) - referred to as 'Water Licence' in the rest of this document
- Memorandum of Understanding (MoU) between NSW Health and the SCA (Clauses 6.1.6 and 6.2) *Sydney Water Catchment Management Act 1998* (Part 4)
- Raw Water Supply Arrangements, *Sydney Water Catchment Management Act 1998* (Part 3)
- Water Act 2007 (C'th).

3.1 Quality assurance and quality control

The SCA's Water Monitoring Program 2010–2015 (SCA, 2010) specifies the requirements for water sample collection and analysis. It describes sampling locations and frequencies, and the parameters to be analysed. Additional samples are collected and analysed for quality assurance and quality control (QA/QC) purposes. The QA/QC program provides confidence in the routine sampling data collected.

Water quality data integrity is assured through the design of the routine and QA/QC sampling regimes and the analysis tools used to review data once it is delivered to SCA. The primary goal of field collected QA/QC samples is to identify, quantify, and document bias and variability in data that result from the collection, processing and handling of samples. This process also assists in identifying opportunities to improve sampling methodologies. This is particularly important when sampling for parameters that are likely to be present in ultra-trace quantities due to measurement uncertainty.

Field collected QA/QC samples include **field duplicates** and **field blanks**. In addition **trip** blanks are prepared at the laboratories and taken on designated sampling trips. The analytical service providers conduct internal quality control analysis per each batch of samples including matrix spikes, duplicates, blanks, replicate analysis and inter laboratory proficiency trials.

The SCA's analytical service providers have management systems that require them to maintain their own internal QA/QC program based on additional analyses on randomly selected batches, with known spikes and blanks. These systems are accredited with the National Association of Testing Authorities (NATA) and ISO 17025:2005. The service providers' QA/QC specialists analyse conformance with specified standards of accuracy and precision to identify any contamination, outliers or errors.

Field duplicates

These consist of approximately five percent of routine samples collected. The primary purpose of duplicate samples is to identify and/or quantify the variability in all, or part, of the sampling and analysis system. Duplicate, triplicate, or greater multiples are considered 'identical' or 'almost identical' in composition and are analysed for the same properties. Variations between the primary sample and the duplicate should be within the laboratories prescribed limits of the analytical methodology for each parameter analysed.

Field blanks

These consist of approximately 2.5 percent of routine samples collected. A blank sample measures the magnitude of contaminant concentration that may have been introduced as a result of sampling-related activities. Blank water is specially prepared distilled, deionised or sterilised water that is laboratory produced, quality-controlled, and carries a certificate of analyte concentrations for each lot of water produced. Field blank samples are collected and processed in the field site in the same manner, and using the same equipment, as the primary sample. These samples are analysed along with routine samples and collected on the same trip. This helps to identify sources of contamination.

Trip blanks

These are done on approximately 2.5 percent of routine sample collection runs. Trip blank sample bottles are filled with clean water at the contractors' depots prior to a sampling run. This helps to identify contamination that may occur during transportation, or from the containers themselves.

The collection and analysis of routine and QA/QC water samples is performed by SCA service providers as part of the contracts. These contracts include requirements for quality assurance practices in the monitoring, sampling, testing and reporting processes. A chain of custody system allows individual samples to be tracked from field collection, through laboratory analysis, to the transfer of results to the SCA's database.

Further details of the QA/QC monitoring for 2012-13 are included in Section 5.1.

3.2 Operating Licence

The Operating Licence requires the SCA to:

- Maintain a water quality management system consistent with ADWG framework.
- Maintain a water quality monitoring program (comprising routine monitoring of raw water) to the satisfaction of NSW Health.
- Develop and monitor a list of specific water quality characteristics and a subset of health-related characteristics derived from the ADWG.
- Conduct a targeted, investigative and event based monitoring program to monitor the occurrence of particular characteristics and contaminants in water.

3.2.1 Routine monitoring

The routine water monitoring program provides information for compliance and operational decision making relating to the catchments, storages, inlets to WFPs, picnic areas and rivers downstream of water supply dams and weirs. Monitoring includes physical, chemical, biological, radiological, hydrological and meteorological parameters through online, field sampling and laboratory analysis.

Routine monitoring in the catchments and storages is used to provide early warning of any risks, while monitoring at the inlet of treatment plants is used to verify the effectiveness of controls.

3.2.2 Raw water supplied for treatment

Raw water is monitored in the delivery system and at inlets to WFPs prior to the water treatment process. This helps verify that water quality meets the agreed criteria.

3.2.3 Storages

The SCA's storages are monitored at various sites and depths to provide detailed information on lake conditions and processes. Monitoring is supported by modelling that assists in assessing current conditions and predicting possible changes. Profiling of storages (i.e. measuring parameters at discrete depths) is undertaken routinely to assist in operational decision-making and help stop hazards entering the water supply.

3.2.4 Catchments

Routine sampling of catchment streams enables the quality of catchment waters to be assessed and any contamination identified. This allows water quality hazards to be managed within an adaptive management framework. Routine hydrometric monitoring measures rainfall and inflows to storages to help predict major inflow events, flooding and any associated water quality incidents.

3.2.5 Picnic area monitoring

The SCA supplies chlorinated water to picnic areas at Fitzroy Falls Reservoir (including the National Parks and Wildlife Service's visitor centre), Cataract, Cordeaux and Avon dams. The SCA has developed and implemented Water Safety Plans that include the required monitoring for individual supply areas.

3.2.6 Algal monitoring

The SCA routinely monitors algae levels in major storages to provide early warning of possible bloom conditions. This ensures that raw water supplied to customers can be treated to meet drinking water guidelines. It also helps avoid the contamination of downstream waterways through environmental releases or transfers. A seasonal sampling program (usually conducted between October and May) applies in storages with a history of algal activity. Monitoring frequency is increased in response to triggers specified in the SCA's Cyanobacteria Response Plan.

3.2.7 *Cryptosporidium* and *Giardia* monitoring

A consolidated monitoring program for *Cryptosporidium* and *Giardia* was implemented in April 2001, following an agreement between the Ministers of NSW Health, Sydney Water and the SCA. This program remained in place for 2012–13.

3.2.8 Wet weather monitoring

Wet weather samples provide information on pollutants associated with rain events or large inflows. The collection and analysis of wet weather water samples across the SCA's area of operations is essential in identifying potential pollution sources. The SCA has installed autosamplers at strategic locations in the catchment, which are triggered by changes in river levels.

3.2.9 Dam seepage

The SCA is required to monitor the structural integrity of all assets, including seepage in, around and through its structures. Dam seepage monitoring is undertaken to comply with *NSW Dam Safety Act 1978*.

3.3 Water Licence

In May 2012 the NSW Office of Water issued the SCA a new water licence under the *Water Management Act 2000*, which is a combination of 'Water Access Licences' and 'Water Supply Work and Water Use Approvals'. Prior to this, Water Management Licence issued under the *Water Act 1912* was in place. The water licence requires environmental flows to be released from reservoirs to help maintain the ecological health of downstream rivers. Water released from reservoirs into rivers can be colder or warmer than the receiving water. This depends on the level of the water offtake in the reservoir (deeper water is usually colder than surface water) and the time of the year. The SCA

undertakes temperature and routine water quality monitoring at a number of downstream sites to assess impacts of SCA operations on downstream river systems.

3.4 Future directions

The first annual review of the SCA's Water Monitoring Program 2010-2015 (SCA, 2010) was completed in December 2011, with commencement of the revised program from early 2012.

Key aspects of the revised monitoring program from 2012 included:

- The storages being monitored at discrete depths, rather than composite depths, on every routine run.
- Characteristics monitored during wet weather had been rationalised to improve the reliability of automatically collected samples.
- More on-line sensors to measure specific analytes have been installed.
- Event and investigative monitoring for known events, such as seasonal lake turnover, large rainfall events and cyanobacteria in raw water are included in the program.

New monitoring sites are being installed in a number of areas across the SCA's catchments to assess water quality impacts where existing or changing land uses indicate a threat to water quality on the basis of the four priority pollutants (nitrates, phosphorus, pathogens, suspended sediments) in the Pollution Source Assessment Tool (PSAT). Flow gauges and automatic samplers are being established at suitable sites to capture information on contaminant sources and pollutant loads and to assist in evaluating the water quality benefits of catchment activities under the SCA's Healthy Catchments Strategy.

The installation of a vertical water quality profiler system, in Lake Burragorang located 500 m upstream of Warragamba Dam (sample location DWA2), was completed in November 2012. This instrument is capable of providing turbidity, pH, conductivity, dissolved oxygen and temperature profiles at one metre intervals up to a maximum depth of 90 m. Profiles are completed every two hours with data being sent to our database at near real time frequency. The installation provides water quality data to our organisation twelve times each twenty four hour period allowing analysts to review water column status without the need to have staff physically perform the profile.

The data generated from the vertical profiler has been used extensively during inflow events to make operational decisions and as an additional dataset for models. The installation of additional vertical profilers across a number of key storages is being investigated.

The water monitoring program recognises the linkage between information derived through the monitoring program, research and investigation through the Science Strategic Plan, and evaluation of activities undertaken by the SCA to address threats to water quality through the Healthy Catchments Strategy (HCS). A revised HCS was developed in the reporting period with the next plan being implemented from 2013, supported by annual programs of catchment activities. Progress against the Science Strategic Plan is reported each six months and the Water Monitoring Program 2010–2015 is being reviewed in 2013 and will be reviewed again in 2015.

The development of Health-Based Targets being proposed by the National Health Medical Research Council (NHMRC) and the response required by NSW Health following treated water turbidity exceedances has increased the focus on the risk of waterborne *Cryptosporidium* and *Giardia* (C&G) in raw water. As a result, the SCA will undertake more intensive monitoring to increase the amount of C&G data. This campaign monitoring program will target critical sites, mostly at raw water offtakes and within the Warragamba and Nepean catchments, where greater detail is required to assess C&G risks. This will mostly target periods when the highest concentrations of C&G are expected, such as during inflow events. In addition to being enumerated, oocysts will be tested for infectivity (viability) and genotyped when sufficient numbers of oocysts are detected. This information is needed to more reliably assess human health risk — a *Cryptosporidium* oocyst must be viable, infectious and a human-pathogenic strain to be a human health risk.

The rolling revision of the Australian Drinking Water Guidelines (ADWG) by the NHMRC was published in November 2011. One of the major changes was the inclusion of new health guidelines for numerous pesticides. During 2012-13 the SCA conducted a risk assessment on the list of pesticides and synthetic organic compounds (SOCs) to assess which chemicals should be included in the SCA water monitoring program. One hundred and fifty chemicals were assessed. A semi-quantitative risk assessment was conducted including data on human health toxicity, mobility and persistence, current usage in SCA catchments and where available SCA water monitoring data from 2000-2012 was also assessed.

The risk assessment identified several pesticides for routine monitoring at inlets to WFPs, as well as occasional investigative monitoring of sewage treatment plant effluents and stormwater runoff from selected sites in high-risk catchments (based on land-use assessments) to better quantify potential sources of pesticides and SOCs. New requirements will be incorporated in the 2013 review of the SCA's water monitoring program.

The second review of the SCA's Water Monitoring Program began in July 2013. This will include the outcomes of the pesticides and SOCs risk assessment, as well as consideration of new sites or analytes which will further improve the monitoring program. Once completed, the revised draft Water Monitoring Program will be sent for endorsement by NSW Health.

4 Applicable guidelines / benchmarks

The SCA has adopted nationally recognised standards and guidelines for a range of water quality characteristics in each part of the water supply network. Different guidelines and standards apply to each part of the supply cycle as water passes from catchment waterways into storages, and then into the delivery network or downstream rivers.

4.1 Australian Drinking Water Guidelines (ADWG) 2011

The Australian Drinking Water Guidelines (NHMRC, 2011) apply to any water intended for drinking, irrespective of the source or where it is consumed. The ADWG framework for managing drinking water quality advocates risk management and preventive measures at all barriers from catchment to consumer.

For water quality characteristics that have been specified as ‘health related’, including metals, pesticides and synthetic organic compounds (Table 4.1), raw water must conform to the ADWG. As conventional water treatment methods are not designed to remove these compounds from raw water, it is preferable to avoid them in the raw water supply through catchment and storage management practices. Routine monitoring of radionuclides is also performed at water filtration plants. Testing for individual radionuclides is performed following a positive gross alpha or gross beta result.

4.2 Raw water supply agreements

The SCA has established terms and conditions of supply with wholesale customers to ensure treated water quality consumed is not harmful to consumers’ health. Raw water supplied for treatment is required to conform to site-specific standards specified in raw water supply agreements (Table 4.2). These standards are based on the treatment capabilities of the plants and the natural characteristics of the catchment. For these parameters and other specific water quality characteristics, raw water is not required to meet drinking water guidelines provided the water can be subsequently treated to meet Australian Drinking Water Guidelines (ADWG) requirements.

Table 4.1 Health-related water quality characteristics

	Specific Water Characteristic	ADWG (2011) Health Guideline
SYNTHETIC ORGANICS – RADIOLOGICAL - PESTICIDES	Amitrole	0.0009 mg/L
	Atrazine	0.02 mg/L
	Chlorpyrifos	0.01 mg/L
	2,4-D	0.03 mg/L
	2,4,5-T	0.1 mg/L
	Diazinon	0.004 mg/L
	Diquat	0.007 mg/L
	Diuron	0.02 mg/L
	Glyphosate	1.0 mg/L
	Heptachlor	0.0003 mg/L
	Hexazinone	0.4 mg/L
	Triclopyr	0.02 mg/L
	Gross alpha	0.5 Bq/L
	Gross beta	0.5 Bq/L
	Benzene	0.001 mg/L
	1,2-Dichloroethane	0.003 mg/L
	1,2-Dichloroethene	0.06 mg/L
	Hexachlorobutadiene	0.0007 mg/L
	Vinyl chloride	0.0003 mg/L
CHEMICAL/BIOLOGICAL/ORGANIC	Arsenic	0.01mg/L
	Barium	2 mg/L
	Boron	4 mg/L
	Iodide	0.5 mg/L
	Mercury	0.001 mg/L
	Molybdenum	0.05 mg/L
	Selenium	0.01 mg/L
	Silver	0.1 mg/L
	Tin	N/A
	Beryllium	0.06 mg/L
	<i>Escherichia coli</i>	Seek advice from NSW Health and liaise with customers if the thresholds for these analytes in Raw Water Quality Incident Response Plan are exceeded
	Enterococci	
	<i>Clostridium perfringens</i>	
	<i>Cryptosporidium</i>	
	<i>Giardia</i>	
	Toxin producing cyanobacteria	
	Toxicity	
	Cyanobacteria biovolume	

Footnotes

- 1 Section shaded **yellow** contains health related water quality characteristics – these characteristics must not exceed Australian Drinking Water Guidelines (NHMRC, 2011) in raw water supplied for treatment.
- 2 Section shaded **blue** contains characteristics for which drinking water guidelines exist although these are not applicable for raw water. However, SCA must endeavour to supply the best quality raw water available so that it can be treated to meet Australian Drinking Water Guidelines.

Table 4.2 Raw water supply agreements – Site specific standards

PARAMETER	Prospect WFP	Warragamba WFP Orchard Hills WFP	Macarthur WFP Value of Parameter Based on Demand Range (ML/d)				Illawarra WFP	Woronora WFP	Nepean WFP	Cascade WFP	Kangaroo Valley WFP	Wingecarribee † WFP
			185- <265	125- <185	80- <125	<80						
Turbidity (NTU^)	40	40	10	25	50	60	10	10	150	15	20	40
True colour (CU^)	60	60	40				50	70	60	60	70	70
Iron (mg/L^)	3.5	3.5	0.6	0.8	1.1	1.3	1.1	1	5	3	1.1	1.1
Manganese (mg/L^)	1.4	1.4	0.2	0.25	0.3	0.35	0.4	0.1	1.5	0.3	NA	NA
Aluminium (mg/L^)	2.6	2.6	0.4	0.5	0.75	0.95	1.4	0.4	1.0	0.2	NA	NA
Hardness (mg/L as CaCO ₃)	25 – 70	25 - 70	6 – 30	6.0 – 32.2			0 – 30	2 – 30	2 – 35	0 – 40	0 – 36.5	0 - 36.5
Alkalinity (mg/L as CaCO ₃)	15 – 60	15 - 60	0 - 15				0 – 10	0 – 15	0.5 – 25	0 – 30	0 - 29	0 - 35
pH (pH units)	6.3 – 7.9	6.3 - 7.9	5.7 – 7.7				6.2 – 7.2	5.1 – 7.5	4.8 – 7.7	6.0 – 7.9	6.5 – 8.5	6.5 – 8.5
Temperature (°C)	10 – 25	10 - 25	8 - 25				10 – 25	10 – 25	10 – 25	10 – 25	NA	NA
Algae (ASU)	1000*	2000	**see note				5000	5000	2000	2000	5000	5000

* Maximum for Prospect WFP is 1000 ASU, except if turbidity is greater than 10NTU or true colour is greater than 30 CU, then the maximum algae criterion will be 500 ASU.

** Algal limits for Macarthur WFP (average of 3 samples): 500 ASU small individual cells (<10µm) of filamentous or colony-forming species or 100 ASU large cells (>10µm) of branching or gelatinous species.

[^] Upper limits are shown for these parameters.

† Same arrangement for Goulburn-Mulwaree Council for water supplied via the Goulburn pipeline

4.3 ANZECC 2000

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (referred to as the ANZECC Guidelines, 2000) provide a guide for setting water quality objectives required to sustain current or likely future environmental values for natural and semi-natural water resources in Australia and New Zealand. Water quality in the SCA's storages and catchment waterways are compared against relevant sections of the ANZECC Guidelines.

4.4 Benchmarks for storages

Benchmarks for storages are derived from the guidelines for freshwater lakes and reservoirs (ANZECC, 2000) for the 95-99 percent level of species protection (Table 4.3).

Table 4.3 Water quality benchmarks for storages

Analyte	Units	Benchmark range
pH	pH units	6.5-8.0
Chlorophyll- <i>a</i>	µg/L	<5
Dissolved oxygen	%sat	90-110
Total nitrogen	mg/L	<0.35
Total phosphorus	mg/L	<0.01
Turbidity	NTU	<20.0
Total manganese	mg/L	<1.9
Total aluminium	mg/L	<0.055

4.5 Benchmarks for catchments

The SCA benchmarks water quality in catchment streams against the ANZECC (2000) guideline ranges for upland rivers (Table 4.4).

Table 4.4 Water quality benchmarks for catchment streams

Analyte	Units	Benchmark range
pH	pH units	6.5 – 8.0
Chlorophyll- <i>a</i>	µg/L	< 5
Dissolved oxygen	% sat	90 - 110
Total nitrogen	mg/L	< 0.25
Total phosphorus	mg/L	< 0.02
Turbidity	NTU	0 – 25

4.6 Benchmarks for downstream rivers

Benchmarks for water quality downstream of SCA's dams and weirs are derived from lowland rivers ecosystem types (ANZECC, 2000).

Table 4.5 Water quality benchmarks downstream of storages

Analyte	Units	Benchmark range
pH	pH units	6.5 - 8.5
Chlorophyll- <i>a</i>	µg/L	< 5
Dissolved oxygen	%sat	85 - 110
Total nitrogen	mg/L	< 0.5
Total phosphorus	mg/L	< 0.05
Turbidity	NTU	< 50

4.7 Benchmarks for picnic area supplies

Benchmarks for the picnic area supplies are based on ADWG (2011) threshold ranges, where relevant. Some benchmarks are prompts for action, such as chlorophyll-*a*, which triggers algal monitoring in the picnic area supply.

Table 4.6 Water quality guidelines for specific parameters at picnic areas

Analyte	Units	Threshold
Total chlorine residual	mg/L	0.2 - 0.5
pH	pH units	6.5 - 8.5
Turbidity	NTU	< 5
Total Iron	mg/L	< 0.3
Total Aluminium	mg/L	< 0.2
Total Manganese	mg/L	< 0.1
<i>E. coli</i>	orgs/100mL	Should not be detected
Algal toxins (Microcystin-LR equivalents)	µg/L	<1.3
Chlorophyll- <i>a</i>	µg/L	<5
Potentially toxin producing algal cells	cells/mL	<6,500 [^]

[^] See cyanobacteria benchmarks in Table 4.7.

4.8 Benchmarks for cyanobacteria

The SCA routinely monitors levels of algae in major storages to provide early warning of possible bloom conditions and to ensure that raw water supplied to customers can be treated to meet drinking water guidelines. Algal monitoring is also conducted to avoid contaminating downstream waterways through environmental releases or transfers.

Despite Lake Yarrunga and Fitzroy Falls Reservoir being the only SCA storages with recreational access, the SCA applies the National Health and Medical Research Council Recreational Waters Guidelines (NHMRC, 2008) for catchments and lakes. The raw water and picnic areas benchmarks are from the ADWG (NHMRC, 2011).

Table 4.7 Cyanobacteria benchmarks throughout the SCA's area of operations

Analyte	Units	Threshold
Catchment and lake sites*		
<i>Microcystis aeruginosa</i>	cells/mL	50,000
Total cyanobacteria biovolume	mm ³ /L	4
Toxicity (Microcystin LR toxicity equivalents)	µg/L	10
Raw water and picnic area water supplies^		
<i>Microcystis aeruginosa</i>	cells/mL	6,500
<i>Cylindrospermopsis raciborskii</i>	cells/mL	15,000
<i>Anabaena circinalis</i>	cells/mL	20,000
Toxicity (Microcystin LR toxicity equivalents)	µg/L	1.3
Toxicity (Cylindrospermopsin)	µg/L	1.0
Toxicity (Saxitoxin, anatoxins)	µg/L	3.0

*National Health and Medical Research Council Guidelines for Managing Risks in Recreational Water 2008.

^ADWG 2011 specify actions in response to various alert level ranges for *Microcystis aeruginosa*, *Anabaena circinalis* and *Cylindrospermopsis raciborskii* (i.e. >2,000 cells/mL = consider toxicity testing). These triggers are based on cell counts and biovolume.

4.9 Benchmarks for *Cryptosporidium* and *Giardia*

The Australian Drinking Water Guidelines (ADWG) do not contain guideline values for *Cryptosporidium* and *Giardia* in raw or treated drinking water. However, ADWG (2011) recommends a multi-barrier approach to minimise the risks of these pathogens. Investigative testing is encouraged in response to events that could increase the risk of contamination (e.g. heavy rainfall). The SCA implements additional monitoring during high risk events.

Cryptosporidium and *Giardia* monitoring in the catchments is undertaken to provide an early warning function to enable optimal configuration of the raw water supply system in the event of high levels of *Cryptosporidium* and/or *Giardia* detections within the storages. Catchment monitoring also contributes to the understanding of sources which can then improve the robustness of risk assessments.

The SCA responds to detections of *Cryptosporidium* and *Giardia* in raw water supply in accordance with the Raw Water Quality Incident Response Plan (RWQIRP) developed in consultation with NSW Health and wholesale customers. The SCA's RWQIRP identifies four event levels for raw water:

- Alert Level: 1 – 10 (oo)cysts (IFA /10 L adjusted for recovery)
- Minor Incident: 11 – 100 (oo)cysts (IFA /10 L adjusted for recovery)
- Major Incident: 101 – 1000 (oo)cysts (IFA /10 L adjusted for recovery)
- Emergency: >1000 (oo)cysts (IFA /10 L adjusted for recovery).

5 Routine monitoring

5.1 Quality Assurance/Quality Control

During 2012–13 4, 431 routine water quality samples were collected for testing. The Quality Assurance/Quality Control (QA/QC) samples taken over the same period were equivalent to 10.8% of the routine samples collected. A breakdown of QA/QC sampling is shown in Table 5.1 below.

Table 5.1 Quality assurance and quality control sampling summary for 2012-13

Routine Sampling Region	No. of samples	Duplicates	Field Blanks	Trip Blanks
Area A (North West Region)	2083	120	55	56
Area B (South East Region)	2348	132	70	48
TOTAL	4431	252	125	104
Percent of total		5.7%	2.8%	2.3%

The majority of sites required for monitoring under the SCA's Water Monitoring Program 2010–2015 were sampled at, or close to, the required frequency. Some catchment sites were not sampled due to no flow, and some storage samples were not collected from close to the dam walls while they were spilling to protect the safety of workers.

Tools used to analyse QA/QC samples include contractor anomaly reporting, internal database reports, reviews of contractor processes, and assessment of the implications of anomalies by key internal data users with appropriate statistical and/or water quality expertise.

The process aims to ensure a consistent and timely resolution of anomalies and is outlined in a protocol document.

QA/QC samples that had a result outside the lab designated criteria (outlined in the analytical procedures manual for field duplicates), or positive results for field or trip blanks, were reported to the SCA by service providers as anomalous data requiring review. Most of these were accepted as 'natural variability' between concurrent samples (particularly for biological parameters), or were within the limits of experimental variation with no significant impact on results, and no further action was required.

During the year the SCA monitored data through the water information systems to ensure data integrity was maintained. This involved continuous review and anomaly reporting of the process of acquiring and storing water monitoring information. The intent of this was to check that data supplied by the laboratories is processed, loaded and retrieved correctly by the SCA's water quality database and associated systems. The SCA found that the process of transferring results to the SCA's database accurately reproduces appropriate data from the laboratory including dates, sites and values.

Anomalies reported during 2012–13 included:

Biological and algal analysis

On 10 occasions the variation between algal duplicate samples were outside of the prescribed limits and were reported. Variation at this level is expected when measuring biological systems with concurrent raw water sampling techniques. These results did not lead to any misinterpretation of water quality that required action by the SCA.

On eight occasions the variation in other biological samples was outside the prescribed limits for each respective method and were reported as anomalous. Variation at this level is expected in raw water samples and as with algal analysis, did not influence water quality results so no further action was required.

Metals (aluminium, manganese and iron)

On eight occasions metals (predominately aluminium) were detected in blanks and field trip samples. Further work is ongoing to assess if these results represent systemic issues. As all anomalies were slight detections and highly infrequent, it is unlikely the results would have led to any misinterpretation of water quality requiring action by the SCA.

Total organic carbon

On five occasions total and dissolved carbon anomalies were detected and reported. Occasional variation between samples for carbon analysis is expected due to the ubiquitous nature of the analyte. Due to the low concentrations of these infrequent anomalies, the results did not lead to any misinterpretation of water quality requiring action by the SCA.

Nitrogen

On six occasions nitrogen anomalies were detected and reported. The SCA uses highly sensitive analysis and all anomalies were of a very low level. Variation at this sensitivity is not unusual in raw water samples. The results did not lead to any misinterpretation of water quality requiring action by the SCA.

Quality control measurements outside of prescribed limits were detected in a further three samples. These samples were collected from a number of monitoring sites and the anomalies varied across the samples. In all cases either the levels of anomaly were low or were considered a result of sample heterogeneity. SCA tracks these types of anomalies to determine if any emerging trends warrant corrective action. There was no evidence of this in 2012–13.

5.2 Warragamba system

Sampling sites in the Warragamba system (including Prospect Reservoir) are shown in Figure 5.1 below.

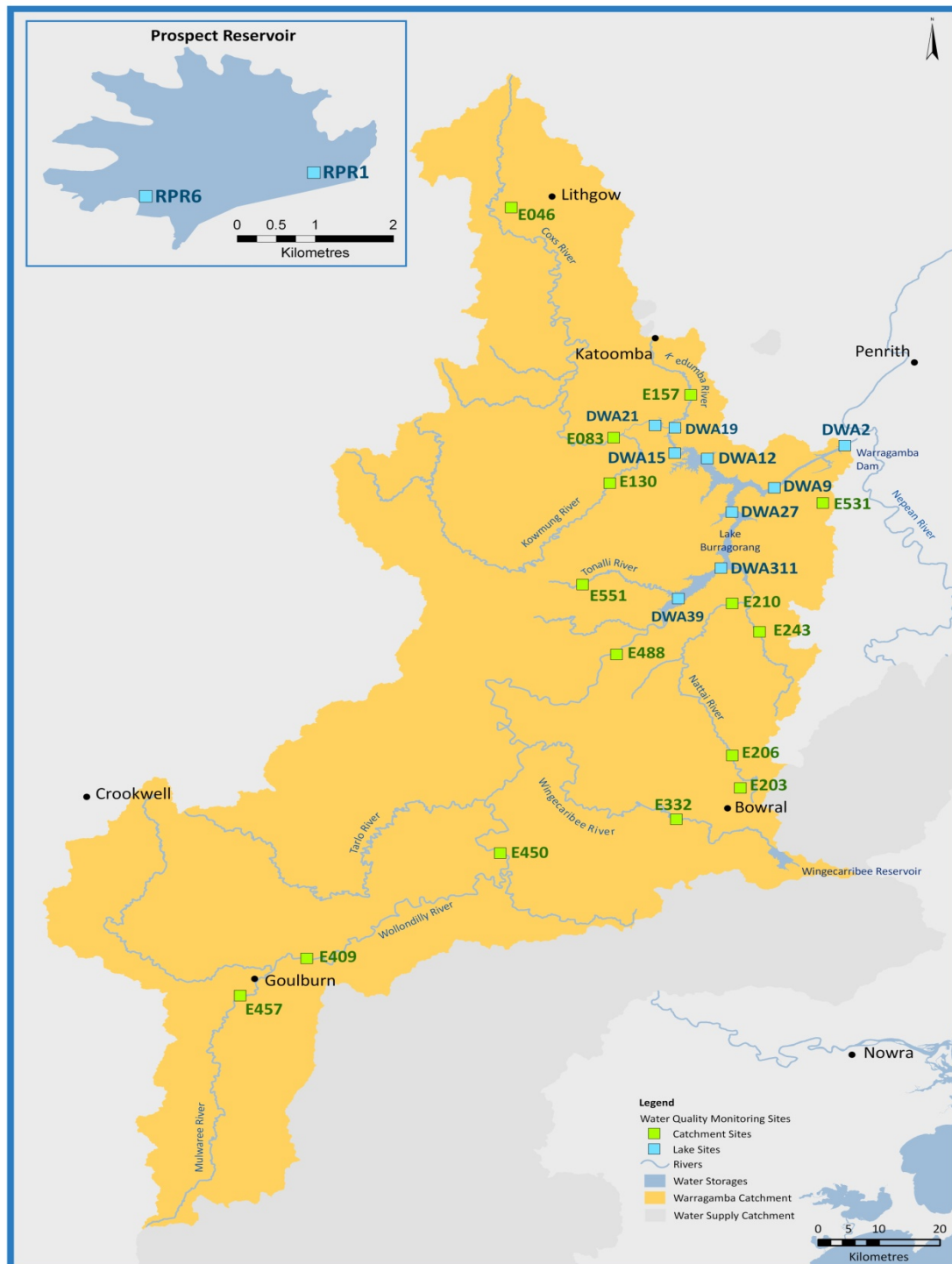


Figure 5.1 Sampling sites in the Warragamba system (including inset Prospect Reservoir)

5.2.1 Catchments

The Warragamba catchment has 15 routine monitoring sites, extending from Farmers Creek (E046), close to the town of Lithgow, to Mulwaree River (E457) south of Goulburn as shown in Figure 5.1. The results for selected analytes at each site are compared with benchmarks in Table 5.2 below. Refer to Appendix A1.1 for the statistical summary of the data.

Table 5.2 Warragamba system catchments - percentage of samples exceeding benchmarks

Station Code	Flow condition	Number of samples	Dissolved Oxygen (%Sat)	Turbidity Field	pH	Phosphorus Total	Nitrogen Total	Chlorophyll- <i>a</i>
Coxs River								
E046	dry	11	0	0	9	100	100	9
	wet	1	0	0	0	100	100	0
E083	dry	11	0	0	0	0	27	36
	wet	1	0	0	0	100	100	0
Kowmung River								
E130	dry	10	10	0	0	0	10	0
	wet	2	0	0	0	0	100	0
Kedumba River								
E157	dry	11	45	0	0	9	82	0
	wet	1	0	0	0	0	0	0
Nattai River								
E203	dry	12	25	0	0	100	100	33
	wet	0	NA	NA	NA	NA	NA	NA
E206	dry	11	9	0	0	64	100	0
	wet	1	0	0	0	0	100	100
E210	dry	12	42	0	0	8	83	25
	wet	0	NA	NA	NA	NA	NA	NA
E243	dry	10	30	0	20	0	0	10
	wet	2	50	0	100	0	0	0
Wingecarribee River								
E332	dry	12	58	0	8	83	100	100
	wet	0	NA	NA	NA	NA	NA	NA
Wollondilly River								
E409	dry	10	40	0	40	89	100	60
	wet	2	50	0	0	100	100	50
E450	dry	9	22	0	56	25	100	22
	wet	3	0	0	33	33	100	67
E488	dry	10	30	0	50	10	90	50
	wet	2	0	0	50	50	100	50
Mulwaree River								
E457	dry	10	70	0	60	78	100	60
	wet	2	50	0	0	50	100	100

Station Code	Flow condition	Number of samples	Dissolved Oxygen (%Sat)	Turbidity Field	pH	Phosphorus Total	Nitrogen Total	Chlorophyll- <i>a</i>
Werriberri Creek								
E531	dry	10	60	0	0	10	20	10
	wet	2	100	0	0	50	100	0
Tonalli River								
E551	dry	11	45	0	0	0	9	9
	wet	1	0	0	0	0	100	0

Water quality results for each major river system are analysed in sections that follow.

Wollondilly Catchment

The Wollondilly River is the largest river system within the SCA's area of operations, draining the southern areas of the Lake Burragorang catchment. Land use within the catchment is primarily natural bushland and low intensity pasture.

Water quality is routinely monitored at three sites along the Wollondilly River:

- Murray's Flat (E409) – approximately 10 km downstream of Goulburn
- Golden Valley (E450) – approximately 50 km downstream of Goulburn
- Jooriland (E488) – near the Wollondilly arm inlet to Lake Burragorang.

During the reporting period discharge from the Wollondilly River represented approximately 44% of total inflow to Lake Burragorang. A significant wet weather event occurred on 26 June 2013, discharging a peak of 156,000ML per day at Jooriland (E488).

Table 5.2 presents the percentage of samples exceeding the benchmarks specified in Table 4.4. Turbidity remained below the benchmark value at all three sites in both wet and dry conditions. pH was within the benchmark value range in approximately half of dry flow condition samples at all three sites. The pH value was higher than the recommended benchmark range in one of the two wet weather samples taken at Jooriland (E488) and in one of the three wet weather samples taken at Golden Valley (E450).

Total phosphorus regularly exceeded the benchmark value at Murrays Flat (E409), with downstream sites showing fewer exceedances (Table 5.2). Total nitrogen is observed to decrease at downstream sites despite exceeding the benchmark at all sites on most sampling occasions. The same trend was observed in the 2011-12 reporting period where both phosphorus and nitrogen concentrations decreased downstream while regularly exceeding the benchmark values.

Chlorophyll-*a* concentrations at Murrays Flat (E409) and Jooriland (E488) exceeded the benchmark values in approximately half of all samples. Chlorophyll-*a* concentrations were considerably lower in dry flow conditions at Golden Valley (E450), exceeding the guideline values in only 20% of samples. However chlorophyll-*a* exceeded benchmark values in two of the three wet weather samples taken

at Golden Valley (E450). Despite the chlorophyll-*a* exceedances algal numbers remained well below benchmark values.

Dissolved oxygen (percentage saturation) at Murrays Flat (E409) was outside the benchmark range on over 40% of sampling occasions. At downstream sites, concentrations fell within the benchmark value range more frequently. Less than 30% of samples fell outside the benchmark range at the two downstream sites.

Wingecaribee River Catchment

The Wingecaribee River flows in a westerly direction, from Robertson through Wingecaribee Reservoir and into the Wollondilly River downstream of Berrima. It is also used to transfer waters from the Shoalhaven Scheme.

Soils in the area are rich loamy clay soils supporting highly productive grazing lands and horticultural crops. Given reliable rainfall and productive soils, pastoralists are able to maintain relatively high stocking rates of livestock (primarily cattle).

The SCA routinely monitors water quality at:

- Berrima Weir (E332) – downstream of the Wingecaribee Reservoir and the Berrima Sewage Treatment Plant outfall.

No wet flow condition samples were collected within the Wingecaribee catchment during the monitoring period.

Total nitrogen and chlorophyll-*a* concentration at Berrima Weir (E332) exceeded benchmark concentrations on all sampling occasions during dry flow conditions. Total phosphorus also exceeded the benchmark concentration in the majority of samples. These results were congruent with results from previous years.

In spite of this, cyanobacteria concentrations at this site remained low throughout the year, with no exceedances.

In contrast to the previous reporting period, turbidity did not exceed the benchmark value.

Mulwaree River Catchment

The Mulwaree River occupies the southernmost extent of the Lake Burragorang catchment, joining the Wollondilly River at Goulburn. Land use in the catchment is primarily agricultural.

Routine monitoring is undertaken at:

- Towers Weir (E457) – located approximately 10 km upstream of the Wollondilly confluence.

Samples taken during dry conditions were found to consistently exceed the nutrient benchmark values. Total nitrogen in particular exceeded the benchmark concentration in all samples. Chlorophyll-*a* was found to exceed the guideline 60% of the time in dry flow conditions and the

median chlorophyll-*a* concentration at Towers Weir (E457) was 5.4 µg/L, which is 0.4 µg/L above the recommended benchmark value.

Two samples were taken from the Mulwaree River during wet conditions. The results were generally similar to the dry flow samples, with nutrients, chlorophyll-*a*, and dissolved oxygen exceeding benchmark values in at least one of the two samples.

Coxs River catchment

Coxs River is the second largest tributary in the Warragamba catchment and contributed approximately 30% of the total inflow volume during 2012-13. Land use is primarily native bushland, forestry, pasture and some mining (in the Lithgow/Wallerawang region).

The SCA routinely monitors water quality at two sites:

- Farmers Creek (E046) – located in the upper reaches of the Coxs River, upstream of Lake Lyell and downstream of the Lithgow Sewage Treatment Plant.
- Kelpie Point (E083) – located in the Special Areas surrounding Lake Burragorang in the lower reaches of the Coxs River.

Nutrients exceeded ANZECC benchmark values in all samples. Turbidity and dissolved oxygen were within guideline ranges for the reporting period. pH and chlorophyll-*a* exceeded the benchmark value on one occasion during dry flow conditions.

At Kelpie Point (E083) dissolved oxygen, turbidity and pH were below or within benchmark values at all times. Total nitrogen and chlorophyll-*a* exceeded the benchmark concentration in approximately one third of dry flow condition samples. Nutrients exceeded the benchmark values in one wet flow sample.

Kowmung River catchment

The Kowmung River contributed approximately 16% of the total inflow to Lake Burragorang in 2012-13. The catchment is dominated by pristine forest.

Routine water quality is monitored at

- Cedar Ford (E130) – located approximately 15 km upstream from the Coxs River confluence.

The Cedar Ford site (E130) is known for excellent water quality, and this was maintained throughout the reporting period. Dissolved oxygen and total nitrogen marginally exceeded the ANZECC benchmark values in one of 10 dry flow condition samples. Total nitrogen exceeded the benchmark value in the two wet flow samples, once with a relatively high concentration of 1.78 mg/L.

Kedumba River catchment

The Kedumba River is a small tributary that drains into the Coxs River Arm of Lake Burragorang. The catchment is primarily bushland with some historic settlements amongst isolated cleared areas.

Water quality is monitored mid-catchment at:

- Maxwells Crossing (E157) – approximately 10 km upstream of Lake Burragorang inflow.

Good water quality was maintained throughout the reporting period. While the majority of total nitrogen results were found to exceed the benchmark values, the degree of exceedance was small and is not expected to have impacted on ecological health. There were no exceedances in the one wet flow sample.

Nattai River catchment

The Nattai River drains the Southern Highlands, flowing through the Nattai National Park. The headwaters of the river are affected by urban runoff and discharges from the Braemar Sewage Treatment Plant (into Gibbergunyah Creek). A majority of the catchment is pristine forested areas with some agricultural and residential areas around Mittagong, Hilltop and Thirlmere.

Routine monitoring sites are located on the major tributaries:

- Nattai River at the Craggs (E206) – approximately 5 km downstream of the Nattai River and Gibbergunyah Creek confluence
- Nattai River at Smallwoods Crossing (E210) – located in the lower Nattai, approximately 4 km upstream of the Nattai and Little River confluence
- Gibbergunyah Creek at Braemar STP (E203) – immediately downstream of the Braemar STP discharge
- Little River (E243) – mid catchment, approximately 7 km upstream of the confluence with the Nattai River.

Discharges from Braemar STP make up a large portion of the Gibbergunyah Creek baseflow. Very good water quality was maintained with respect to turbidity and pH. Chlorophyll-*a* exceeded the benchmark value in one third of dry flow condition samples. Total nitrogen and total phosphorus exceeded the benchmark value in all dry flow condition samples. The Gibbergunyah Creek site (E203) is directly downstream of the effluent outfall where nutrients are not yet subject to in-stream processes.

The effects of dilution and in-stream processes resulted in reduced nutrient concentrations at the Craggs (E206). Compared to Gibbergunyah (E203), nitrogen concentrations (median and maximum) have been reduced by one third at The Craggs (E206), with even greater reductions in total phosphorus. This trend continued to the downstream station at Smallwoods Crossing (E210), where similar reductions were observed.

The pristine bushland of the Little River catchment (E243) was generally within guideline values in 2012-13.

Werriberri Creek catchment

Land use in the Werriberri catchment is a mix of native forest, agricultural and rural residential, with some peri-urban development west of Picton. Werriberri Creek enters Lake Burragorang

approximately five kilometres upstream of the Warragamba Dam raw water supply offtakes, and as such is of particular concern with regards to water supplied for treatment.

The routine monitoring site is located at:

- Werombi (E531) – downstream of the Werombi township approximately 10 km upstream of Lake Burragorang.

Water quality was generally good in 2012-13 however there were some minor non-conformances. During dry flow condition sampling, dissolved oxygen fell below the minimum benchmark value on 60% of sampling occasions, total nitrogen exceeded the benchmark 20 percent of the time, and total phosphorus and chlorophyll-*a* 10% of the time.

Nutrients and dissolved oxygen exceeded the benchmark values in both of the wet flow samples.

Tonalli River catchment

The Tonalli River is a small, ephemeral river within the Special Areas surrounding Lake Burragorang. Land use here is primarily bushland, however derelict mines (Yerranderie Silver Mining Field) in the area have been identified as potential sources of contaminated mine waste material. In response, the SCA has undertaken rehabilitation works to mitigate mine waste contamination.

The SCA monitors water quality at:

- Tonalli River at Fireroad (E551) – mid catchment, approximately 12 km upstream of Lake Burragorang.

Water quality in the Tonalli River was generally good during the year. With regards to potential mine waste contamination, metal concentrations were low. Full pH compliance was observed with no evidence of acid mine drainage. The low dissolved oxygen values recorded were probably a result of the ephemeral nature of the stream allowing stagnation of the pools. Total nitrogen marginally exceeded the benchmark value in the one wet flow sample.

5.2.2 Storages

The Warragamba catchment drains into Lake Burragorang. The SCA has nine routine monitoring sites on Lake Burragorang (Figure 5.1). Prospect Reservoir has two routine sampling sites, RPR1 and RPR6. The results are compared with benchmarks (see section 4.4.) for these sites in Table 5.3 below. Refer to Appendix A1.2 for the statistical summary of the data.

Table 5.3 Warragamba system storages - percentage of samples exceeding benchmarks

Station Code	Number of samples	Turbidity	pH	Dissolved Oxygen (%Sat)	Phosphorus Total	Nitrogen Total	Aluminium Total	Manganese Total	Chlorophyll-a
Lake Burragorang - Coxs Arm									
DWA12	24	0	0	42	60	100	32	0	0
DWA15	7	0	29	29	50	100	33	0	67
DWA19	6	0	17	83	83	100	17	0	100
DWA21	6	0	17	50	67	100	17	0	100
Lake Burragorang - Wollondilly Arm									
DWA27	26	0	0	50	60	100	52	0	15
DWA311	7	0	0	71	67	100	67	0	33
DWA39	6	0	0	50	100	100	67	0	67
Lake Burragorang - Gorge									
DWA2	55	0	0	47	58	100	31	0	19
DWA9	31	0	0	52	58	96	38	0	12
Prospect Reservoir									
RPR1	13	0	23	15	23	8	15	0	34
RPR6	8	0	0	25	0	0	67	0	39

Lake Burragorang

Lake Burragorang is comprised of three distinct sections:

- Coxs Arm – drains the predominantly naturally forested catchments of the Coxs, Kowmung and Kedumba rivers.
- Wollondilly arm – drains the agricultural catchments of the Wollondilly, Wingecarribee and Mulwaree rivers and the forested Nattai and Little rivers.
- Gorge – is the narrow and deep section downstream of the confluence of the Coxs and Wollondilly arms. Werriberri Creek enters the Gorge approximately 5 km upstream of Warragamba Dam wall.

Lake Burragorang experienced three significant inflow events within the reporting period. These occurred in January, February and June 2013. The lake filled and spilled on the latter two of these occasions.

The first two inflows entered the storage in the surface waters and did not have a detrimental effect on the water quality in the lake except for a slight rise in the already elevated true colour. The third

event, occurring in June, entered the storage as an underflow along the bottom of the lake, was particularly turbid and brought in elevated true colour. By selecting supply from an outlet high in the water column as the inflow approached any detrimental impacts on raw water supply from this inflow were avoided.

Turbidity remained within the ANZECC benchmark at all sites in spite of the inflows. The median value for turbidity at DWA2 was 1.41 NTU.

pH was generally not a problem, but fell outside the guidelines (6.5-8.0) up to one third of the time, which is typical for this storage. All of the sites that fell outside of the guidelines were upstream sites. At the site closest to the dam wall and offtakes, DWA2, the median pH value was 7.57, the maximum was 7.86.

Dissolved oxygen concentrations were typically seasonally depressed in the bottom waters of the lake due to the effects of thermal stratification and oxygen consumption in the hypolimnion. This is typical behaviour for this storage. The median dissolved oxygen concentration at DWA2 was 90.6% saturation.

Nutrients (nitrogen and phosphorus) were elevated throughout the storage for most of the year due to infiltration of these elements with inflow waters. This increase in nutrients translated into elevated chlorophyll-*a* concentrations in the surface waters. Despite the elevated nutrient concentrations in the surface waters, no cyanobacterial exceedances were observed.

Wet weather events led to an increase in organic constituents and **true colour** within the lake. The true colour median was 19.5 CU @ 400 nm, which is higher when compared to drier years. True colour of water can be due to a number of factors, including the presence of dissolved organic matter from vegetation and soil as well as from metals (such as iron and manganese) which can be attached to the organic matter.

Manganese concentrations remained low and relatively stable throughout the year, with 100% compliance at all sites.

Total aluminium remained elevated at most sites, with the concentration above the benchmark at DWA2 in 31% of samples. This was not unusual as aluminium is typically elevated in flood waters.

Prospect

Prospect Reservoir has a very small catchment and receives the bulk of its water from Upper Nepean dams via the Upper Canal.

Turbidity remained within the benchmark in all samples.

pH values exceeded the benchmark in 23% of samples at RPR1, however the maximum recorded value of 8.06 pH units was only slightly above the upper range value of 8.0 pH units for storages. The pH was within the benchmark range for all samples collected at RPR6. Median values for RPR1 and RPR6 were 7.89 and 7.78 respectively.

Dissolved oxygen saturation fell outside of the benchmark values at RPR1 in 15% of samples, and at RPR6 in 25% of samples. The aerator was not operated during and after transfers into the reservoir in late 2012. Non operation of the aerator resulted in decreases in the dissolved oxygen concentrations however this was not detrimental to aquatic life or an issue for treatment.

Total nitrogen and total phosphorus exceeded the benchmark at RPR1 on eight percent and 23% of occasions respectively. Nutrient values at RPR6 remained within benchmark values.

Total manganese concentration complied with the recommended benchmarks on all sampling occasions at both sites. **Total aluminium** exceeded the benchmark at RPR1 and RPR6 on 15% and 67% of occasions respectively. Median aluminium concentrations for RPR1 and RPR6 were 0.05 and 0.06 mg/L respectively. There were no issues with treating this water.

Chlorophyll-*a* concentrations at both sites were elevated in 34% and 39% of samples. No potentially toxin producing cyanobacteria exceedances were noted.

5.2.3 Water Filtration Plants

Lake Burragorang is the sole supply to Orchard Hills and Warragamba WFPs. It also supplies 80% of the Prospect WFP raw water demand. Variable offtakes on the dam wall allow selection of optimum water quality for supply. The results of sampling, at the inlet point of these plants, are compared with site specific standards (see Table 4.2) in Table 5.4 below. Refer to Appendix A1.3 for the statistical summary of the data.

Table 5.4 Warragamba system raw water supply -percentage of samples outside site specific standards

Location	Site Code	Number of samples	Alkalinity (mgCaCO ₃ /L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Iron Total (mg/L)	Manganese Total (mg/L)	pH	Temperature (Deg C)	Total Hardness (mgCaCO ₃ /L)	True Colour at 400nm	Turbidity (NTU)
Orchard Hills	HBR1	12	0	0	0	8	0	0	0	0	0	0
Warragamba	HWA2	12	0	0	0	0	0	8	0	0	0	0
Prospect	PWFP10	12	0	0	0	0	0	0	0	0	0	0

Throughout 2012-13 supply to Prospect achieved 100% compliance with the site specific standards. Supply to Warragamba WFP was below the standard for **pH** in eight percent of samples (one sample recording 6.6 pH). Supply to Orchard Hills exceeded the total iron guideline on eight percent of occasions, this comprised of one sample which was considered to be an anomaly (see Section 8.2.1 for more details).

True colour complied with the site specific standards at all times during 2012-13. While within the standards, true colour levels were elevated in comparison to drier years and caused some issues for treatment.

All samples taken in this system showed 100% compliance with the **heavy metals, pesticide and synthetic organic compound** guidelines as outlined in the ADWG (Table 4.1). **Gross alpha** and **gross beta** were not detected.

5.3 Upper Nepean system

Sampling sites in the Upper Nepean system are shown in Figure 5.2 below.

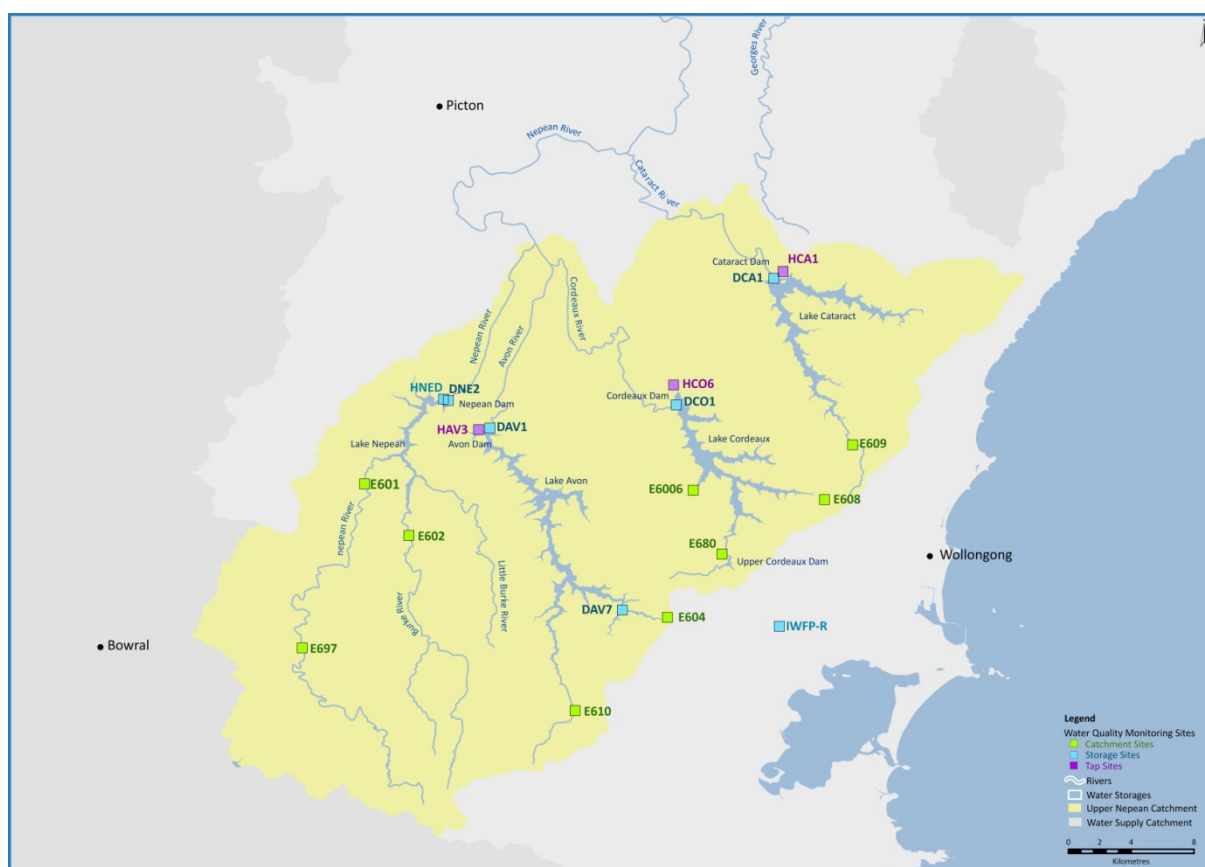


Figure 5.2 Sampling sites in the Upper Nepean system.

5.3.1 Catchments

The Upper Nepean catchment includes four reservoirs: Lake Cataract, Lake Cordeaux, Lake Avon and Lake Nepean. Across the four storages there are nine routine sampling sites in the catchment (outlined in Figure 5.2 above). The results of sampling at these Upper Nepean catchment sites are compared with benchmarks in Table 5.5. Refer to Appendix A2.1 for the statistical summary the of data.

Table 5.5 Upper Nepean catchments - percentage of samples exceeding benchmarks

Station Code	Flow condition	Number of samples	Dissolved Oxygen (%Sat)	Turbidity Field	pH	Phosphorus Total	Nitrogen Total	Chlorophyll-a
Nepean catchment								
E601	dry	12	8	0	0	0	83	0
	wet	0	NA	NA	NA	NA	NA	NA
E602	dry	11	0	0	27	0	0	0
	wet	1	0	0	100	0	0	0
E697	dry	11	27	0	9	27	91	18
	wet	1	0	0	0	100	100	0
Avon catchment								
E604	dry	12	25	0	8	0	0	0
	wet	0	NA	NA	NA	NA	NA	NA
E610	dry	10	10	0	0	10	10	0
	wet	1	0	0	0	0	0	0
Cataract catchment								
E609	dry	11	27	0	45	18	9	0
	wet	0	NA	NA	NA	NA	NA	NA
Cordeaux catchment								
E6006	dry	11	45	0	100	18	0	0
	wet	1	0	0	100	0	0	0
E608	dry	12	33	0	0	8	0	17
	wet	0	NA	NA	NA	NA	NA	NA
E680	dry	11	45	0	0	27	0	18
	wet	1	0	0	100	0	100	0

Cataract Catchment

The Cataract catchment is primarily natural forest, however there are some portions which have been cleared for roads, high voltage power lines and colliery ventilation shafts. These activities are limited and unlikely to have significant impacts on water quality. There has been some major road works associated with the widening of Picton Road which may have short term impacts on the upper reaches of the Cataract River Catchment.

The area is currently experiencing significant mining development (primarily longwall coal mining), which the SCA monitors for any impacts to water quality.

The routine water monitoring site is located at

- Cataract River (E609) – approximately 1 km upstream of Lake Cataract.

No wet weather samples were collected this year. Almost one third of samples were outside the benchmark value for dissolved oxygen and one fifth above the benchmark value for total phosphorus. Although 45% of samples fell below the benchmark for pH, this was more a reflection on the catchment's vegetation as the waters from these areas are generally more acidic. Water quality from Cataract River (E609) did not show any impact from upstream road works during dry weather.

Cordeaux Catchment

The Cordeaux catchment is dominated by large areas of pristine woodlands, open forests and heathland, which all contribute to good water quality.

The area has in the past and continues to experience significant mining development (primarily longwall coal mining), which the SCA monitors for any impacts to water quality.

The Cordeaux catchment has three water monitoring sites located at:

- Cordeaux River (E680) – Cordeaux River inflow to Lake Cordeaux
- Goondarin Creek (E608) – approximately 1 km upstream from Lake Cordeaux
- Sandy Creek (E6006) – Sandy Creek inflow to Lake Cordeaux.

At Sandy Creek (E6006) pH was below benchmark, but this was more a reflection on the catchment's vegetation as the waters from these areas are generally more acidic. No wet weather samples were collected this year from Goondarin Creek (E608). Over 30% of samples from these three sites were outside of the benchmark value for dissolved oxygen. Nearly 20% of samples exceeded the chlorophyll-*a* benchmark at Cordeaux River (E680) and Goondarin Creek (E608) sites.

Avon Catchment

Apart from the Upper Avon pumping station, there has been little human impact in the Avon catchment. The undisturbed forested catchment yield good quality runoff. The Avon catchment is characterised by a lack of major rivers or streams, but there are many perennial and intermittent drainages.

The area is currently experiencing significant mining development (primarily longwall coal mining), which the SCA monitors for any impacts to water quality.

Approximately 6,500ML during 2012-13 were transferred from Lake Nepean to Lake Avon via the Nepean – Avon tunnel during the reporting period.

The two monitoring sites are located at:

- Flying Fox Creek No 3 (E604) – inflow location to Lake Avon
- Avon River (E610) – inflow location to Lake Avon.

Both sites exhibited good water quality. Flying Fox Creek No 3 (E604) had pH readings below the benchmark during dry weather. This is a reflection of the catchment itself, which consists of

weathered Hawkesbury Sandstone with catchment vegetation types that account for the low pH. Most variables were well within the benchmarks.

Nepean Catchment

Large portions of the Nepean catchment are pristine woodland. The Nepean River catchment has farming across approximately 40% of the land, while the Burke catchment is native forest.

The Nepean catchment is monitored at three locations:

- Nepean River (E697) – approximately 15 km upstream from Lake Nepean
- Nepean River (E601) – inflow location to Lake Nepean
- Burke River (E602) – inflow location to Lake Nepean.

Rural activity, combined with transfers from Wingecarribee Reservoir, impacts on water quality. This offers some explanation for the exceedances in turbidity (particularly the Nepean River sites), total nitrogen and phosphorous. Burke River (E602) water quality was generally good during 2012-13 as compared to the Nepean River sites (E697 and E601), which is a reflection of the more pristine environment.

5.3.2 Storages

The Upper Nepean system includes four reservoirs: Lake Nepean, Lake Avon, Lake Cordeaux and Lake Cataract. Across the four storages there are five routine sampling sites (Figure 5.2). The results for the Upper Nepean storage sites are compared with benchmarks in Table 5.6 below. Refer to Appendix A2.2 for the statistical summary of the data.

Table 5.6 Upper Nepean system storages - percentage of samples exceeding benchmarks

Station Code	Number of samples	Turbidity	pH	Dissolved Oxygen (%Sat)	Phosphorus Total	Nitrogen Total	Aluminium Total	Manganese Total	Chlorophyll-a
Lake Avon									
DAV1	12	0	25	58	8	0	25	0	0
DAV7	12	0	0	25	0	0	8	0	17
Lake Cataract									
DCA1	12	0	33	17	8	0	100	0	17
Lake Cordeaux									
DCO1	12	0	0	25	8	0	25	0	33
Lake Nepean									
DNE2*	12	0	17	50	50	92	92	0	25

*Site DNE2 includes results from DNE1

Lake Nepean

The primary routine monitoring was undertaken 200 m upstream of the Nepean dam wall (DNE2). During spill events routine monitoring was undertaken from the dam wall (DNE1) to ensure safety of the water sampling crews.

Turbidity remained below the water quality benchmark in all routine samples. **pH levels** fell below the minimum threshold on 17% of samples (two occasions), recording a minimum of 6.4 pH.

Dissolved oxygen compliance was the same as during 2011-12, with 50% of samples being below the benchmark. Low levels of dissolved oxygen can be experienced in Lake Nepean when artificial aeration is not used and the lake is allowed to stratify. The lowest levels of dissolved oxygen were experienced during March to May 2013 following an underflow which pushed low oxygen waters up towards the surface.

Nutrient concentrations in Lake Nepean generally exceeded benchmark values. The median concentration of total nitrogen of 0.43 mg/L is above the benchmark level (92% exceeded). Total phosphorus exceeded the guidelines on 50% of occasions. Nutrient concentrations in Lake Nepean were impacted by large inflows during the reporting period, with similar impacts as inflows during 2010-11.

Total manganese concentrations remained low and compliant during 2012-13. **Total aluminium** exceedances increased from 67% in 2011-12 to 92% this year. A number of large inflow events throughout the reporting period are likely to be responsible for the increase recorded within the lake. The median concentration within the lake of 0.09 mg/L is similar to the median total aluminium concentrations recorded in the catchment streams (Nepean River (E601) 0.10 mg/L and Burke River (E602) 0.08 mg/L).

Wet weather events led to an increase in organic constituents and **true colour** within the lake. The true colour median was 15.7 CU @ 400 nm, which is higher when compared to drier years. True colour of water can be due to a number of factors, including the presence of dissolved organic matter from vegetation and soil as well as from metals (such as iron and manganese) which can be attached to the organic matter.

Chlorophyll-*a* concentration in Lake Nepean exceeded the benchmark on 25% of occasions. The maximum chlorophyll-*a* concentration was recorded in July 2012, during which time algae concentrations were not significant. This also coincided with the declining phase of the cyanobacteria growth.

Bacterial water quality was satisfactory in Lake Nepean. The indicators Enterococci, *E. coli* and *Clostridium perfringens* were rarely detected and only at very low numbers (9, 3 and 4 cfu/100mL respectively).

Lake Avon

Lake Avon is sampled routinely at two locations, at the valve house in the upper reaches of the lake (DAV7) and at the dam wall (DAV1).

Turbidity remained low and below the water quality benchmark in all samples within Lake Avon. **pH levels** were within the benchmarks at the upper lake site but fell below the minimum threshold on 25% of samples at the dam wall site. The pH of waters in the Avon catchment are known to be acidic at times, this is a result of the natural geology and vegetation in the area.

The **dissolved oxygen** levels within Lake Avon were high throughout most of the year, remaining above 80% saturation at the dam wall and 88% saturation in the upper lake. Artificial aeration within Lake Avon has had a positive impact on water quality, contributing to the high oxygen levels. The dam wall site recorded greater variability outside the benchmarks, with 33% of samples slightly above the upper limit and 25% of samples slightly below the lower limit for dissolved oxygen.

Nutrients were low within Lake Avon. Total nitrogen was well below the benchmark on all occasions at both lake sites. Total phosphorus was also low, only slightly exceeding the threshold limit of 0.01 mg/L on one sampling occasion at the upper lake site with a result of 0.014 mg/L.

Total manganese levels were compliant at all times. The **total aluminium** compliance was poorer during 2012-13 when compared to results from 2011-12. Total aluminium concentrations increase during wetter years when there is more natural leaching of aluminium from soils and rocks running off from the catchment into the lake.

There were no issues with chlorophyll- α or algae within Lake Avon. There were low level detections of bacterial indicators, with a maximum average daily *E. coli* result of 67 cfu/100mL recorded at the Upper Valve House. There were no issues with treating the raw water supplied to the Illawarra WFP.

Lake Cataract

Lake Cataract is sampled near the dam wall (DCA1) on a monthly basis.

Turbidity was low in Lake Cataract. The **pH** was also low at times, resulting in 33% of samples falling below the lower threshold. This is typical of the Cataract catchment, particularly following rainfall events.

Lake Cataract stratifies each year, which can lead to low **dissolved oxygen** levels. Dissolved oxygen compliance was 17% during 2012-13, the same as during 2011-12.

Total manganese levels complied at all times. **Total aluminium**, however, exceeded the benchmark on all occasions. Similar to other lakes in the Upper Nepean, increases in total aluminium are related to the catchment geology and increased wet weather during the year. Both Lake Cataract (DCA1) and the Cataract River (E609) recorded median total aluminium concentrations of 0.09 mg/L, above the ANZECC benchmark of 0.055 mg/L.

Nutrient concentrations and **chlorophyll-*a*** levels were low.

Lake Cordeaux

Lake Cordeaux is sampled near the dam wall (DCA1) on a monthly basis.

Generally water quality in Lake Cordeaux was good. Median values for most of the physico-chemical indicators of water quality were well within the recommended ANZECC benchmarks. The **dissolved oxygen** at times fell below the lower threshold and this is expected in a lake which stratifies.

Nutrients were also low within the lake. There were improvements in **chlorophyll-*a*** compliance this year, with 33% of samples exceeding the benchmark compared to 42% of the samples collected in 2011-12. The chlorophyll-*a* threshold of 5 µg/L does not necessarily indicate an issue with algae, but is used as an operational trigger which initiates algae analysis. There were zero potentially toxin producing cyanobacteria detected in Lake Cataract.

Total manganese complied at all times during the year, but aluminium exceeded benchmark in 25% of samples. This can be attributed to inflow events producing elevated aluminium levels.

5.3.3 Water Filtration Plants

Water is supplied from the Upper Nepean system to three water filtration plants: Macarthur, Nepean and Illawarra (water from these dams is also supplied to Prospect WFP via the Upper Canal System). Routine samples were taken at the inlets of Macarthur (HMAC1), Nepean (HNED) and Illawarra (IWFP-R) WFPs. The results at the inlet point of these three plants are compared with site specific standards (refer to Table 4.2) in Table 5.7 below. Refer to Appendix A2.3 for the statistical summary of the data.

Table 5.7 Upper Nepean system raw water supply - percentage of samples exceeding site specific standards

Location	Site Code	Number of samples	Alkalinity (mgCaCO ₃ /L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Iron Total (mg/L)	Manganese Total (mg/L)	pH	Temperature (Deg C)	Total Hardness (mgCaCO ₃ /L)	True Colour at 400nm	Turbidity (NTU)
Macarthur	HMAC1	12	0	0	0	0	0	0	0	0	0	0
Nepean	HNED	12	0	0	0	0	0	0	0	0	0	0
Illawarra	IWFP-R	12	0	0	0	0	0	17	0	0	0	0

Lake Nepean is the only source of supply for the Nepean WFP. Along with Lake Cordeaux and Lake Cataract it supplies the Macarthur and Prospect WFPs. The Illawarra WFP is supplied exclusively from Lake Avon via the outlet works at Upper Avon. Each of these WFPs is sampled monthly at the inlet to the plant.

Raw water samples taken at the inlet to the Macarthur WFP showed good performance this year. The Raw Water Supply Agreement site specific standards vary for Macarthur WFP depending on flow rates (see Table 4.2 for standards). During 2012-13 samples were collected when flow demand to the WFP were <80 ML/day and 80-125 ML/day, the respective standards for both flow ranges were met on all occasions.

The indicator organism *E. coli* was detected at a maximum of 190 cfu/100 mL in January 2013 following heavy rainfall. The detection was likely to be from runoff within the catchment downstream of Cataract Dam. There are no known pathogen risks in the catchment downstream of the dam.

All samples at the inlet to Nepean WFP complied with the site specific standards in the Raw Water Supply Agreement. Elevated true colour combined with low turbidity during the reporting period resulted in treatment difficulties at Nepean WFP, however true colour remained well within BWSA standards for all routine samples.

The inlet to the Illawarra WFP (supplied from the upper waters of Lake Avon) was generally compliant with the guidelines, but was below the **pH** standards in 17% of samples. This was an improvement since last year, which recorded 42% of samples outside the standards. Raw water is extracted from shallow upper reaches which are affected by inflows, which are typically low in pH and also low alkalinity.

Heavy metals, pesticides and synthetic organic compounds sampled at the inlet to the plants showed 100% compliance with the ADWG. All results were either below the limit of reporting, or well below health guideline values. **Gross alpha** and **gross beta** were not detected at Macarthur, Nepean or Illawarra WFPs.

5.4 Woronora system

Sampling sites in the Woronora system are shown in Figure 5.3 below.

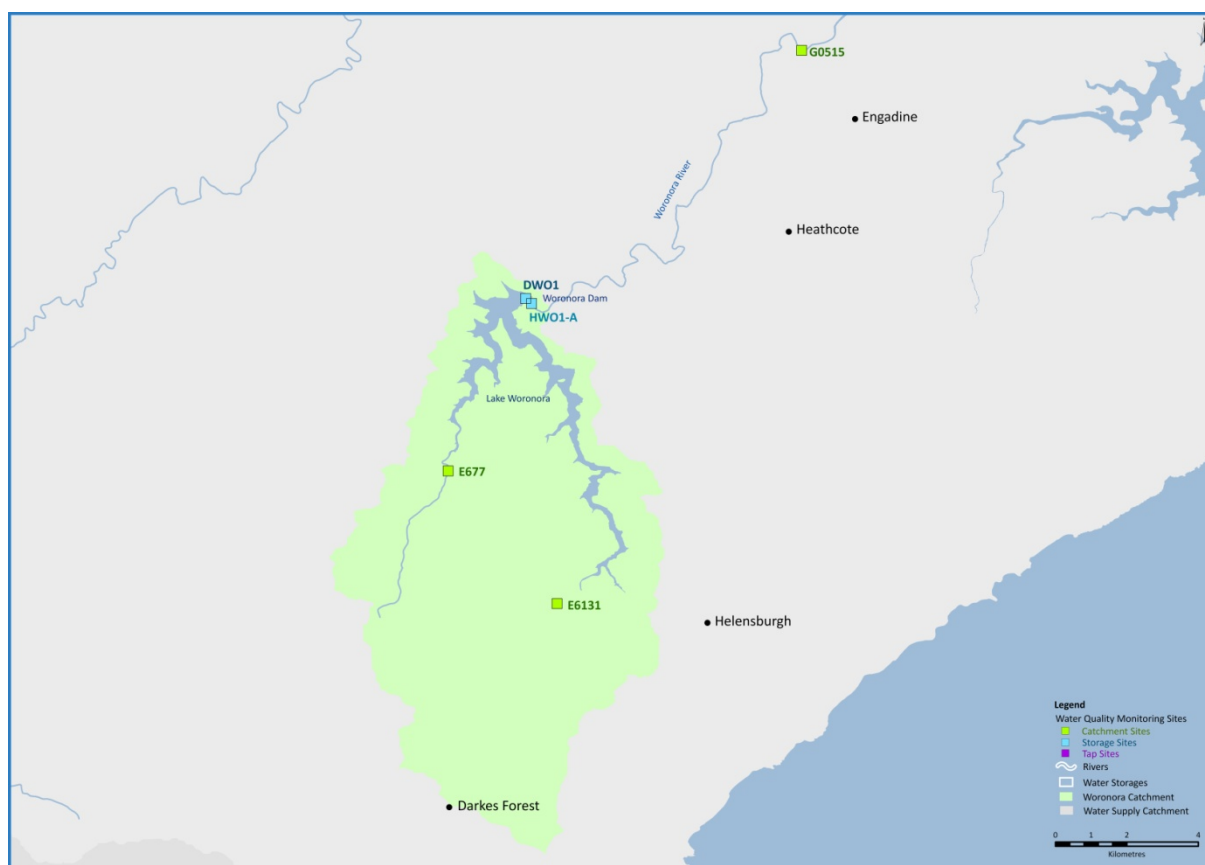


Figure 5.3 Sampling sites in the Woronora system.

5.4.1 Catchments

The Woronora system has two routine sampling sites and one storage sampling site shown in Figure 5.3. The results of catchments sites are compared with benchmarks in Table 5.8 below. Refer to Appendix A3.1 for the statistical summary of the data.

Table 5.8 Woronora system catchments - percentage of samples exceeding benchmarks

Station Code	Flow condition	Number of samples	Dissolved Oxygen (%Sat)	Turbidity Field	pH	Phosphorus Total	Nitrogen Total	Chlorophyll-a
E6131	dry	11	0	0	0	0	0	0
	wet	1	0	0	0	0	0	0
E677	dry	12	33	0	100	0	0	0
	wet	0	NA	NA	NA	NA	NA	NA

The catchment of Lake Woronora is largely native bushland and is jointly managed by the SCA and National Parks. The area is currently experiencing significant mining development (primarily longwall coal mining), which the SCA monitors for any impacts to water quality.

Two sites are routinely monitored:

- Waratah Rivulet (E6131) – inflow location to Lake Woronora
- Woronora River (E677) – inflow location to Lake Woronora.

The pH values in the Woronora River (E677) were below the benchmark. This is likely to be the result of natural catchment processes such as poorly buffered Hawkesbury Sandstone. As in previous years, water quality was consistently good.

5.4.2 Storage

Within the Woronora storage there is one routine monitoring site, DW01, which is 50 m upstream from the dam wall. The results for this site are compared with benchmarks in Table 5.9 below. Refer to Appendix A3.2 for the statistical summary of the data.

Table 5.9 Woronora system storages - percentage of samples exceeding benchmarks

Station Code	Number of samples	Turbidity	pH	Dissolved Oxygen (%Sat)	Phosphorus Total	Nitrogen Total	Aluminium Total	Manganese Total	Chlorophyll-a
DWO1	12	0	25	33	8	0	100	0	0

Median **pH** and **turbidity** were within the benchmark ranges however pH measurements were recorded below the minimum threshold in three samples. This is due to inflows which have naturally low pH. **Dissolved oxygen** levels were high, ranging from 80-110% saturation.

Concentrations of most **nutrients** were low in Lake Woronora during 2012–13. **Chlorophyll-a** remained low as did algal counts.

Total manganese concentrations were low and compliant in 2012-13. **Total aluminium** concentrations exceeded the benchmark on all occasions. The aluminium comes from catchment runoff, streambeds and base flow discharges flowing into Lake Woronora, which are naturally high in this element, particularly during wet weather events. The results are similar to concentrations reported in previous years.

Bacterial water quality was very good, with only low levels of bacterial indicators detected generally following rainfall.

5.4.3 Water Filtration Plant

Lake Woronora is the sole source of supply for the Woronora WFP, with raw water samples being taken from the pipeline supplying the plant (HWO1-A). The results for this site compared with site specific standards (see Table 4.2) in Table 5.10 below. Refer to Appendix A3.3 for the statistical summary of the data.

Table 5.10 Woronora system raw water supply - percentage of samples exceeding site specific standards

Location	Site Code	Number of samples	Alkalinity (mgCaCO ₃ /L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Iron Total (mg/L)	Manganese Total (mg/L)	pH	Temperature (Deg C)	Total Hardness (mgCaCO ₃ /L)	True Colour at 400nm	Turbidity (NTU)
Woronora	HWO1-A	12	0	0	0	0	0	0	0	0	0	0

Consistent with previous years, the samples taken at Woronora WFP were 100% compliant with both site specific standards and ADWG for all analytes. All pesticide and synthetic organic compounds results were below the limit of reporting. **Gross alpha** and **gross beta** were not detected.

5.5 Blue Mountains system

Sampling sites in the Blue Mountains system are shown in Figure 5.4 below.

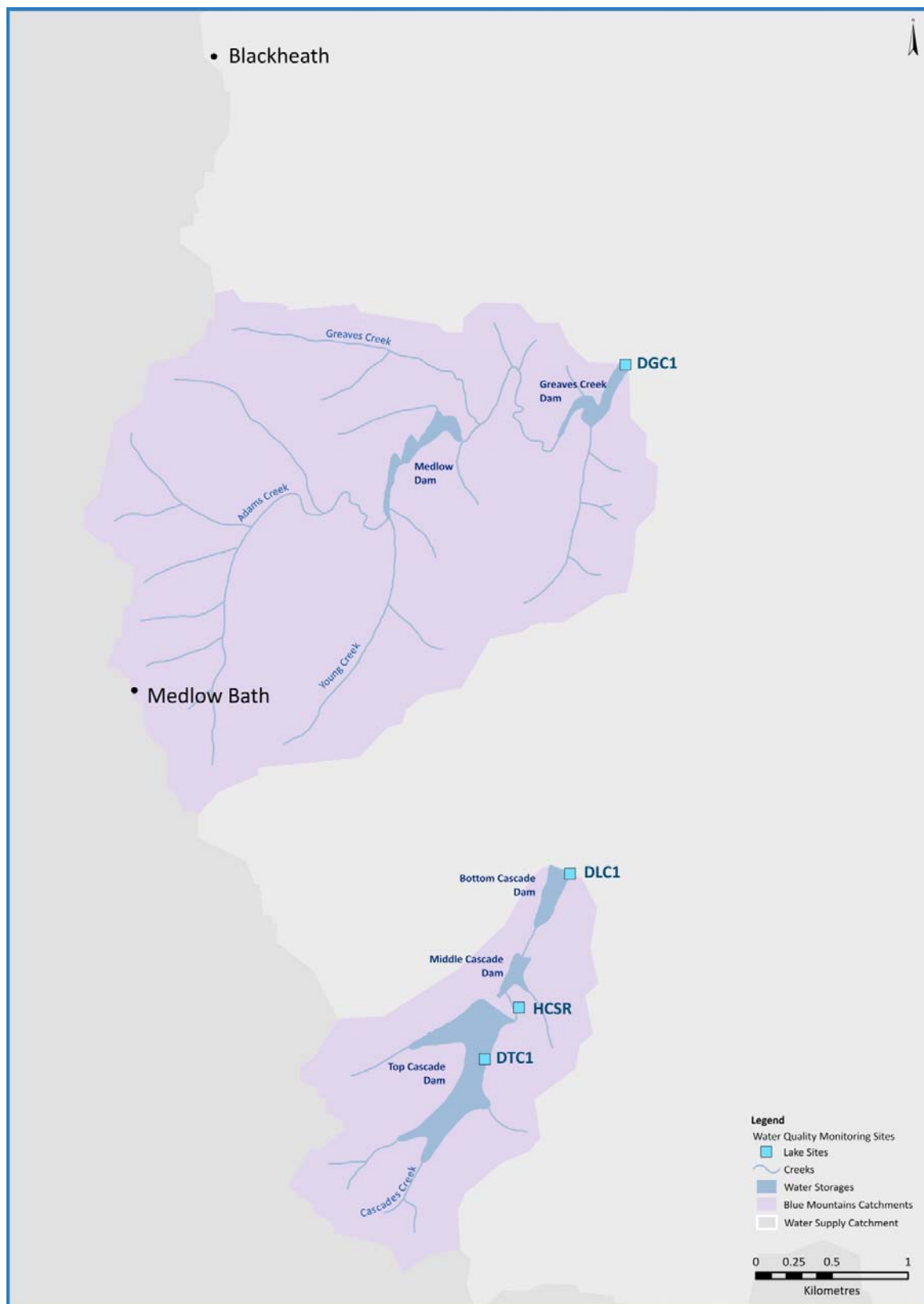


Figure 5.4 Sampling sites in the Blue Mountains system.

5.5.1 Catchments

The Blue Mountains catchments are very small (less than 20 sq km in total) and inflow water quality is represented by water quality in the lakes. There are no routine monitoring sites in the Blue Mountains catchments.

5.5.2 Storages

Lakes Medlow, Lake Greaves, Lower, Middle and Top Cascades make up the group of storages in the Blue Mountains system. Supply to the Blue Mountains system can be supplemented by transferring water from the State Water managed water sources of Oberon Dam or Duckmaloi Weir, located in the Fish River system. There are three routine monitoring sites in the storages (DGC1, DLC1, DTC1). The results for these sites are compared with benchmarks in Table 5.11 below. Refer to Appendix A4.1 for the statistical summary of the data.

Table 5.11 Blue Mountains system storages - percentage of samples exceeding benchmarks

Station Code	Number of samples	Turbidity	pH	Dissolved Oxygen (%Sat)	Phosphorus Total	Nitrogen Total	Aluminium Total	Manganese Total	Chlorophyll-a
Lake Greaves									
DGC1	12	0	83	92	50	0	100	0	10
Lower Cascade									
DLC1	6	0	0	67	0	0	0	0	0
Top Cascade									
DTC1	12	0	0	75	17	0	50	0	13

Lake Greaves

The water quality of Lake Greaves is the same as in previous years and is a reflection of the catchment geology.

Lake Greaves returned water quality values within the benchmark values with the following exceptions for pH, dissolved oxygen and total phosphorus described below.

pH was found to fall outside of the benchmark values on 83% of occasions. All of the exceptions outside of the benchmark were for low (acidic) pH. The median value for pH at Lake Greaves was 5.98 pH units. This is attributed to the lack of buffering potential in the source waters.

Dissolved oxygen failed to meet the benchmark throughout most of the year, with 92% of samples falling outside of the benchmarks. The median value at this site for dissolved oxygen was 86.4% saturation.

Total phosphorus was found to be above the benchmark value in 50% of samples, with a median value of 0.011 mg/L. This is higher than is typical for this storage, but not unexpected in years with significant inflow.

Lower Cascade

Water quality at Lower Cascade was reported within the benchmark values for most analytes, with only dissolved oxygen saturation falling outside of the benchmarks on 67% of sampling occasions. Median value for this analyte was 86.7% of saturation.

Top Cascade

Water quality results in the Top Cascade Lake was generally good, with the only excursions outside of the benchmarks being dissolved oxygen (75% of samples), total phosphorus (17% of samples) and total aluminium (50% of samples), the latter attributed to inflows, and chlorophyll- α in 13% of samples.

5.5.3 Water Filtration Plants

Water from the Blue Mountains system is treated at the Cascades Water Filtration Plant (drawn from Top Cascade Lake). The results at the inlet point (HCSR) of this plant are compared to site specific standards (refer to Table 4.2) are in Table 5.12 below. Refer to Appendix A4.2 for the statistical summary of the data.

Table 5.12 Blue Mountains system raw water supply - percentage of samples exceeding site specific standards

Location	Site Code	Number of samples	Alkalinity (mgCaCO ₃ /L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Iron Total (mg/L)	Manganese Total (mg/L)	pH	Temperature (Deg C)	Total Hardness (mgCaCO ₃ /L)	True Colour at 400nm	Turbidity (NTU)
Cascade	HCSR	12	0	0	0	0	0	0	25	0	0	0

Temperature fell below the lower threshold on 25% of occasions. These temperature failures are unavoidable in the winter months in the Blue Mountains, and non-compliance did not affect treatment. All other analytes conformed with the site specific standards.

Water quality was excellent in relation to health characteristics at the inlet to Cascades WFP, with all **pesticides, heavy metals** and **synthetic organic compounds** returning values within the ADWG.

Gross alpha and **gross beta** were not detected.

5.6 Shoalhaven system

Sampling sites in the Shoalhaven system are shown in Figure 5.5 below.



Figure 5.5 Sampling sites in the Shoalhaven system

5.6.1 Catchments

The Shoalhaven catchment has six routine monitoring sites, as illustrated in Figure 5.5. The summary of exceedances at the catchment sites is summarised in Table 5.13 below. Refer to Appendix A5.1 for the statistical summary of the data.

Table 5.13 Shoalhaven system catchments - percentage of samples exceeding benchmarks

Station Code	Flow condition	Number of samples	Dissolved Oxygen (%Sat)	Turbidity Field	pH	Phosphorus Total	Nitrogen Total	Chlorophyll-a
Kangaroo River								
E706	dry	9	44	0	0	89	78	33
	wet	3	0	0	0	100	100	0
Mongarlowe River								
E822	dry	11	27	0	9	9	9	0
	wet	1	0	0	0	100	100	100
Corang River								
E8311	dry	12	33	0	8	0	8	0
	wet	0	NA	NA	NA	NA	NA	NA
Shoalhaven River								
E847	dry	12	25	0	0	8	17	0
	wet	0	NA	NA	NA	NA	NA	NA
E860	dry	11	0	0	0	82	0	0
	wet	1	0	100	0	100	100	100
E861	dry	10	0	0	0	40	30	40
	wet	0	NA	NA	NA	NA	NA	NA

Shoalhaven Catchment

Covering an area of approximately 4,645 sq km the Shoalhaven River catchment is the largest sub-catchment of Lake Yarrunga. The Shoalhaven River occupies the southernmost extent of the Lake Yarrunga catchment and flows in a northerly direction. Sheep and cattle grazing and native bushland are the predominant land uses.

Three routine water quality monitoring sites are located (in order) on the Shoalhaven River at:

- Mountview (E860) – upper catchment in the Braidwood area
- Hillview (E861) – mid catchment, approximately 10 km downstream of the Mongarlowe River confluence
- Fossickers Flat (E847) – inflow location to Lake Yarrunga.

During the monitoring period 80% of samples recorded phosphorus exceedances at Mountview (E860). Downstream at Hillview (E861) and Fossickers Flat (E847) total phosphorus appears to have attenuated in-stream with fewer exceedances. Less filterable phosphorus was detected than in low flow conditions suggesting the majority was particulate, with nitrogen also being predominately organic.

Total nitrogen exceeded the benchmark in 30% of samples at Hillview (E861) and 17% of samples at Fossickers Flat (E847). Further investigation suggests that the majority of the nitrogen detected was organic nitrogen and is probably from natural sources.

Chlorophyll-*a* exceedances were also noted at Hillview (E861) but not at the other sites. The proportioning of the chlorophyll response into algae species and cell numbers reflects low risk, being represented by a small number of cells but diverse range of algae, diatoms and cyanobacteria. This probably reflects typical runoff conditions and is unlikely to be an ecological concern.

Kangaroo River Catchment

The Kangaroo River catchment is largely cleared for grazing and dairy farming. Increasing urban and residential development has been identified as a potential threat to water quality.

Water quality is measured routinely at:

- Hampden Bridge (E706) – downstream of the Kangaroo Valley township.

As with previous years, nutrients (total nitrogen and total phosphorus) continued to exceed the benchmark values on most sampling occasions. Turbidity exceedances were also recorded in the three wet weather samples. Urban and agricultural run-off combined with red-brown earth soils (naturally high in phosphorus) are thought to be the main nutrient contributors.

The chemical response to the hydrology of this system shows variability. The proportion of nitrogen sub indicators (organic nitrogen and nitrates) ranged from negligible to over 50% of the total nitrogen pool depending upon sample. Total phosphorus exceedances were responsive to increases in filterable phosphorus, suggesting that a base concentration of particulate phosphorus is exported irrespective of flow conditions. This probably reflects variability in rainfall distribution in this catchment. Despite nutrient concentrations consistently exceeding benchmarks, chlorophyll-*a* concentration remained within benchmark and thereby reflects little short term ecological risk in this system.

Mongarlowe River catchment

The Mongarlowe River has a small catchment (approximately 400 sq km) east of Braidwood. The catchment is primarily forested, within National Parks, private conservation and managed forests. About one third of the catchment is cleared for grazing.

Water quality is routinely monitored mid-catchment at:

- Mongarlowe township (E822) – mid catchment, east of the Braidwood township.

Under dry flow conditions only one sample exceeded total nitrogen and total phosphorus benchmarks. The sample was almost completely organic nitrogen and particulate phosphorus, reflecting exports from a relatively undisturbed catchment.

Corang River catchment

The Corang River is a small river with a catchment area of approximately 500 sq km. It joins the Shoalhaven River before continuing on to Lake Yarrunga. A vast majority of the catchment is natural bushland with some small scale grazing in the western downstream sections.

Water quality is routinely monitored at:

- Meengora (E8311) – lower catchment, 2 km upstream from the Shoalhaven River confluence.

Water quality during dry flow was found to be of a high quality, with minor exceedances of dissolved oxygen, pH and chlorophyll-a noted during this reporting period.

5.6.2 Storages

The Shoalhaven catchment drains into Lake Yarrunga, with Fitzroy Falls and Wingecaribee Reservoirs having small catchments of their own. There are five routine sampling sites in these storages, illustrated in Figure 5.5. The results are compared with benchmarks in Table 5.14 below. Refer to Appendix A5.2 for the statistical summary of the data.

Table 5.14 Shoalhaven system storages - percentage of samples exceeding benchmarks

Station Code	Number of samples	Turbidity	pH	Dissolved Oxygen (%Sat)	Phosphorus Total	Nitrogen Total	Aluminium Total	Manganese Total	Chlorophyll-a
Fitzroy Falls Reservoir									
DFF6	12	0	8	0	92	25	83	0	100
Lake Yarrunga - Shoalhaven Arm									
DTA1	12	8	17	50	100	75	100	0	33
DTA5	11	0	0	45	100	36	100	0	36
Lake Yarrunga - Kangaroo Arm									
DTA8	12	0	8	42	100	42	100	0	77
Wingecaribee Reservoir									
DWI1	12	0	0	17	92	17	100	0	95

Lake Yarrunga

Like many other storages, water quality in Lake Yarrunga was negatively impacted by large inflows during the reporting period.

Turbidity was outside of the benchmarks at DTA1 on eight percent of occasions, with the spikes generally corresponding to rain events.

Dissolved oxygen concentrations fell below the ANZECC benchmarks up to 50% of the time at DTA1. The other sites also recorded anoxic conditions in the hypolimnion in a significant number of the profiles taken. Anoxic conditions in the bottom waters of this non-destratified lake are typical.

High **nutrient** concentrations (total nitrogen and phosphorus) were observed throughout the reporting period, with almost 100% of samples exceeding the benchmark for total phosphorus. This reflects the nature of the catchment with agricultural enterprises abundant. Directly related to the high phosphorus concentrations, chlorophyll-*a* concentrations were above the benchmark in between 33% and 77% of samples. The median chlorophyll-*a* concentration recorded at DTA8 was 8.2 µg/L. The highest recorded at DTA8 was 21.3 µg/L.

The high inflow volumes have impacted the **aluminium** concentration at all of the sites in Lake Yarrunga, with nearly all of the samples exceeding the ANZECC benchmark. This is typical for this storage.

Fitzroy Falls Reservoir

Sampling in this reservoir is undertaken at site DFF6 (midlake).

Turbidity results were within the ANZECC benchmark values all year.

The median value for **pH** was 7.65, with only eight percent of samples exceeding the benchmark value.

Phosphorus and **nitrogen** concentrations were elevated in a significant number of samples, with 92% returning a result above the benchmark for phosphorus. Associated with the elevated nutrients the chlorophyll-*a* concentration was above the benchmark level in 100% of samples. The median value for chlorophyll-*a* was 13.84 µg/L, with a maximum of 29.43 µg/L.

Similar to Lake Yarrunga, and most likely impacted from transfers from that storage as well as local runoff from inflows, the total **aluminium** concentration was above the benchmark value in 83% of the samples taken.

Wingecarribee Reservoir

Sampling in Wingecarribee Reservoir is undertaken at DWI1, from the wall near the offtake.

Total phosphorus exceeded the benchmark in 92% of samples, with **total nitrogen** exceeding 17% of the time. Unsurprisingly given the nutrient status of the storage, the chlorophyll-*a* concentration was found to be elevated in 95% of samples.

Total aluminium concentrations also exceeded the benchmark in 100% of samples, while manganese concentrations remained within the benchmark on all occasions.

5.6.3 Water Filtration Plants

Water from the Shoalhaven system is routinely sampled at the inlet point of the Wingecarribee (HWI1) and Kangaroo Valley (HKV1) WFPs. The results are compared to site specific standards (refer to Table 4.2) in Table 5.15 below. Refer to Appendix A5.3 for the statistical summary of the data.

Table 5.15 Shoalhaven system raw water supply - percentage of samples exceeding site specific standards

Location	Site Code	Number of samples	Alkalinity (mgCaCO ₃ /L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Iron Total (mg/L)	Manganese Total (mg/L)	pH	Temperature (Deg C)	Total Hardness (mgCaCO ₃ /L)	True Colour at 400nm	Turbidity (NTU)
Kangaroo Valley	HKV1	13	0	0	0	0	0	0	0	0	0	8
Wingecarribee	HWI1	13	0	0	0	0	0	0	0	0	0	0

Samples taken from the inlet to Wingecarribee WFP showed 100% compliance with both ADWG and site specific standards. Routine samples to Kangaroo Valley WFP also met the guidelines with the exception of turbidity which exceeded the site specific standard on eight percent of occasions.

The foliar herbicide **triclopyr** was detected 10 times out of a total of 12 samples at Wingecarribee, yet all of the detections were well below the guideline value of 0.2 mg/L.

Gross alpha and **gross beta** were not detected.

Significant numbers of indicator bacteria were noted in the samples throughout the year associated with inflow events. These did not adversely affect the quality of the treated water supplied.

5.7 Algal monitoring

The SCA undertakes sampling for algae concurrently with routine catchment and storage monitoring (Section 3.2). For algae, grab samples are collected closer to the water surface for the catchment sites, and depth composite samples in the range of 0-6m are collected for storage sites. In storages with a history of algal activity, seasonal monitoring is conducted between the warmer months of October and May. These sites are monitored at an increased frequency (weekly) to facilitate early detection of emerging algal events. Routine algal monitoring at WFPs is also undertaken.

National Health & Medical Research Council (NHMRC) Guidelines for Managing Risks in Recreational Water (NHMRC, 2008) are used to compare results for catchment and storages. Australian Drinking Water Guidelines (NHMRC, 2011) are used for water supplied for treatment. While the latter applies to drinking water, the SCA uses the same guideline to raw water supplied for treatment as a conservative approach to managing risks.

Reported results consider both routine and seasonal monitoring. Statistical summaries are provided in Appendix A.

5.7.1 Warragamba system

Catchments

Water quality in the Warragamba catchment was satisfactory during 2012-13 in terms of cyanobacteria. All monitoring locations complied with the recreational guidelines for potentially toxin producing cyanobacteria count, toxicity and cyanobacteria biovolume.

Sub-catchments feeding to Kowmung and Kedumba rivers complied with the chlorophyll-*a* criterion of 5 µg/L. Nattai River also complied with the chlorophyll-*a* criterion, except once during wet weather. Sub-catchments feeding to Coxs River, Little River and Werriberri Creek occasionally exceeded the chlorophyll-*a* criterion. Wollondilly River frequently exceeded the chlorophyll-*a* criterion, particularly Wingecarribee River at Berrima Weir exceeded the threshold throughout the year with the peak concentration of 92 µg/L. However, the stipulated guidelines for cyanobacteria count, biovolume or toxicity was not exceeded at any of these Warragamba catchment sites.

Storages

Samples were collected routinely at nine locations in Lake Burragorang during 2012-13. All monitoring locations complied with the cyanobacteria guidelines. Chlorophyll-*a* concentration exceeded 5 µg/L at eight locations on occasions, with the highest result of approximately 13.3 µg/L recorded in the upper reaches. However, the potentially toxin producing cyanobacteria count did not exceed the guidelines. Toxicity analysis was undertaken for only microcystin toxins, which remained below 0.3 µg/L microcystin-LR toxicity equivalents at all locations. The reported population of *Microcystis aeruginosa* remained very low (below 350 cells/mL) compared to the guideline of 6,500 cells/mL and the alert level of 2,000 cells/mL. The peak *Anabaena circinalis* population was below 1,000 cells/mL, compared to the guideline and alert level of 20,000 cells/mL and 6,000 cells/mL respectively.

Among the monitoring locations in the Coxs arm (DWA12, DWA15, DWA19 and DWA21), the peak chlorophyll-*a* concentration was up to approximately 13.3 mg/L. Potentially toxin producing cyanobacteria counts were well below the toxicity analysis threshold of 2,000 cells/mL, hence microcystin toxicity analysis was not undertaken for the samples from the Coxs arm.

The Wollondilly arm reported a peak chlorophyll-*a* concentration of 10 µg/L but *Microcystis aeruginosa* counts did not exceed the toxicity analysis threshold of 2,000 cells/mL. However, an unknown species of *Microcystis* was reported at one location (DWA39) at 4,000 cells/mL in the Wollondilly arm. Toxicity levels remained below the level of detection in the Wollondilly arm during the reporting period.

Potentially toxin producing cyanobacteria counts did not exceed the toxicity analysis threshold in any of the samples from the gorge (DWA2 and DWA9). The peak population of *Microcystis aeruginosa* and unknown species of *Microcystis* were 175 cells/mL and 1,160 cells/mL respectively. The peak *Anabaena circinalis* population was 200 cells/mL. A special sample collected in September 2012 reported a *Microcystis aeruginosa* population of 6,700 cells/mL near the dam wall (DWA2). This appeared to be an anomaly as no *Microcystis aeruginosa* were detected in the samples collected a week before and a week after this sample at DWA2, and the results showed that microcystin toxicity was below the detection limits (<0.3 µg/L).

Prospect Reservoir was used to supply raw water for drinking purposes in 2012-13 when the Upper Canal and Warragamba Pipelines were shut down for maintenance, and during the presence of higher colour in Lake Burragorang and the Upper Nepean system. Prospect Reservoir was monitored extensively at two sites — closer to the raw water pumping station (RPR6) and mid-lake (RPR1). All samples complied with the cyanobacteria guidelines for drinking water. Chlorophyll-*a* concentration exceeded 5 µg/L in less than 40% of the samples, with a peak concentration of 9.6 µg/L. Neither *Microcystis aeruginosa* nor *Anabaena circinalis* were detected but an unknown species of *Microcystis* was detected at a peak concentration of 370 cells/mL. The microcystin toxicity was below the limit of detection.

Water Filtration Plants

Algal monitoring in the raw water supply to Orchard Hills, Warragamba and Prospect WFPs found no ADWG exceedances, with no detections of *Anabaena circinalis*. *Microcystis aeruginosa* was not detected in raw water to Warragamba WFP, but was detected twice at low levels (below 15 cells/mL) at Orchard Hills and Prospect WFPs.

5.7.2 Upper Nepean system

Catchments

Nine catchment stream sites were monitored routinely within the system in 2012-13 in the Upper Nepean catchment. Water quality with respect to the presence of cyanobacteria and its associated impacts in all Upper Nepean catchment streams was satisfactory. All monitoring locations fully complied with the recreational guidelines for potentially toxin producing cyanobacteria count, toxicity and cyanobacteria biovolume. Chlorophyll-*a* concentration exceeded the trigger for additional analyses in all but three sites, twice at each site. Peak chlorophyll-*a* concentration was 6.7 µg/L and 9.6 µg/L respectively at Nepean River (E697) and Cordeaux River (E680), and was 80.5 µg/L at Goondarin Creek (E608). Potentially toxin producing cyanobacteria was not detected at any of these sites.

Storages

Water quality with respect to the presence of cyanobacteria and its associated impacts was satisfactory in all reservoirs in the Upper Nepean system, as all sites complied with the cyanobacteria guidelines. Each routine monitoring location was sampled 12 times throughout 2012-13. All reservoirs reported exceedances of the chlorophyll-*a* guideline of 5 µg/L at least twice, with a peak concentration of 8.5 µg/L.

Chlorophyll-*a* concentration exceeded the 5 µg/L criterion in Lake Avon near the off-take (DAV7) in two of the 12 routine samples, with a peak concentration of 5.6 µg/L. Irrespective of chlorophyll-*a* concentration, unconditional cyanobacteria counting was conducted at DAV7 as stipulated in the water monitoring program for the direct water supply sites. No *Microcystis aeruginosa*, *Anabaena circinalis* cells or microcystin toxins were detected at this monitoring location in 2012-13. Chlorophyll-*a* concentration remained below 5 µg/L near the dam wall (DAV1), hence no further cyanobacteria analysis was undertaken.

In Lake Cordeaux (DCO1) chlorophyll-*a* concentration exceeded the 5 µg/L threshold in four of the 12 routine samples, with a peak concentration of 7.4 µg/L. Only two of the 12 routine samples exceeded 5 µg/L, with a peak concentration of 5.8 µg/L in Lake Cataract (DCA1). Cyanobacteria analysis was undertaken for those samples, and no *Microcystis aeruginosa* or *Anabaena circinalis* cells were reported from Lake Cataract or Lake Cordeaux. In the absence of potentially toxin producing cyanobacteria, toxicity analysis was not required for these samples.

Lake Nepean was monitored near the dam wall at two different locations, as samplers are not permitted in the lake closer to the wall when the dam is spilling. The monitoring was moved from the

routine site (DNE2) to the dam wall (DNE1) in July 2012 and March 2013. Routine samples from both monitoring locations complied with cyanobacteria guidelines. Chlorophyll-*a* concentration exceeded the 5 µg/L in three of the 12 routine samples, with a peak concentration of 8.47 µg/L. Only 34 cells/mL of *Microcystis aeruginosa* cells was recorded in the routine samples and at 153 cells/mL in one of the special samples. *Anabaena circinalis* was not detected in any of these samples. Toxin analysis was not required.

Water Filtration Plants

Water quality at raw water supply sites to Macarthur, Nepean and Illawarra WFPs complied with the cyanobacteria guidelines during 2012-13. Twelve routine samples were collected at Nepean and Illawarra WFPs and 13 samples were collected at Macarthur WFP. *Anabaena circinalis* was not present in any of these samples. *Microcystis aeruginosa* was not detected in Macarthur or Avon samples. Four of the samples from Nepean reported *Microcystis aeruginosa* with a peak value of 310 cells/mL, significantly below the ADWG guideline of 6,500 cells/mL.

5.7.3 Woronora system

Catchments

Water quality with respect to cyanobacteria in the Woronora catchment streams complied with the guidelines in 2012-13. Neither the Waratah Rivulet (E6131) nor Woronora River (E677) exceeded the chlorophyll-*a* trigger of 5 µg/L during the reporting period and as such, required no further analysis.

Storages

Chlorophyll-*a* and cyanobacteria compliance were achieved at all times in Lake Woronora. The peak chlorophyll-*a* concentration was 3.4 µg/L. Unconditional cyanobacteria counting were conducted at DWO1 as stipulated in the Water Monitoring Program for the direct water supply sites. Neither *Anabaena circinalis* nor *Microcystis aeruginosa* species were detected in any of those samples. Cyanobacteria toxin analysis was not required.

Water Filtration Plants

The quality of raw water supplied to Woronora WFP was very good with respect to cyanobacteria, as neither *Anabaena circinalis* nor *Microcystis aeruginosa* species were detected in any of the samples.

5.7.4 Blue Mountains system

Storages

Cyanobacteria monitoring was conducted in the Blue Mountain system at Lower Cascade Reservoir (DLC1), Top Cascade Reservoir (DTC1) and Lake Greaves (DGC1) during 2012-13. Chlorophyll-*a* concentration did not exceed 5 µg/L at Lower Cascade Reservoir during the reporting period, with a peak concentration of 2.6 µg/L. Thirty nine routine samples were collected from Lake Greaves and from Top Cascade Reservoir. In terms of chlorophyll-*a* concentrations, four of the samples from Lake Greaves (peak concentration of 6.2 µg/L) and five samples from Top Cascade (peak concentration of 7.0 µg/L) exceeded the chlorophyll-*a* concentration criterion. No *Microcystis aeruginosa* nor *Anabaena circinalis* were detected and toxicity was below the level of detection on all sampling occasions.

Water Filtration Plants

Water quality at inflow to Cascades WFP was satisfactory with no detections of *Microcystis aeruginosa* or *Anabaena circinalis*.

5.7.5 Shoalhaven system

Catchments

Six routine catchment stream sites were monitored in the Shoalhaven system during 2012-13. All locations complied with the recreational guidelines for potentially toxin producing cyanobacteria count, toxicity and cyanobacteria biovolume.

One third of the routine samples from Kangaroo River (E706) exceeded chlorophyll-*a* benchmark of 5 µg/L during the reporting period. Of the five sampling locations in the sub-catchments draining to the Shoalhaven River, four locations (E822, E8311, E847 and E860) never exceeded the chlorophyll-*a* threshold of 5 µg/L during the reporting period. Samples collected at Hill View in the Shoalhaven River (E861) exceeded the chlorophyll-*a* threshold of 5 µg/L in 40% of samples, with a peak concentration of 7.5 µg/L. Cell counting was undertaken nine times at these sites during this period and potentially toxin producing *Microcystis aeruginosa* or *Anabaena circinalis* cyanobacteria species were not detected.

Storages

Water quality in Lake Yarrunga, Wingecarribee Reservoir and Fitzroy Falls Reservoir was satisfactory in terms of cyanobacteria in 2012-13 as all monitoring locations complied with the guidelines for potentially toxin producing *Microcystis aeruginosa* or *Anabaena circinalis* cyanobacteria count, toxicity and cyanobacteria biovolume. Wingecarribee Reservoir directly supplies raw water for drinking purposes and the results were within drinking water guidelines.

Lake Yarrunga was monitored at three locations during the reporting period. Chlorophyll-*a* concentration exceeded 5 µg/L at all locations during 2012-13. The Shoalhaven Arm (DTA5) and Dam

Wall (DTA1) exceeded the benchmark for chlorophyll-*a* four times, with peak values of 8.0 µg/L (out of 11 samples) and 6.8 µg/L (out of 12 samples) respectively. Thirty eight routine samples were collected at DTA8 during the reporting period, and 77% of the samples exceeded the benchmark for chlorophyll-*a*, with a peak value of 23.7 µg/L. *Microcystis aeruginosa* or *Anabaena circinalis* cells were not detected any of these samples. However, an unknown species of *Microcystis* was reported once at approximately 1,500 cells/mL during 2012-13.

Chlorophyll-*a* concentration exceeded 5 µg/L in most of the routine samples collected from Wingecarribee Reservoir (DWI1: 37 out of 38) and Fitzroy Falls Reservoir (DFF6: 12 out of 12) in 2012-13. The peak concentration exceeded 20 µg/L, with 23.7 µg/L in Wingecarribee Reservoir and 29.4 µg/L in Fitzroy Falls Reservoir. All samples were analysed for algae/cyanobacteria abundance and toxicity. The reported peak *Microcystis aeruginosa* population was very low (140 cells/mL) for Wingecarribee Reservoir. *Anabaena circinalis* was reported in three samples in Wingecarribee Reservoir, with a very low peak population of 480 cells/mL. *Microcystis aeruginosa* was not detected but an unknown species of *Microcystis* was reported in a number of samples with a peak population of 2,600 cells/mL. In Fitzroy Falls Reservoir *Microcystis aeruginosa* was reported at very low level (140 cells/mL), but *Anabaena circinalis* was not present. Microcystin toxicity was not detected in Wingecarribee Reservoir. Toxin analysis was not undertaken for Fitzroy Falls Reservoir samples.

Of thirty eight routine samples from Bendeela Pondage (DBP1), nearly 90% exceeded the chlorophyll-*a* benchmark of 5 µg/L, with a peak concentration of 42.7 µg/L. A very low peak population of 40 cells/mL of *Microcystis aeruginosa* and a population of 1,660 cells/mL of an unknown species of *Microcystis* were reported. Microcystin toxicity analysis was undertaken for all samples, but reported results below detection limit.

Water Filtration Plants

Water quality of raw water supplied to Kangaroo Valley and Wingecarribee WFPs complied with the cyanobacteria guidelines and did not require toxicity analysis due to very low algal cell counts. Neither *Microcystis aeruginosa* nor *Anabaena circinalis* cells were detected in any of these samples. An unknown species of *Microcystis* was detected at low level in the raw water to Kangaroo Valley (290 cells/mL) and Wingecarribee (530 cells/mL). Toxin analysis was not required.

5.8 *Cryptosporidium* and *Giardia* monitoring

Routine monitoring is undertaken in catchments, storages and delivery networks at varying frequencies as agreed between the SCA, Sydney Water and NSW Health. Statistical summaries are provided in Appendix A.

5.8.1 Catchments

Monitoring for *Cryptosporidium* and *Giardia* is undertaken at eight selected streams in the Warragamba catchment as part of an ongoing pathogens program. The sampling schedule is monthly, except for Werriberri Creek (E531) which is weekly.

Cryptosporidium oocysts were detected at low concentrations (up to 5 oocysts IFA/10L) at four sites: Kowmung River (E130), Werriberri Creek (E531), Nattai River (E210) and Little River (E243), and slightly higher (up to 11 oocysts IFA/10L) at Coxs River (E083). Overall, oocysts were detected in 14% of samples from all sites (excluding Gibbergunyah Creek E203). In contrast, as in previous years, Gibbergunyah Creek (E203) registered the greatest *Cryptosporidium* content (92% of samples with up to 440 oocysts IFA/10L).

Giardia was once again most common at Gibbergunyah Creek (E203), being detected in all samples. The median concentration of *Giardia* observed at this site was 22 cysts IFA/10L with a maximum of 135 cysts IFA/10L. *Giardia* cysts were detected infrequently at the other sites and when cysts were detected in the Kowmung, Kedumba, Nattai, Wollondilly rivers and Werriberri Creek they were at low concentrations (up to 4 cysts IFA/10L).

Special testing found that 100% of *Cryptosporidium* oocysts and *Giardia* cysts present at Gibbergunyah Creek (E203) are non-infectious and do not pose a health risk despite the comparatively high IFA oo(cyst) counts. The Gibbergunyah Creek monitoring site is located downstream of the Braemar STP effluent discharge point. Like most STPs in the catchment, Braemar STP has been upgraded to include UV disinfection. UV disinfection works by affecting the DNA of microorganisms so that they cannot reproduce. In the case of *Cryptosporidium* which has a robust cell wall, the inactivated oocysts still remains present in the effluent stream, but are essentially dead as they are no longer able to cause infection.

5.8.2 Storages

Routine monitoring was conducted six days per week at one lake site (DWA2) in Lake Burragorang, twice weekly at two sites (RPR1 and RPR6) in Prospect Reservoir, and weekly at one site (DWI1) in Wingecarribee Reservoir. (Oo)cysts did not exceed the alert level at any of the lake sites during 2012-13. Both *Cryptosporidium* and *Giardia* were detected infrequently and at low concentrations in these samples. *Cryptosporidium* was detected in 0.6% of samples from DWA2 (up to 2 oocysts IFA/10L) and two percent and three percent of samples from RPR1 and RPR6, respectively (up to 7 oocysts IFA/10L). *Giardia* was detected in 0.3% of samples from DWA2 (1 cyst IFA/10L) and four to six percent of samples from the other three sites (up to 4 cysts IFA/10L). The results are detailed in Appendix A.

5.8.3 Water Filtration Plants

A joint monitoring program in raw water at the water filtration plants is undertaken by Sydney Water and results are provided to the SCA and NSW Health for:

- Macarthur WFP (MACSP1A)
- Prospect WFP (composite sample)
- Nepean, Illawarra, Woronora and Cascade WFP composite (COMP16).

The Prospect WFP sample is a composite of the sources supplying raw water. Approximately 93% and 95% of samples were below the level of detection for *Cryptosporidium* and *Giardia* respectively. Most of the (oo)cysts were at very low concentrations, except for an exceptional composite sample on 21 March 2013 in which *Cryptosporidium* was detected at a concentration of 10.2 IFA/10L adjusted for laboratory recovery. As per the protocol, the component samples were analysed but no (oo)cysts were detected in any of the components. The Upper Canal (HPR1) was a component of the Prospect composite sample on 275 occasions during the year. *Giardia* was detected in 8 (2.9 %) of samples and *Cryptosporidium* in 2 (0.7 %) of these samples.

Pathogen concentrations were below the limit of detection for the vast majority of Macarthur WFP samples. *Cryptosporidium* was detected in three of 52 samples at concentrations ranging from approximately 2–3 oocysts IFA/10L. *Giardia* was detected in two of 52 samples at a concentration of approximately 3 cysts IFA/10L. Similarly, *Cryptosporidium* and *Giardia* were rarely detected and at low concentration from COMP16 samples. *Cryptosporidium* and *Giardia* were each detected in a single sample at a concentration of approximately 2 (oo)cysts IFA/10L.

5.9 Picnic area monitoring

Routine monitoring is undertaken at Avon, Cataract, Cordeaux and Fitzroy Falls picnic area taps where drinking water is supplied directly from the storages after chlorination. The results from picnic area monitoring are compared with applicable guidelines (Section 4.7) and are presented in Table 5.16 below. Refer to Appendices A2.4 (Upper Nepean) and A5.4 (Fitzroy Falls) for the statistical summaries of the data.

Table 5.16 Picnic areas - percentage of samples exceeding benchmarks.

Station Code	Number of samples	pH	Iron Total	<i>E. coli</i>	Aluminium Total	Manganese Total	Turbidity	Chlorine Residual	Chlorophyll-a	Toxic Cyanobacterial Count*	Microcystin LR equivalent*
HAV3	52	0	0	2	2	0	0	87	0	NA	NA
HCA1	52	2	100	2	0	14	0	63	0	NA	NA
HCO6	52	0	51	2	6	18	4	87	0	NA	NA
HFFR	51	0	0	2	2	0	0	92	0	NA	NA

* The Table 5.16 has no data for toxic cyanobacteria count or Microcystin as the chlorophyll- α triggers did not warrant algal monitoring.

The turbidity at all of the picnic taps was generally very low, with median turbidity being <1 NTU at all four sites. The Cordeaux picnic tap (HCO6) exceeded the aesthetic guideline on four percent of samples. These exceedances were from two sample occasions where a maximum turbidity of 16.1 NTU was recorded. On both of these occasions the samples also recorded a high chlorine residual, high total iron and high total manganese concentrations, which is likely to have contributed to the elevated turbidity.

The NHMRC (2011) has the aesthetic guideline for total iron set at 0.3 mg/L. The Cataract picnic tap exceeded this on 100% of samples, with the median result being 0.62 mg/L. The Upper Nepean catchments, in particular the Cataract catchment, have high levels of naturally occurring iron. The median concentration in the Cataract River (E609) is 0.79 mg/L, which contributed to the iron concentrations recorded within Lake Cataract and the picnic tap. The Cordeaux picnic tap (HCO6) also recorded poor compliance with a median total iron of 0.31 mg/L. There were no issues reported by consumers in regards to the quality of water supplied at the picnic areas.

Guidelines for total manganese were met on all occasions at Avon picnic tap (HAV3) and Fitzroy Falls picnic tap (HFFR). Compliance at Cataract and Cordeaux was poorer, exceeding the aesthetic guideline in 14% and 18% of samples respectively. The health guideline of 0.5 mg/L was exceeded on two occasions at the Cordeaux picnic tap. Subsequent sampling on both occasions revealed considerably lower concentrations of manganese.

Total aluminium remained below the benchmark value at the Cataract picnic tap. Compliance was slightly poorer at the remaining three picnic taps, although the median concentrations were low

ranging from 0.02 mg/L at both Avon and Cordeaux picnic taps and 0.09 mg/L at Fitzroy Falls picnic tap.

E. coli should not be detected in drinking water supplies. All four sites recorded exceedances on two percent of samples (one sampling event), recording a maximum of one *E.coli* organism/100 mL during each detection. As per the Water Safety Plans for the picnic areas, the reticulation system was flushed and resampled with no detections. NSW Health was notified of the result and action taken. There were no issues reported by consumers in regards to the quality of water supplied at the picnic areas.

The guidelines recommend a residual free chlorine concentration of 0.2-0.5 mg/L after a contact time of 30 minutes for adequate disinfection. Chlorine dosing and contact time are appropriate at the dosing plants, however there was poor compliance to these values at the picnic area taps, largely due to water age in the distribution system. The median chlorine residual concentrations for Cordeaux, Avon and Fitzroy picnic areas were outside of this recommended range, with only Cataract recording an appropriate median of 0.3 mg/L. The Fitzroy Falls picnic tap generally recorded chlorine residual above the upper limit, recording a median of 0.87 mg/L, with 92% of samples higher than 0.5 mg/L. Conversely, the Cordeaux, Cataract and Avon picnic taps were more likely to breach compliance with a result below the 0.2 mg/L threshold. Water safety plans for the picnic areas are being reviewed, including the options to improve chlorine residual at the picnic taps.

5.10 Dam seepage monitoring

Chemical monitoring of seepage waters is conducted at the SCA dams to:

- determine the origin and/or path of leakage/seepage in the dam
- assess concrete degradation
- assess dispersive behaviour and erodability of embankment and foundation soil.

The dams sampled for chemical analysis of seepage waters this year were Avon, Cataract, Cordeaux, Nepean, Prospect, Tallowa, Warragamba, Wingecaribee and Woronora. All of these dams are tested annually.

Prospect and Wingecaribee dams are tested for a variety of metals, particularly their sodium absorption ratio. Metals testing is also conducted at Avon, Cataract, Cordeaux, Nepean, Tallowa, Warragamba and Woronora dams, with net calcium levels the key indicator of concrete degradation at these dams.

A site upstream in the storage is tested at all dams to provide a control point. A variety of sites downstream at these dams are also tested. For example, net levels of calcium (i.e. calcium levels at the test site minus calcium levels in the storage water) are included in an equation to determine concrete degradation rates.

No safety concerns (relating to chemical monitoring or concrete degradation) were identified for any dams during 2012-13.

6 Monitoring for the Water Licence

The SCA's Water Licence requires environmental flows to be released from storages to maintain the ecological health of downstream rivers. The SCA continued to comply with its Water Licence in 2012-13.

6.1 Water quality

Rivers downstream of the storages are routinely monitored at 17 sites. The results are compared against benchmarks (see section 4.6) in Table 6.1 below (refer to Appendix A6 for the data). Results of downstream storage monitoring are reported periodically to NSW Office of Water in accordance with Water Licence requirements.

Table 6.1 Downstream of storages - percentage of samples exceeding benchmarks

Station Code	Number of samples	Turbidity Field	pH	Dissolved Oxygen (%Sat)	Phosphorus Total	Nitrogen Total	Chlorophyll-a
E303	38	N/A	N/A	N/A	N/A	N/A	95
E851	12	0	8	50	8	8	17
G0515	12	0	67	75	0	0	0
N14	12	0	0	33	0	25	100
N21	12	0	0	33	0	17	100
N35	12	0	0	50	8	67	100
N42	11	0	9	36	9	18	100
N44	12	0	0	33	0	58	92
N57	12	0	0	50	0	25	75
N64	11	0	0	27	0	55	45
N67	12	8	0	17	17	58	83
N75	12	8	0	17	0	42	75
N85	12	8	0	33	8	17	33
N86	12	0	0	25	0	0	0
N881	12	0	0	8	0	0	0
N92	12	0	0	42	0	17	8

Hawkesbury-Nepean River downstream of the storages is routinely monitored at 11 sites, from the Nepean River at Maldon Weir (N92) to the Hawkesbury River at Wisemans Ferry (N14). Sites on the Woronora River at the Needles (G0515) and downstream of Tallowa Dam (E851) are also monitored. The Wingecarribee River at Sheepwash Bridge (E303), located below the Wingecarribee Reservoir, is only monitored for algae.

The Wingecarribee River (E303) had poorer chlorophyll-*a* compliance during 2012-13 with 95% of samples exceeding the benchmark, compared to 33% in 2011-12. There were no issues with algae recorded in the Wingecarribee River.

The results for the Woronora River (G0515) showed that the physicochemical parameters pH and dissolved oxygen sometimes fell outside the recommended benchmarks. All other analytes were within the benchmarks on all occasions.

Along the Hawkesbury-Nepean River there were a number of sites where chlorophyll-*a* values were above the benchmark. All four sites on the Hawkesbury River (N14, N21, N35 and N42) recorded higher values than the recommended benchmark of 5 µg/L at sites on all sampling occasions. Chlorophyll-*a* is used as an indicator of plant biomass and a non-specific indicator of the trophic status of a water body. An increase in chlorophyll-*a* can denote an increase in algae which may result in low levels of dissolved oxygen and negatively affect ecosystem health. The dissolved oxygen values at these four sites were at times outside the benchmark range, however the median values were all within the recommended range.

The sites downstream in the Hawkesbury River had poor water quality. This is likely to be the result of land use in this area, which is particularly high in nutrients. Potential sources of nutrients include runoff from fertilised grass and croplands, failing septic systems, runoff from animal manure and storage areas, and industrial discharges. The Hawkesbury River at Windsor (N35) had comparatively poorer water than other downstream sites, with values for dissolved oxygen, total nitrogen and chlorophyll-*a* outside the benchmark limits more than 50% of the time. There were improvements in nutrients (total phosphorus and total nitrogen) compliance at this site, particularly phosphorus, recording only eight percent of samples above the benchmark in 2012-13 compared to 58% in 2011-12. The total phosphorus median and maximum at Windsor (N35) were 0.032 mg/L and 0.063 mg/L respectively, much higher than the respective median and maximum at Lake Burragorang (DWA2) which recorded 0.011 mg/L and 0.025 mg/L.

The upper limit of the benchmark set for turbidity is relatively high (50 NTU). Three sites recorded a small percentage of samples (eight percent) above this level. A maximum of 71 NTU was recorded at Nepean River at Sharpes Weir (N75), with a median of 4.7 NTU. Given the wet weather events experienced during the year, these compliance and median values are all acceptable results for river systems.

Water quality at Upper Nepean sites, Pheasants Nest (N86) and Broughtons Pass (N881) was excellent. Broughtons Pass achieved the best overall compliance in the downstream river sites. Dissolved oxygen was the only analyte which did not achieve full compliance at Broughtons Pass. This was due to one sampling event (eight percent) which recorded elevated dissolved oxygen at 111% saturation, slightly above the 110% saturation benchmark.

6.2 Water quantity

Above average rainfall was experienced in 2012-13 resulting in spills from some dams. Annual inflows into lakes Nepean, Yarrunga (Tallowa Dam) and Burragorang (Warragamba Dam) for last 17 years is compared with mean and medians in Figure 6.1 below.

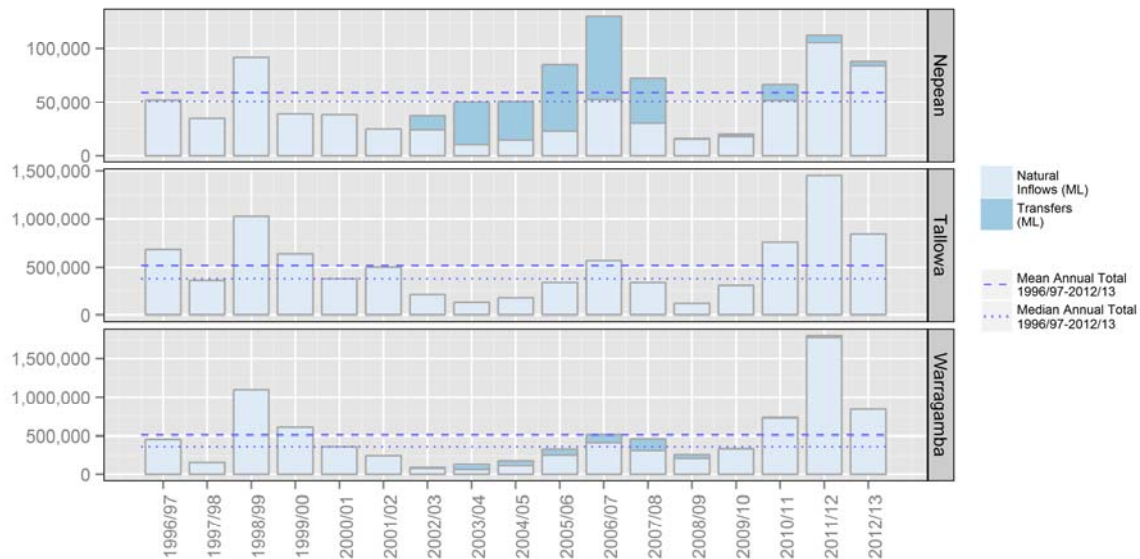


Figure 6.1 Annual inflows into Lake Nepean, Lake Yarrunga (Tallowa) and Lake Burragorang (Warragamba) since 1996-97

Environmental release requirements for Woronora, Cataract, Cordeaux, Avon, Nepean, Broughtons Pass, Pheasants Nest and Tallowa are calculated as a function of inflows on a daily basis. There is a fixed environmental flow for Wingecarribee Reservoir.

Quantities released and spilled are shown in Figures 6.2 – 6.9.

6.2.1 Upper Nepean system

Cataract Dam

Figure 6.2 below shows environmental flow releases and spills from Cataract Dam.

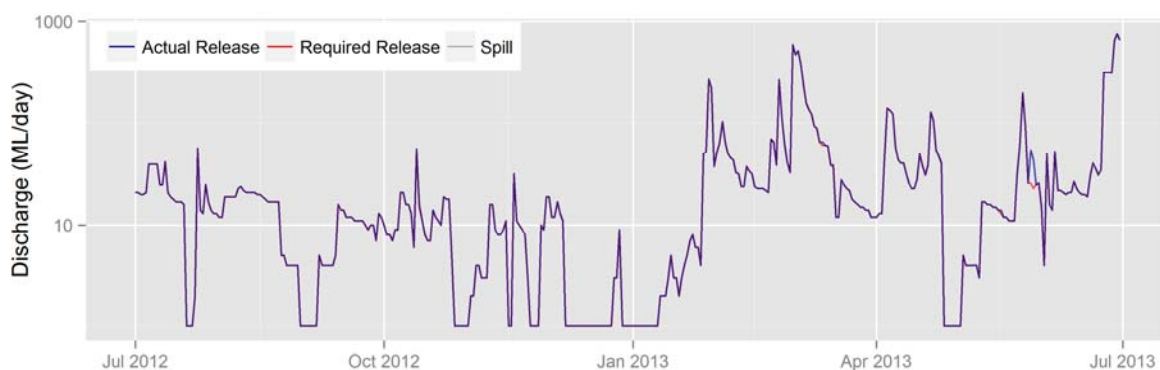


Figure 6.2 Environmental releases and spills – Cataract Dam

Approximately 13,600 ML was discharged as environmental flows from Cataract Dam in 2012-13. The releases ranged from a minimum of 1 ML/d up to 755 ML/d in June 2013. The average release over the 12 months was 37 ML/d.

There were no spills from Cataract Dam during 2012-13.

Cordeaux Dam

Figure 6.3 below shows environment flow releases and spills from Cordeaux Dam.

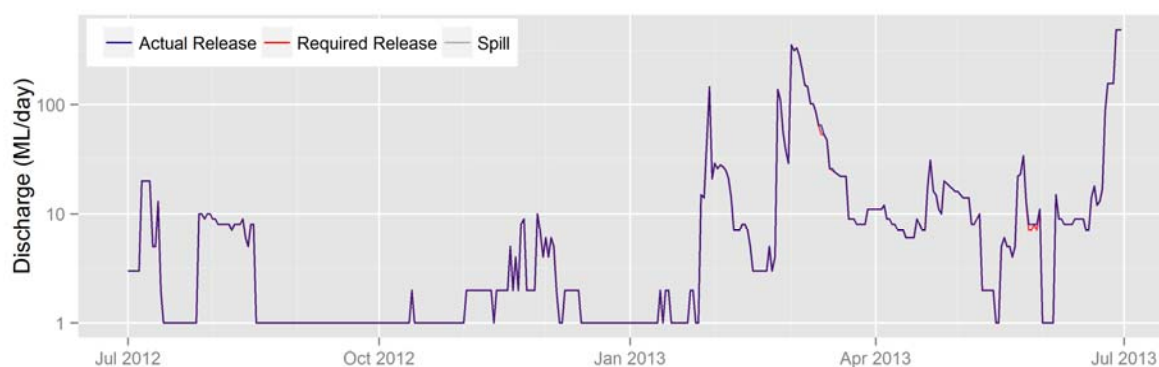


Figure 6.3 Environmental releases and spills – Cordeaux Dam

Approximately 6,800 ML was discharged as environmental flows from Cordeaux Dam in 2012-13. The releases ranged from a minimum of 1 ML/d up to 485 ML/d in June 2013. The average release over the 12 months was 19 ML/d.

There were no spills from Cordeaux Dam during 2012-13.

Avon Dam

Figure 6.4 below shows environmental flow releases from Avon Dam.

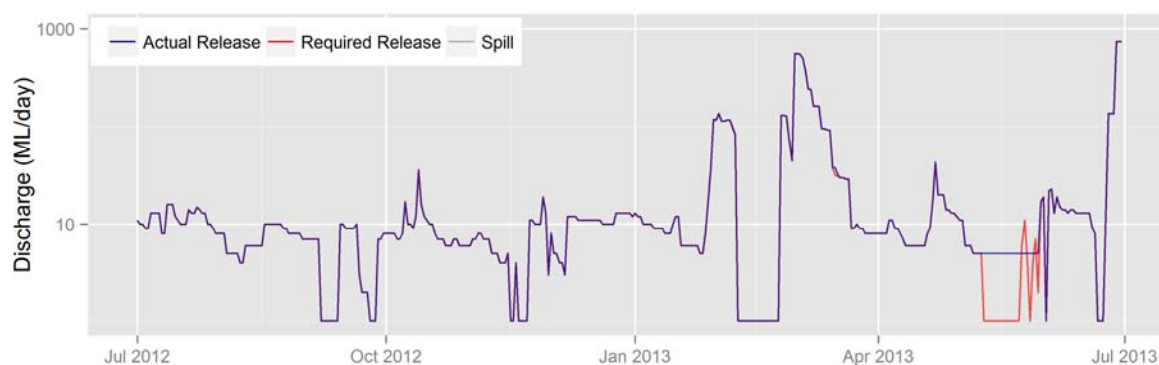


Figure 6.4 Environmental releases and spills – Avon Dam

Approximately 11,000 ML was discharged as environmental flows from Avon Dam in 2012-13. The releases ranged from a minimum of 1 ML/d up to 742 ML/d in June 2013. The average release over the 12 months was 30 ML/d.

There were no spills from Avon Dam during 2012-13.

Nepean Dam

Figure 6.5 below shows the environmental flows releases and spills from Nepean Dam.

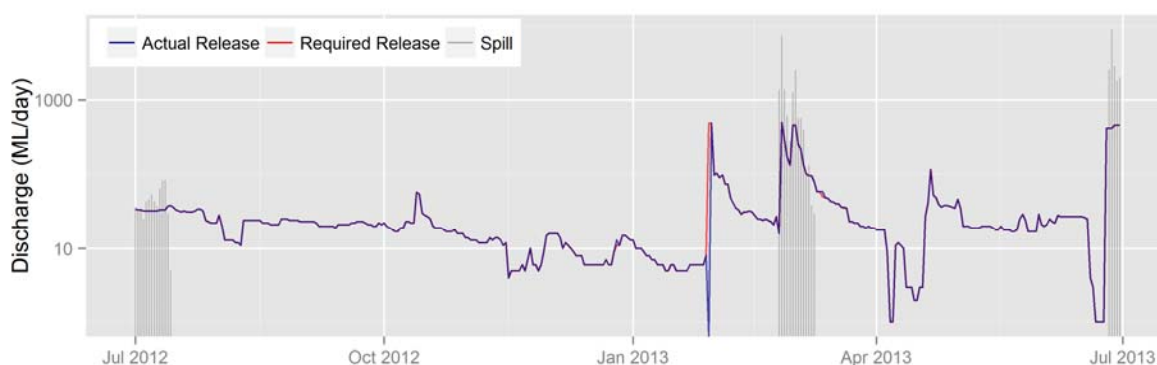


Figure 6.5 Environmental releases and spills – Nepean Dam

Approximately 13,400 ML was discharged as environmental flows from Nepean Dam in 2012-13. The releases ranged from a minimum of 0 ML/d up to 494 ML/d in February 2013. The average release over the 12 months was 37 ML/d.

In addition to environmental flow releases approximately 35,000 ML was recorded as spill during 2012-13 with a peak discharge of 8,941 ML/d in June 2013.

Broughtons Pass Weir

Figure 6.6 below shows the environmental flow releases from Broughton Pas Weir.

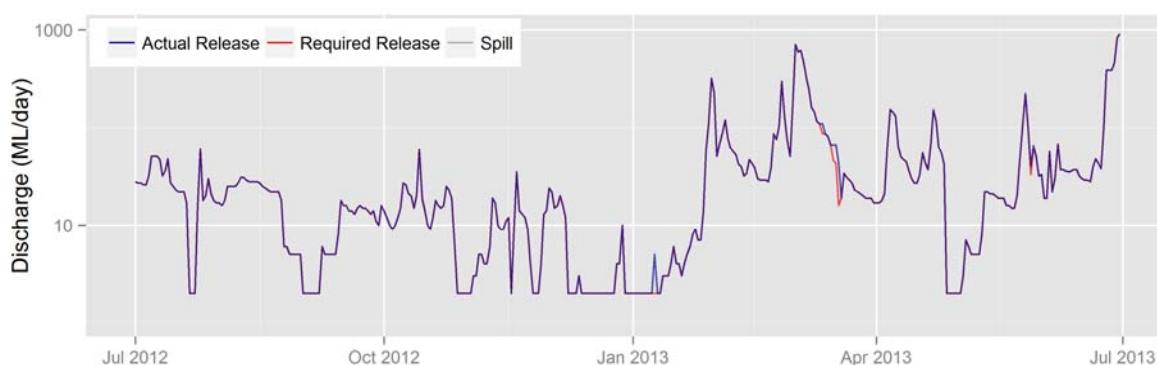


Figure 6.6 Environmental releases – Broughtons Pass Weir

Approximately 16,000 ML was discharged from Broughtons Pass Weir as environmental flows in 2012-13. The discharge ranged from a minimum of 2 ML/d up to 911 ML/d in June 2013. The average discharge (including spill) over the 12 months was approximately 46 ML/d.

Pheasants Nest Weir

Figure 6.7 below shows the environmental releases from Pheasants Nest Weir.

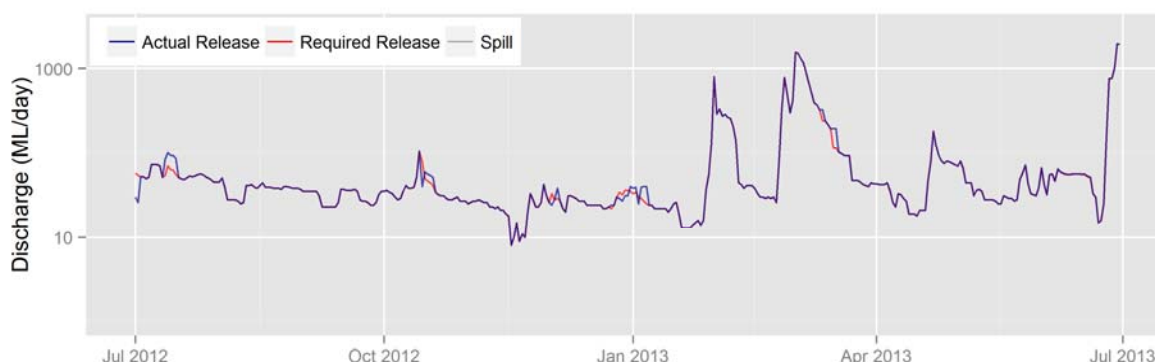


Figure 6.7 Environmental releases – Pheasants Nest Weir

Approximately 34,700 ML was discharged from Pheasants Nest Weir as environmental flows in 2012-13. The discharge ranged from a minimum of 8 ML/d up to 1,999 ML/d in June 2013. The average discharge including spills over the 12 months was approximately 95 ML/d.

6.2.2 Woronora system

Woronora Dam

Figure 6.8 below shows the environmental releases from Woronora Dam.

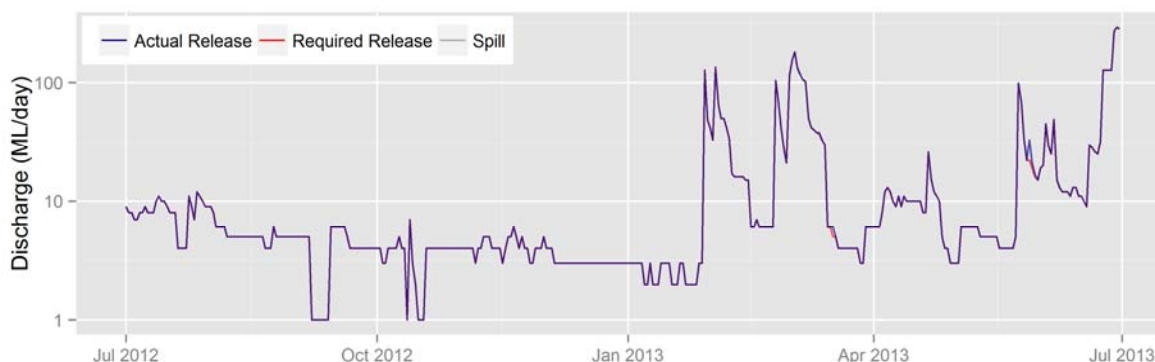


Figure 6.8 Environmental releases and spills – Woronora Dam

Approximately 5,800 ML was discharged as environmental flows from Woronora Dam in 2012-13. The releases ranged from a minimum of 1 ML/d up to 292 ML/d in June 2013. The average release over the 12 months was 16 ML/d.

There were no spills recorded from Woronora during 2012–13.

6.2.3 Shoalhaven system

Tallowa Dam

Figure 6.9 shows the environmental flow release and spills from Tallowa Dam.

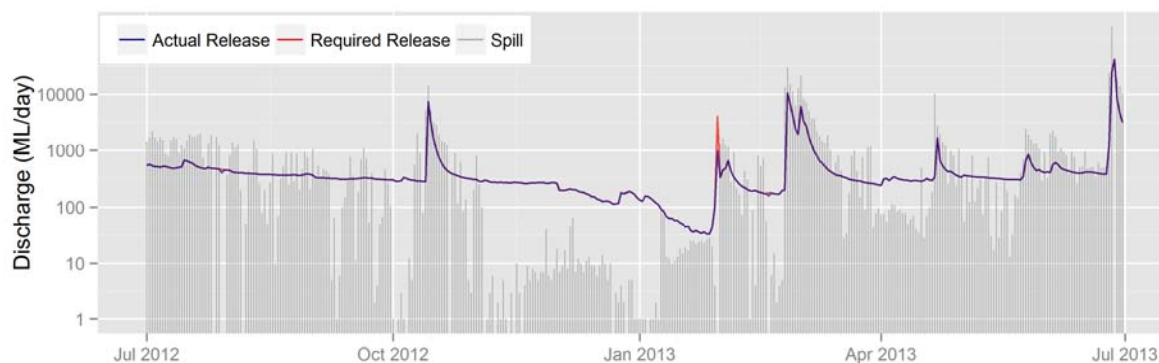


Figure 6.9 Environmental releases and spills – Tallowa Dam

Approximately 251,000 ML was discharged as environmental flows from Tallowa Dam in 2012-13. The average release over the 12 months was 689 ML/d.

In addition to environmental flow releases approximately 560,000 ML was recorded as spill over the period with a peak discharge of around 161,000 ML/d in June 2013.

6.3 Thermal impacts of environmental releases

Water released from storages can often be significantly warmer or cooler than downstream systems due to the depth of offtake, thermal stratification and greater thermal mass. Large releases of thermally disparate waters into downstream systems can significantly impact on downstream riverine systems by disrupting the migration of fish and altering macroinvertebrate assemblages. To assess the effect of environmental releases made along natural watercourses, water temperature is measured (at 15 minute intervals) at a number of locations downstream of SCA storages.

Except for Tallowa and Avon, water released as environmental flows came from the outlets in the dam walls set for water supply for treatment.

While the SCA endeavours to provide the highest quality water for environmental flows, system configuration precludes diversion specifically for environmental flow in the Upper Nepean storages. As such, all Upper Nepean environmental flows are sourced from offtake depths determined to provide the highest quality water for human consumption.

To determine potential thermal impacts, the temperature of storage inflows and environmental releases for the reporting period are compared. In this instance, storage inflows provide a measure of expected water temperatures under natural conditions. Downstream temperatures are taken from the immediate downstream hydrometric stations.

Only systems with environmental flow requirements are presented, namely the Upper Nepean, Woronora and Shoalhaven systems.

6.3.1 Upper Nepean system

The Upper Nepean system comprises the Avon, Cataract, Cordeaux and Nepean catchments, all of which are subject to environmental releases.

Daily temperature data was recorded at the following SCA hydrometric stations, representing reference catchment conditions:

- Avon catchment – Avon River at Summit Tank
- Cataract catchment – Cataract River at Corrimal
- Cordeaux catchment – Sandy Creek at Fire Road 15
- Nepean catchment – Nepean River at Nepean Dam inflow.

Downstream water temperature was recorded at Menangle Weir on the Nepean River. This represents the first hydrometric station after the confluence of all Upper Nepean Storage releases. The station is approximately 20 km downstream of Lake Cataract.

As shown in Figure 6.10 downstream temperatures at Menangle Weir are consistently higher than the inflow reference temperatures, indicating no persistent downstream cold water impacts as a result of environmental releases. Furthermore, downstream temperatures and reference temperature profiles exhibit similar small scale changes and seasonal trends. Reference temperatures display greater small scale variability resulting from their smaller flow.

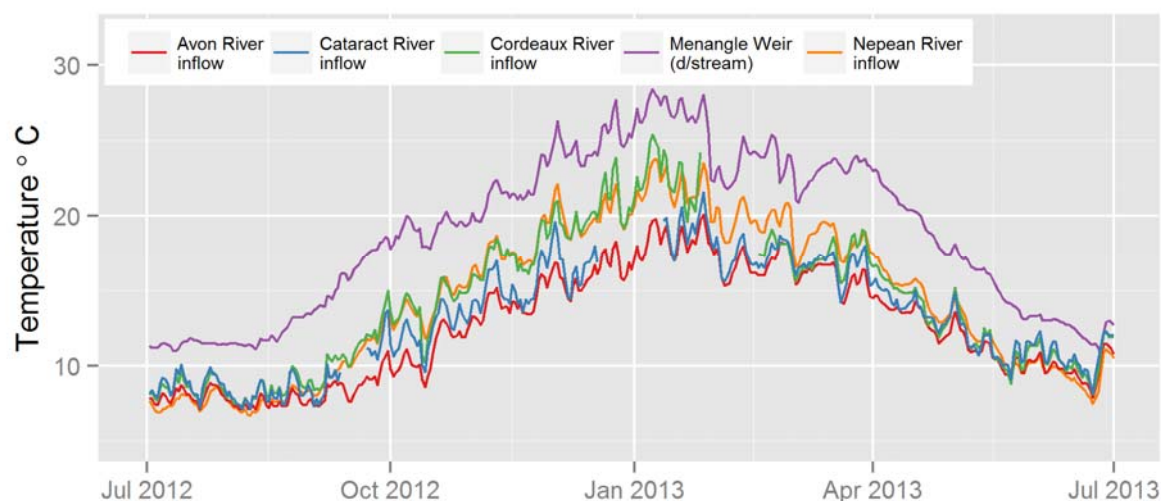


Figure 6.10 Upper Nepean system temperature profile

6.3.2 Woronora system

As with the Upper Nepean storages, the system configuration at Lake Woronora does not support offtakes specifically for environmental releases. As a result, environmental releases may be significantly cooler than surface waters due to thermal stratification. Downstream water

temperatures in the Woronora River are analysed to detect any evidence of persistent cold water impacts.

Reference temperatures for the Woronora catchment are recorded daily at the major inflow locations to Lake Woronora:

- Woronora River at Fire Rd 9F
- Waratah Rivulet at Fire Rd 9J.

Downstream temperatures were recorded daily at The Needles on the Woronora River, approximately 10 km downstream from the environmental release point.

As seen in Figure 6.11 below, the downstream temperature at The Needles (G0515) closely matches the reference temperatures. Both show a strong seasonal trend and very similar small scale variations, resulting from local weather conditions.

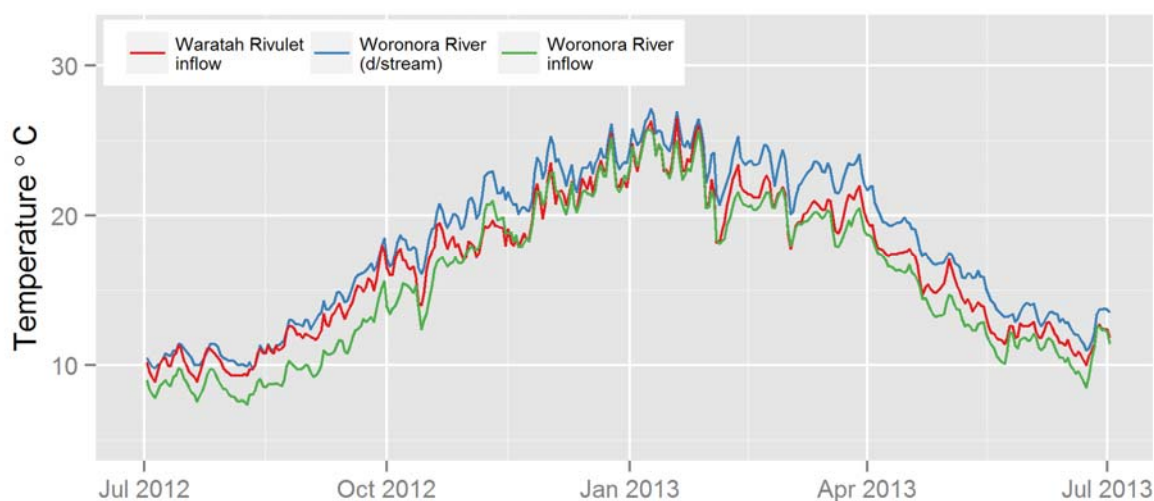


Figure 6.11 Woronora system temperature profile

6.3.3 Shoalhaven system

Since 2008, environmental releases from Lake Yarrunga have been supplied either as spills or via an overshot gate on the Tallowa Dam, which allows for the preferential release of surface waters. There is also a high level outlet which contributes to the environmental release via the fishway. As surface waters are not subject to thermal stratification, they should more closely match downstream temperatures.

Reference temperatures for Lake Yarrunga were recorded daily on the major tributaries:

- Shoalhaven River at Fossickers Flat
- Kangaroo River at Hampden Bridge.

Downstream temperatures were recorded daily at:

- Shoalhaven River downstream of Tallowa Dam
- Shoalhaven River at Grassy Gully.

The site at Tallowa Dam is immediately downstream of the environmental releases and provides a good measure of the release temperature. Grassy Gully is approximately 20 km downstream of the Tallowa Dam.

Figure 6.12 below shows that temperatures at both downstream sites closely match those of the upstream Shoalhaven reference site. The similarity between the two downstream sites suggests the environmental releases are very near ambient condition.



Figure 6.12 Shoalhaven system temperature profile

7 Targeted and investigative monitoring

The SCA undertakes targeted and investigative monitoring to understand and assess impacts that are not addressed by the routine monitoring program. The results of the monitoring are discussed in greater detail in the sections below.

A summary of water quality incidents during 2012-13 is included in Section 8.

7.1 Wet weather monitoring

To assist in evaluating impacts on water quality from runoff during significant rainfall events, the SCA undertakes wet weather sampling. A key component of the wet weather monitoring program is the use of autosampler stations which are programmed to automatically take samples once a river height trigger has been reached.

Wet weather monitoring is used to quantify the water quality risks for incoming waters to storages. During high rainfall events and/or spill events, catchments are often closed to operational traffic and storages closed to boat traffic to protect the health and safety of staff and members of the public. Using auto-samplers helps to acquire valuable water quality information on the water quality effects of rainfall events.

A review of the SCA's water monitoring program during 2011-12 resulted in the installation of four new autosamplers in the catchment in 2012-13. This will help verify the pollutant source risk assessments and support the analysis of catchment interventions and scientific investigations. Autosamplers that have longer holding times (i.e. river samples that can be held for longer periods before they are analysed) have been purchased to improve the success in gaining wet weather data.

The SCA maintains two types of autosamplers, measuring the following analytes:

- Type 1 – total organic carbon, suspended solids, total phosphorus, total nitrogen, total aluminium, total iron and total manganese.
- Type 2 – total nitrogen, total phosphorus, *Cryptosporidium* and *Giardia*.

Where specific water quality issues have been identified, additional analytes are sampled on request. At high priority reservoir inflow locations, both auto-sampler types have been installed. Given the differing sampling mechanisms, trigger values may differ between the two autosampler types. Type 2 samples are reserved for locations identified as potentially significant pathogen sources, requiring a much larger sample volume (hence the lower number of samples). Table 7.1 shows number of samples collected for each site during the year.

2012-13 was wet compared with historical averages, with high inflow events in February/March 2013. Across the 26 autosampler locations a total of 660 Type 1 samples and 39 Type 2 samples were taken.

Table 7.1 Number of wet-weather samples from SCA autosamplers 2011–12

Site Code	Autosampler			
	Type 1		Type 2	
	Number of Samples (total)	Number of Days(days)	Number of Samples (total)	Number of days (days)
Warragamba System				
E083	5	1	1	1
E130	27	8	4	4
E157	25	9	3	3
E203	0	0	14	9
E206	75	21	0	0
E243	7	2	0	0
E332	29	6	0	0
E409	19	6	0	0
E450	41	8	0	0
E457	24	5	0	0
E488	6	2	1	1
E531	40	9	7	7
E551	18	3	0	0
E083	5	1	1	1
Upper Nepean System				
E6006	12	4	0	0
E604	30	5	0	0
E609	12	5	0	0
E610	35	8	0	0
Shoalhaven System				
E680	25	9	0	0
E706	45	9	9	9
E822	22	6	0	0
E860	17	5	0	0
E861	6	4	0	0
Woronora System				
E6131	40	10	0	0
E677	38	9	0	0
G0515	62	11	0	0
TOTAL	660	165	39	34

Note: Type 1 – total organic carbon, suspended solids, total phosphorus, total nitrogen, total aluminium, total iron and total manganese and Type 2 – total nitrogen, total phosphorus, *Cryptosporidium* and *Giardia*.

7.2 Macroinvertebrate monitoring

The Macroinvertebrate Monitoring Program (MMP) is an annual assessment of the ecological health of river sites in the SCA's drinking water supply catchment. In 2012 the ecological health of the catchment sites has improved slightly from 2011, as AUSRIVAS grades had improved at approximately 60% of all sites. This may be a reflection of the increased river flows across many of these sites in recent years. Macroinvertebrate sampling was conducted at 60 sites in 27 sub-catchments (Figure 7.1), collecting 119 individual samples, a slight increase compared with the 2011 MMP.

Macroinvertebrate sampling was conducted at 26 sites from 12 sub-catchments in the Warragamba Dam catchment in 2012. Almost 60% of sites were rated to be in a Reference or Above Reference condition, down slightly on the 2011 results. Eight sites from five sub-catchments declined in AUSRIVAS rating compared to the previous year.

Twelve sub-catchments were sampled in the Tallowa Dam catchment, with macroinvertebrate monitoring conducted at 26 sites in 2012. Almost 60% of sites were rated by AUSRIVAS to be in a Below Reference condition and 30% of sites rated in Reference condition. Catchment wide, these results are an improvement when compared to the previous year's findings.

Four sites in the Metropolitan catchment were sampled for macroinvertebrates in 2012, whereas only one site was sampled in 2011. Only one of the four sites sampled in the Metropolitan catchment was rated in 2012 to be in Reference condition. The remaining sites were rated to be Below Reference condition. AUSRIVAS ratings for the three Blue Mountains sub-catchment sites were similar to 2011 and ranged from Reference to Well Below Reference condition. Health at the single Woronora sub-catchment site improved compared to 2011.

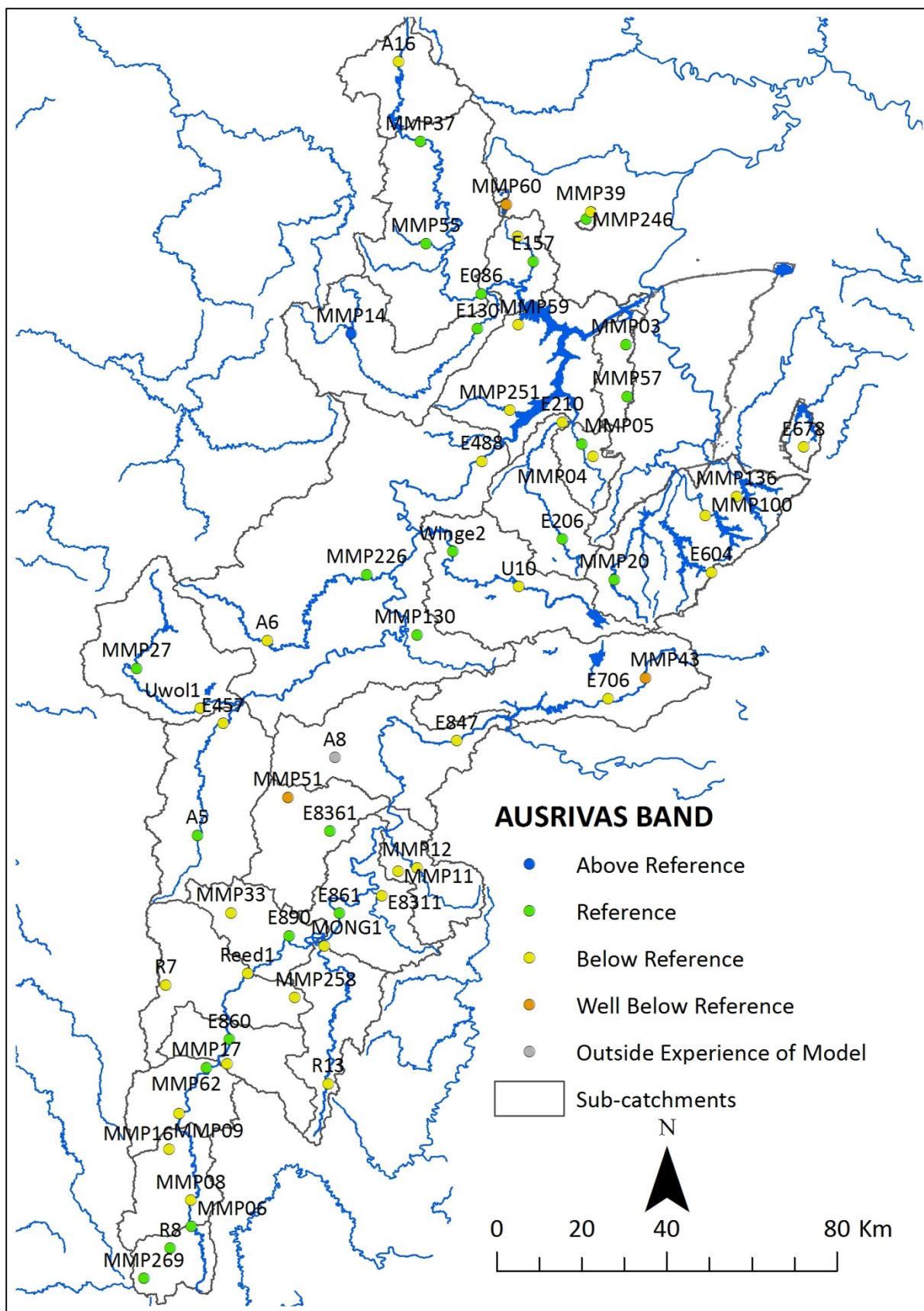


Figure 7.1 AUSRIVAS ratings for each of the sites sampled in 2012

7.3 Scientific monitoring

7.3.1 Scientific research

The SCA undertakes monitoring to inform our scientific investigations. The SCA's science program aims to provide on-time and reliable scientific advice, tools and investigations for sound operational decisions. Science also helps warn of emerging issues through access to local and global knowledge and networks.

The Science Strategic Plan 2010-15 outlines the scientific priorities for the SCA. Science is delivered through the focused work of the SCA's Science unit and the operational activities and projects undertaken by the broader organisation. It involves scientific investigations and research, modelling, translating knowledge into practice, scientific evaluation and validation. Science is also furthered through collaboration with external researchers (providing a longer term or specialist focus).

Validation of the Grazing Evaluation Model

A preliminary grazing runoff pollutant model is being developed using information from relevant literature and regional datasets. The model is being calibrated and verified from field trials and property-scale monitoring. The model will enable the organisation to more confidently measure and assess the pollutant exports from grazed hill slopes and the effectiveness of grazing interventions. It will inform the design/selection of any future interventions and best management practices, and extrapolate the findings to larger catchments.

The project is being conducted in three stages. Activities in 2012-13 were focussed on Stage 1.

1. *Field Trials* – Construction of temporary weirs in minor drainage lines within grazing paddocks and installation of rain gauges, autosamplers and probes to monitor pathogens and nutrients under different runoff events to provide calibration data for the model.
2. *Collection of data* on stock movements, faecal loadings and decay, groundcover variability etc.
3. *Model Refinement* – Development and calibration of model functions and parameters for mobilisation, and transport of pathogens and nutrients based on field data.

Impact of mining on reservoir sediments

A number of creeks in the SCA's catchments subject to longwall mining have experienced subsidence, causing cracking of bedrock and streambeds and loss of surface water into underground routes. This can also impact the quality of water being transported into reservoirs, particularly during and after rainfall events, through increased levels of iron and manganese.

A sampling program was undertaken in 2012 to determine whether there is a significant accumulation of iron in the sediments of Woronora Reservoir, and whether the levels can be attributed to the impacts of longwall mining.

Statistical analysis indicates that there is no significant difference in the average iron concentrations between sediments from Woronora (unmined) and Waratah (mined) tributaries. On the other hand the average concentrations of manganese, nickel, cobalt, zinc differ significantly, being higher in

sediments from mining impacted Waratah tributary. The results suggest that manganese and trace metals could provide better indication of the impacts of mining than iron. Further analysis of the data is being undertaken.

Sewage Treatment Plant Evaluation Study

A study monitoring the effectiveness of sewerage projects in reducing pathogenic loads is in progress. This work will determine the loading, infectiveness and persistence of pathogens discharged from STPs within the catchment. It will assess whether there is any significant difference in the loadings from different treatment/operational systems and help the SCA develop an improved understanding of the limitations of current analytical methods.

Preliminary results show that while *Cryptosporidium* was consistently present in STP effluent discharged to catchment streams, all STPs rendered the *Cryptosporidium* non-infectious. This study will continue until 2016.

On-Site Sewage Disposal Evaluation Study

Innovative detection methods for sewage effluent contamination are being investigated and trialled. Sampling of pollutant indicators (including microbial, nutrients, pharmaceuticals and personal care products) has provided encouraging initial results. The presence of pharmaceutical and personal care products indicates that effluent from onsite sewage systems is making its way into entering waterways in Kangaroo River and Robertson.

Robertson and the Kangaroo Valley are unsewered villages. Base line data has been collected for the villages, which are being sewered with the construction of new STPs. Limited data were available on the discharge of pollutants (nutrients and pathogens) from existing on-site sewage systems to adjacent waterways/reservoirs, and also on the potential net reduction in the pollutant loads achieved once the sewerage schemes are built. A monitoring and evaluation program will be developed to evaluate the effectiveness of catchment interventions.

Effect of chlorination on *Giardia*

The Upper Canal delivers water in the Metropolitan storages (Nepean, Avon, Cordeaux and Cataract reservoirs) from Broughtons Pass to Prospect WFP. The water is chlorinated at the tunnel entrance at Broughtons Pass. The main purpose of chlorination is to reduce *Giardia* viability in the raw water prior to reaching the Prospect WFP.

In 2013 the SCA commenced an assessment of whether chlorination is effective or necessary in reducing *Giardia* to an acceptable level of risk. Preliminary analysis indicates there is no significant difference between the proportion of samples containing *Giardia* found in the trial so far and historical data. The sampling program will continue until sufficient data are collected to determine whether there is a statistically significant difference between chlorinating and not chlorinating in both dry and wet weather conditions. The risk assessment will initially take the precautionary approach of assuming all (unchlorinated) cysts are viable.

Sources of taste and odour producing compounds

Prospect Reservoir is an integral part of Sydney's water supply system and it is strategically placed as a potential back up supply. Customer complaints about taste and odour have been attributed to water quality from Prospect Reservoir in the past with above average complaints coinciding with time of supply from Prospect Reservoir. While Prospect Reservoir has had occasional detections of known taste and odour producing compounds the definitive sources of these compounds are not well established.

A combination of sediment coring, water profile sampling, and biofilm sampling is being undertaken in Prospect Reservoir to identify organisms that may cause taste and odour production. The results will be used to inform our future water monitoring and supply options.

7.3.2 Scientific research partnerships

The SCA is a member of several national and international research organisations. This helps us to learn and share knowledge on important water issues.

Our partnerships in 2012-13 include:

- Water Quality Research Australia (WQRA) – a research centre that focuses on nationally applicable collaborative research about drinking water quality, recycled water and wastewater management.
- eWater Source Modelling Community - a publically owned not-for-profit partnership that supports the implementation and use of Source as the new national hydrological modelling platform in Australia. eWater collaborates with members to share knowledge and resources for innovation and best practice in water management.
- Water Research Foundation (US based) – the largest drinking water research organisation in the world covering the urban water sector.
- Water Environment Research Foundation (US based) – looks at the natural processes, ecosystems and other physical processes that impact our understanding of water systems, conducting research across fresh and marine environments.
- Australian Water Association (AWA) supports the Australian water sector in the delivery of effective and sustainable water management practices. AWA runs a comprehensive program of conferences, workshops, publications, industry programs, training courses and networking, as well as an annual conference and exhibition.
- Water Services Association of Australia (WSAA) is the peak industry body that brings together and supports this Australian urban water industry. The SCA is a member of various WSAA networks, collectively sharing information and focussing on key and emerging issues in the sector.

7.4 Emerging Issues

The SCA, in close consultation with NSW Health and its customers, including Sydney Water, kept abreast of any emerging water quality issues. While of itself not a health issue, elevated levels of colour in raw water challenged treatment capacity at some plants. Sources and causes of colour, supply configuration and treatment options have been investigated. Contingencies like source selection, blending and pre-chlorination have helped manage the situation. Investigations into colour will continue into the coming year.

8 Incidents and events

Water quality incidents are managed in accordance with the SCA's Raw Water Quality Incident Response Plan (2010). The plan sets out water quality trigger levels for various actions and notifications. Any water quality issue that poses a potential risk to public health is reported to NSW Health immediately and incident responses are developed in consultation with relevant stakeholders.

The SCA's Water Monitoring Program 2010–2015 also specifies monitoring required in anticipation of events which pose potential threats to raw water quality, such as large inflow events and seasonal turnover in Lake Burragorang. The pre-planned monitoring during periods leading to and during such events allows operational changes to be made proactively and prevents events manifesting into incidents.

During 2012–13 there were no emergency incidents, two major incidents and 19 minor water quality incidents recorded by the SCA across its area of operations (see Appendix C). The high rainfall events in March and June 2013 were significant, but were managed well with no significant water quality impacts on supplied water.

8.1 Heavy rainfall event

After numerous small rain events in the early months of 2013 a significant rainfall event occurred in June, beginning with approximately 120 mm average rainfall across the Warragamba catchment on 25 June 2013. Warragamba Dam rapidly filled and spilled over the ensuing days.

The inflow was tracked using the real time monitoring network and field sampling as it entered the storage until the resulting plume of flood water reached the dam wall on the 2 July (see Figure 8.1). As the flood water approached the wall, a timely change to a supply outlet higher in the water column successfully avoided contamination of the water being supplied.

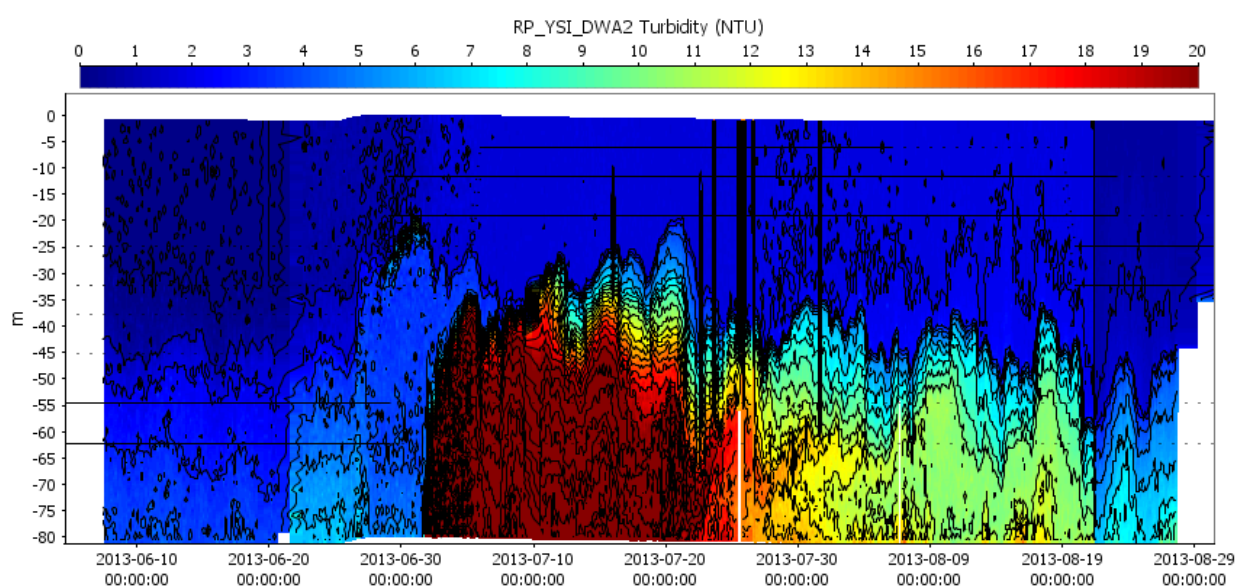


Figure 8.1 Static profiler output showing the turbid plume in Lake Burragorang following heavy rainfall in June 2013

In the lead up to the arrival of the flood waters the Warragamba pipeline was configured so that, in the event that the plume impacted the water column high enough to enter the supply the dam could be taken offline. Clean water could then be supplied to Warragamba and Orchard Hills water filtration plants for some days from the pipeline and Prospect WFP could be supplied from the Upper Canal and Prospect Reservoir. This was the first time the pipeline was configured in this way but was not required.

Significant additional monitoring of the flood waters was undertaken throughout the event to inform configuration changes.

The flood water was characterised by high turbidity and colour, and travelled down the storage as an underflow (along the bottom of the lake), ultimately impacting the water column at the dam wall from 40 m below the surface down to the bottom. Within the flood water plume nutrients and true colour were elevated, along with the iron and aluminium common in flood waters from this catchment.

8.2 Major water quality incidents

The SCA recorded two major water quality incidents during 2012–13. Each had the potential to impact drinking water quality. Effective incident response ensured no adverse effects were experienced in water quality delivered to the WFPs.

8.2.1 Elevated metal detections in Orchard Hills raw water

On 18 December 2012 raw water sampling at the inlet to Orchard Hills WFP (HBR1) detected total iron in abnormally high concentrations. The concentration for total iron (3.66 mg/L) was in the major incident level range as outlined in the SCA Raw Water Quality Incident Response Plan (RWQIRP). There is no health guideline relating to raw water for iron.

When this result was reviewed some anomalies were identified and the lab was asked to repeat the analysis. This analysis confirmed the original results as accurate. The sampling contractors confirmed that the sample was taken by experienced employees familiar with the site. The sample was taken according to established procedure with no abnormal conditions identified.

The results were inconsistent with samples taken the previous day at the inlet to Warragamba WFP (HWA2, which is supplied from the same source) and samples taken by Sydney Water at Orchard Hills WFP on 17 December 2012. Results for this sample were typical, with total iron recording 0.28 mg/L.

As per the SCA's RWQIRP, Sydney Water was notified of the result. Sydney Water confirmed that the plant was operating normally at the time and had continued to operate with treated water meeting drinking water guidelines. The cause of the high metal concentration remains unknown. Follow up samples have not identified any issues with potential metal contamination.

8.2.2 Elevated Algae Areal Standard Units in Kangaroo Valley raw water

On 3 April 2013 raw water sampling at the inlet to Kangaroo Valley WFP (HKV1) recorded a total algae biomass (areal standard units (ASU)) of 5,351 ASU/mL. This result was at the major incident range (>5,000 ASU/mL) as per the SCA's RWQIRP. ASU is a measure of the surface area of the algal cells. There is no health guideline for algae ASU. It is primarily used as an indicator for the potential for water filtration plant filters to become blocked, slowing flow through the plant and requiring more frequent filter cleaning.

The sample collected on 3 April was an escalation of the minor incident reported from sampling on 28 March 2013, which recorded 4,187 ASU/mL in the raw water. The high ASU was related to the high counts of the blue-green algae *Cyanonephron* present in the samples. This type of algae is not known to produce any toxins and is generally not problematic. The seasonal conditions during this time of year were likely to have contributed to the increase in algal growth.

Shoalhaven City Council was notified of these results. Shoalhaven City Council, which manages the Kangaroo Valley WFP, reported that they were not experiencing any issues with treating the water. Follow-up routine sampling on 22 April at HKV1 reported a significant decrease in the algae ASU to 2,589 ASU/mL. The incident was downgraded and subsequently closed with further decreases in ASU recorded.

9 Trend analysis

Trend analysis identifies persistent changes in water quality parameters resulting from natural (e.g. rainfall, climate) and anthropogenic (e.g. land-use change, catchment interventions) perturbations. The Sydney Catchment Authority undertakes trend analysis biennially, with trend analysis last performed as part of the 2010-2011 Annual Water Quality Monitoring Report including a case study on the application of Generalised Additive Models for water quality trend analysis.

Trend analysis for selected catchment, storage and water filtration plant sites for the 2003 - 2013 period are reported in the sections that follow. As required by the SCA's operating licence's reporting manual, the sites and analytes included in the trend analysis were endorsed by NSW Health and Office of Water. Generalised Additive Models have been used to identify statistically significant (99%) linear trends, reported here as percentage change per year. A technical description of the methodology is provided in Appendix B.

While trend models factor the effect of discharge at the time of sampling, they do not consider the long-term effects resulting from increased rainfall, stream discharge and groundwater baseflow discharges.

Statistically significant trends may not be of concern if:

- a) The magnitude of the change is very small; and/or
- b) The trend is not likely to result in the relevant guidelines/benchmarks being approached or exceeded. For relevant guidelines/ benchmarks refer to Section 4 (Applicable guidelines and benchmarks)

The SCA's Healthy Catchment Strategy and other programs will target initiatives to address those trends where the magnitude of trend is large or result in breaches in relevant guidelines or benchmarks.

The following tables highlight categories of trend based on trend analysis and scientific interpretation:

NA	No significant trend
X or -X	A statistically significant increasing or decreasing trend of no concern because the magnitude of change is either very small or not expected to impact relevant guidelines / benchmarks
X	A statistically significant increasing trend where there is a large change in magnitude and/or potential to exceed relevant guidelines/benchmarks
-X	A statistically significant decreasing trend due to a large change in magnitude and reduce the likelihood of failing relevant guidelines

9.1 Warragamba system

9.1.1 Catchments

Table 9.1 Trend analysis results for the catchment sites draining to Lake Burragorang. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
Coxs River													
E083	14.6	18.3	4.8	0.6	NA	NA	11.4	4.6	10.9	NA	9.1	NA	12.7
Kowmung River													
E130	NA	6.0	NA	NA	10.9	7.9	8.9	NA	NA	NA	7.1	NA	7.4
Kedumba River													
E157	NA	-4.2	3.2	NA	NA	4.8	5.3	7.9	6.2	NA	NA	-2.9	NA
Nattai River													
E203	NA	NA	NA	2.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
E206	NA	NA	NA	1.1	-10.8	NA	NA	3.3	NA	NA	-7.6	NA	NA
E210	-12.5	NA	NA	NA	NA	6.7	NA	NA	-4.9	-4.1	-6.4	NA	-7.6
Little River													
E243	-5.3	NA	NA	NA	NA	-2.4	NA	-7.2	-6.1	-12.4	NA	-5.3	-3.6
Wollondilly River													
E409	NA	-5.8	NA	NA	NA	NA	NA	-6.4	-5.3	-5.1	-23.4	NA	NA
E450	NA	-10.5	NA	NA	NA	NA	NA	16.3	-4.6	NA	-5.8	NA	NA
E488	NA	NA	9.6	-0.6	NA	NA	NA	19.5	NA	NA	NA	3.4	NA
Werriberri Creek													
E531	NA	NA	NA	1.8	NA	NA	NA	NA	NA	NA	NA	NA	NA

*For description of sites see Section 5.2.1. For the map of sites see Figure 5.1.

Sites from the largely forested north-west catchments displayed increasing trends. Metals (iron and manganese) increased at Kelpie Point (E083), Cedar Ford (E130) and Kedumba Crossing (E157) sites. The magnitude of change for aluminium is particularly large at Kelpie Point (E083) and seems to be related to increases in turbidity and rainfall over the reporting period.

Kelpie Point (E083) experienced increasing total phosphorus and corresponding increases in chlorophyll-*a* causing it to exceed the ANZECC benchmark.

A number of decreasing trends were detected at the Nattai River sites. The site at Smallwoods Crossing (E210) in particular, showed nutrients phosphorus and nitrogen decreasing at four percent and six percent per annum respectively. The Nattai River has historically experienced high concentrations of nutrients due to urbanisation, agricultural activity and sewage treatment plant effluent. Turbidity, manganese and aluminium also decreased by 4.9% and 12.5% respectively.

Numerous decreasing trends were also detected at the Little River site (E243) and may be a result of catchment recovery following the 2002 bushfires. This site is associated with very good water quality compared against ANZECC benchmarks.

A large decreasing trend in total phosphorus and total nitrogen was observed at the Murrays Flat (E409) site on the Wollondilly River. A corresponding reduction in chlorophyll-*a* was also observed. The site is immediately downstream of the Goulburn STP which has undergone a number of treatment process reconfigurations and upgrades within the reporting period.

Downstream from Murrays Flat at Golden Valley (E450) the total phosphorus reduced by 5.8% per year with a corresponding reduction in chlorophyll-*a* concentration

9.1.2 Storages

Table 9.2 Trend analysis results for the storage sites within the Warragamba system. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
Lake Burragorang													
DWA12	3.7	5.4	-0.8	-0.7	NA	27.5	12.6	10.1	-3.9	3.4	3.2	13.3	2.6
DWA2	6.7	4.4	-1.0	-1.1	NA	27.4	13.2	NA	NA	3.8	3.0	14.2	2.4
DWA27	8.0	4.9	-0.6	-1.2	NA	39.2	16.9	17.7	2.2	4.6	4.0	15.1	5.1
DWA9	6.7	4.4	-0.9	-1.1	NA	30.1	16.2	12.8	NA	4.1	3.6	13.6	2.4
Prospect Reservoir													
RPR1	NA	NA	NA	NA	NA	NA	11.3	NA	5.0	-2.5	-4.7	NA	-9.3

* For description of sites see Section 5.2.2. For the map of sites see Figure 5.1.

Trend analysis was performed on four sites within Lake Burragorang (Table 9.2). The sites chosen represent distinctive areas of the lake; inflow arms, the Coxs River arm (DWA12), Wollondilly River arm (DWA27), central part of the lake in the Gorge (DWA9) and near offtake (DWA2). As shown in Table 9.2, trends were largely similar across the four sites.

All sites experienced increasing trends in metals, with the largest relative increase in filtered iron. Before 2012 detections of filtered iron were very rare. The increasing trends are largely due to the inflow event in March, 2012 after which filtered iron has been consistently detected at all sites. Concentrations at all sites remained in the 0.1-0.2 mg/L range for the 2012-13 period. True colour also increased over the period and was largely the result of inflows since March 2012 delivering organics and metals to the storage. The continuation of these trends will be largely dependent on future weather patterns.

Nutrients phosphorus and nitrogen increased around 3-4% per year at all sites and are now exceeding ANZECC benchmarks. Again, the March 2012 inflow event produced elevated concentrations at all sites. A corresponding increase in chlorophyll-*a* was also observed causing exceedances of the ANZECC benchmarks.

The SCA's ability to source water from different depths assists in avoiding high concentrations of these characteristics entering raw water supply.

9.1.3 Water Filtration Plants

Table 9.3 Trend analysis results for the water filtration plant monitoring sites within the Warragamba system. Statistically significant trends are reported in percentage change per year.

Site	Alkalinity (mg CaCO ₃ /L)	Aluminium (Total)	Areal Standard Unit (algae)	E.Coli	Iron (Total)	Manganese (Total)	Total Hardness (mg CaCO ₃ /L)	True Colour (@400nm)	Turbidity
Orchard Hills (HBR1)	-3.7	23.8	-7.8	NA	25.1	NA	-2.6	11.3	11.6
Warragamba (HWA2)	-3.2	19.9	20.6	NA	10.8	NA	-3.0	15.0	16.2
Prospect (PWFP10)	NA	16.6	NA	NA	15.9	NA	NA	10.7	NA

The three WFPs within the Warragamba system are primarily supplied by the same system configuration and thus reflect similar trends (Table 9.3).

Iron, aluminium and true colour are displaying increasing trends and are seen to increase rapidly following rainfall events. Despite these large relative increases, the SCA has maintained very high raw water supply agreement compliance.

9.2 Upper Nepean system

9.2.1 Catchments

Table 9.4 Trend analysis results for the catchment sites draining to Lake Nepean, Cataract, Avon and Cordeaux. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
Nepean catchment													
E602	NA	NA	NA	2.0	NA	NA	NA	NA	NA	-9.9	3.6	NA	-9.6
Cataract catchment													
E609	7.1	NA	-2.0	2.6	NA	15.0	NA	3.3	3.4	-10.1	13.2	NA	-9.1
Avon catchment													
E610	NA	NA	NA	2.6	NA	8.6	NA	NA	NA	NA	NA	NA	-25.2
Cordeaux catchment													
E680	12.0	14.7	NA	1.6	NA	15.0	8.0	10.2	8.5	-8.3	12.0	8.6	-8.4

* For description of sites see Section 5.3.1. For the map of sites see Figure 5.2.

Routine monitoring of sites E609, E610 and E680 commenced in 2006 and thus analysis is restricted to data from the 2006 -2013 period. These sites have not been included in trend analysis for previous Annual Water Quality Monitoring Reports. These systems are dominated by protected native forest however, large areas have been longwall mined particularly in the Cordeaux and Cataract catchments.

At most sites metals increased steadily over the period maintaining a strong seasonal pattern with no appreciable response to rainfall events.

9.2.2 Storages

Table 9.5 Trend analysis results for the storages sites within the Upper Nepean system. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
Lake Avon													
DAV1	NA	-6.7	1.8	-1.1	NA	NA	NA	NA	15.9	-5.9	NA	-9.3	-16.0
DAV7	3.1	-2.5	3.6	NA	NA	NA	NA	13.8	6.6	-1.9	NA	1.9	-9.0
Lake Cataract													
DCA1	6.5	-2.6	1.7	NA	NA	10.8	6.5	-10.1	-5.2	-5.1	NA	4.3	-13.8
Lake Cordeaux													
DCO1	NA	NA	3.0	NA	NA	NA	1.6	NA	NA	-4.4	NA	2.2	-7.5
Lake Nepean													
DNE2	11.1	NA	2.2	NA	NA	5.1	4.0	NA	NA	NA	4.0	4.7	-3.3

* For description of sites see Section 5.3.2. For the map of sites see Figure 5.2.

In Lake Cataract, iron and aluminium increased (Table 9.5) causing aluminium to exceed the ANZECC benchmark on all sampling occasions in 2012-13. True colour also increased which is likely to be associated with metals.

Lake Nepean experienced increasing concentrations of aluminium and true colour with aluminium exceeding the benchmark on 92% of sampling occasions in 2012-13. While a small increase in phosphorus was detected no significant change in chlorophyll-*a* was noted.

9.2.3 Water Filtration Plants

Table 9.6 Trend analysis results for the water filtration monitoring sites within the Upper Nepean system. Statistically significant trends are reported in percentage change per year.

Site	Alkalinity (mg CaCO ₃ /L)	Aluminium (Total)	Areal Standard Unit (algae)	E.Coli	Iron (Total)	Manganese (Total)	Total Hardness (mg CaCO ₃ /L)	True Colour (@400nm)	Turbidity
Macarthur (HMAC1)	-4.2	10.5	NA	NA	6.5	3.0	-3.1	4.6	-19.4
Nepean (HNED)	NA	18.8	NA	NA	10.7	5.2	NA	7.5	-12.1
Illawarra (IWFP-R)	NA	NA	-11.6	NA	6.8	22.3	1.2	NA	-7.5

The WFPs within the Upper Nepean system represent differing supply configurations. The Nepean WFP is supplied solely by Lake Nepean, Illawarra WFP solely by Lake Avon and Macarthur WFP is supplied via Broughtons Pass which can receive supply from any of the Upper Nepean storages.

The most notable increases in iron and aluminium were at Macarthur and Nepean and may have contributed to increasing true colour. While manganese increased at all sites, the magnitude of change was greatest at Illawarra.

Despite these trends, the SCA has continued to achieve a high degree of compliance with the site specific standards outlined in the raw water supply agreements. However, the increase in true colour has led to some challenges for Nepean treatment plant operators which can only be supplied from Lake Nepean. Similar issues were averted at Macarthur water filtration plant by sourcing waters from different storages.

9.3 Woronora system

9.3.1 Catchments

Table 2.7 Trend analysis results for the catchment site draining to Lake Woronora. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
E677	NA	NA	NA	NA	NA	NA	10.5	13.8	12.9	NA	NA	NA	-16.4

* For description of site see Section 5.4.1. For the map see Figure 5.3.

The Woronora River site experienced decreasing turbidity while total iron and manganese (total and filtered) increased (Table 9.7). Total iron maintained strong seasonality throughout the reporting period.

9.3.2 Storages

Table 9.8 Trend analysis results for the storages sites within Lake Woronora. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
DWO1	7.2	NA	2.4	NA	20.0	9.5	8.1	12.7	10.6	NA	NA	7.7	-8.4

* For description of site see Section 5.4.2. For the map see Figure 5.3.

The trend site within Lake Woronora is located at the dam wall (DWO1) near the raw water offtake. A number of characteristics were found to have increased over the reporting period, particularly metals (Table 9.8). Total aluminium increased at 7.2% per year and was found to exceed ANZECC benchmarks on all sampling occasions in 2012-13.

9.3.3 Water Filtration Plants

Table 9.9 Trend analysis results for Woronora Water Filtration Plant. Statistically significant trends are reported in percentage change per year.

Site	Alkalinity (mg CaCO ₃ /L)	Aluminium (Total)	Areal Standard Unit (algae)	E.Coli	Iron (Total)	Manganese (Total)	Total Hardness (mg CaCO ₃ /L)	True Colour (@400nm)	Turbidity
Woronora (HWO1-A)	4.6	12.4	NA	NA	12.7	9.7	NA	16.0	-12.0

The Woronora WFP is supplied solely from Lake Woronora. Trend directions followed those found in the lake site (Table 9.9) with all metals increasing over the reporting period. However, maximum metal concentrations over the 2012-13 period were well below the site specific standards outlined in the raw water supply agreement. While true colour has increased over the period, probably in association with metals, it has not created any challenges for water treatment plant.

9.4 Blue Mountains system

9.4.1 Catchments

Given the small size of the Blue Mountains system, there are currently no routine monitoring sites.

9.4.2 Storages

Table 9.10 Trend analysis results for the storages sites within the Blue Mountains system. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
Greaves Creek Dam													
DGC1	5.9	-6.8	-2.0	NA	NA	NA	NA	NA	NA	-7.8	4.4	1.9	2.9
Top Cascade Dam													
DTC1	8.2	-4.1	-3.9	-0.4	NA	11.2	7.0	9.3	-5.2	-8.9	-4.9	3.7	-4.7

* For description of sites see Section 5.5.2. For the map see Figure 5.4.

The storages within the Blue Mountains system are small and subject to transfers between the Blue Mountains storages and from the Fish River system. Over the last 10 years, transfers from Fish River have reduced dramatically and produced gradual changes in water quality characteristics (Table 9.10). Top Cascade Dam (DTC1), which directly supplies Cascade WFP, experienced decreases in nitrogen, phosphorus and chlorophyll-*a*. Total aluminium increased and now regularly exceeds ANZECC benchmarks.

9.4.3 Water Filtration Plants

Table 9.11 Trend analysis results for the Cascade Water Filtration Plant. Statistically significant trends are reported in percentage change per year.

Site	Alkalinity (mg CaCO ₃ /L)	Aluminium (Total)	Areal Standard Unit (algae)	E.Coli	Iron (Total)	Manganese (Total)	Total Hardness (mg CaCO ₃ /L)	True Colour (@400nm)	Turbidity
Cascades (HCSR)	-11.9	13.2	-11.7	NA	11.3	-8.4	-11.0	NA	-5.8

Total iron and aluminium have steadily increased (Table 9.11) possibly due to the decrease in transfers from the Fish River system. Despite the increase, both total iron and total aluminium

concentrations remain well below the site specific standards outlined in the raw water supply agreement.

Decreasing chlorophyll-a in the storages noted above, have led to a considerable decrease in algal biomass (areal standard unit) entering the raw water supply.

9.5 Shoalhaven system

9.5.1 Catchments

Table 9.12 Trend analysis results for catchment sites draining to Lake Yarrunga. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
Kangaroo River													
E706	NA	NA	NA	0.8	NA	NA	NA	6.3	4.9	NA	5.6	NA	-6.2
Shoalhaven River													
E847	-13.9	NA	NA	NA	NA	5.8	NA	NA	NA	-4.6	NA	NA	-20.4

* For description of sites see Section 5.6.1. For the map see Figure 5.5.

The Hampden Bridge (E706) monitoring site on the Kangaroo River was routinely monitored for the entire 2003-2013 period. Routine monitoring for the Fossickers Flat (E847) site on the Shoalhaven River commenced in 2006.

Phosphorus steadily increased during the period with regular ANZECC benchmark exceedances in 2012-13.

Large reductions in turbidity and total aluminium were observed at Fossickers Flat site. A small increase in filtered iron was however observed.

9.5.2 Storages

Table 9.13 Trend analysis results for the storages sites within the Shoalhaven system. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
Fitzroy Falls Reservoir													
DFF6	8.3	4.7	1.9	NA	15.6	NA	NA	NA	-2.0	-2.9	-3.7	NA	NA
Lake Yarrunga													
DTA1	6.3	NA	0.6	NA	NA	NA	2.8	9.3	5.2	NA	5.9	3.2	NA
Wingecarribee Reservoir													
DWI1	13.2	NA	NA	NA	NA	16.5	8.1	7.0	-2.4	-4.6	-2.1	6.3	4.6

* For description of sites see Section 5.6.2. For the map see Figure 5.5.

Over the early part of the reporting period, Fitzroy Falls and Wingecarribee Reservoirs were used regularly for transferring waters from the Shoalhaven system to augment the Warragamba and Metropolitan systems. These transfers influenced the water quality within the reservoirs.

A reduction in nutrients was observed at both Fitzroy Falls (DFF6) and Wingecarribee Reservoir (DWI1) (Table 9.13). Despite the decrease in nutrients, chlorophyll-*a* was found to increase in Fitzroy Falls Reservoir, particularly in the past two years. Aluminium, iron and manganese increased at DWI1 with total aluminium now regularly exceeding ANZECC benchmarks.

Aluminium, iron (total) and manganese (filtered and total) increased in Lake Yarrunga (DTA1) with aluminium exceeding the benchmark in all samples taken in 2012-13. Inflows into the lake increased over the reporting period although no increase in turbidity was detected. Phosphorus increased at six percent per year (and exceeding the ANZECC benchmark in 100% of samples in 2012-13) although no increase in chlorophyll-*a* was found.

9.5.3 Water Filtration Plants

Table 9.14 Trend analysis results for Water Filtration Plant monitoring sites within the Shoalhaven system. Statistically significant trends are reported in percentage change per year.

Site	Alkalinity (mg CaCO ₃ /L)	Aluminium (Total)	Areal Standard Unit (algae)	E.Coli	Iron (Total)	Manganese (Total)	Total Hardness (mg CaCO ₃ /L)	True Colour (@400nm)	Turbidity
Kangaroo Valley (HKV1)	-3.0	NA	NA	NA	-3.9	NA	-2.9	-4.7	NA
Wingecarribee (HWI1)	-4.2	6.1	NA	-15.5	2.9	-3.7	-4.2	-3.1	NA

The Kangaroo Valley WFP is supplied directly from Bendeela Pondage which is replenished from Lake Yarrunga (Table 9.14). Total iron and true colour both decreased over the period yet have become more variable in recent years.

9.6 Downstream sites

9.6.1 Hawkesbury – Nepean system

Trend analysis was performed on five sites along the Hawkesbury–Nepean River. The sites all have associated hydrometric stations and models account for discharge at the time of sampling. Trend results are reported in Table 9.15, with sites arranged from furthest downstream, Yarramundi (N44), to furthest upstream, Pheasants Nest weir (N86).

Table 9.15 Trend analysis results for sites downstream of Upper Nepean storages. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
N44	NA	8.2	-6.6	1.5	-8.5	15.3	5.8	10.4	3.9	-5.3	NA	NA	NA
N57	15.1	10.6	-3.4	NA	21.0	12.9	NA	NA	NA	NA	NA	NA	7.7
N67	NA	NA	-6.0	NA	NA	22.4	NA	26.4	6.9	-4.9	NA	NA	NA
N92	NA	-14.1	-7.6	NA	NA	18.3	10.4	17.1	NA	-5.7	-5.5	NA	-6.5
N86	NA	NA	NA	2.0	NA	12.7	NA	NA	NA	NA	NA	NA	-16.1

* For description of sites see Section 6.1.

All sites were found to have a statistically significant increasing trend in iron (filtered) while a number of sites also experienced increased concentrations of manganese (filtered). Decreasing nitrogen and

phosphorus at Maldon weir (N92) led to decreasing concentrations in chlorophyll-*a*. Chlorophyll-*a* was found to increase at downstream sites Penrith weir (N57) and Yarramundi (N44).

Conductivity decreased at all sites downstream of Pheasants Nest weir (N86). It should be noted that discharge increased at all sites during the reporting period, with the 2003-2007 period being a particularly dry period.

9.6.2 Woronora system

The Needles (G0515) is the only SCA routine monitoring site downstream of Woronora Dam.

Table 9.16 Trend analysis results for the site downstream of Lake Woronora. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
G0515	NA	NA	1.7	-1.4	NA	4.5	5.5	6.1	4.3	NA	NA	NA	-6.2

* For description of site see Section 6.1.

As seen in Table 9.16 small magnitude increasing trends in iron and manganese (filterable and total) were detected. Metal concentrations remain similar to those observed above Lake Woronora, which also exhibited increasing trends for metals. This can be attributed to environmental flows which commenced in early 2000.

9.6.2 Shoalhaven system

The routine site directly below Lake Yarrunga (E851) was selected for trend analysis.

Table 9.17 Trend analysis results for the site downstream of Lake Yarrunga. Statistically significant trends are reported in percentage change per year.

Site*	Aluminium (Total)	Chlorophyll-a	Conductivity	Dissolved Oxygen (%sat)	E.Coli	Iron (Filtered)	Iron (Total)	Manganese (Filtered)	Manganese (Total)	Nitrogen (Total)	Phosphorus (Total)	True Colour (@400nm)	Turbidity
E851	NA	NA	NA	NA	NA	-6.1	-6.8	-16.1	-14.3	NA	6.1	-3.0	-14.9

* For description of site see Section 6.1.

As shown in Table 9.17, iron and manganese decreased alongside turbidity. Increased frequency of spills and release of surface water from Lake Yarrunga are thought to be the main drivers of the reduction.

10 References

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11 Glossary

Aesthetic	Considered pleasant to the senses.
Algae	Simple chlorophyll-bearing plants, mostly aquatic and microscopic in size.
Algal bloom	Rapid growth of algae in surface waters due to an increase in nutrients such as nitrogen and phosphorus and ideal conditions for proliferation.
Alkalinity	The capacity to neutralise acid.
Analytes	Physical, chemical and biological properties analysed.
Catchment	Area where water is collected by the natural landscape. In a catchment, all rain and run-off water eventually flows to a creek, river, lake or ocean, or into the groundwater system.
Chlorophyll- <i>a</i>	Green pigments in plants.
Colour	Colour is a measure of the absorption of light in certain frequencies by water. Colour in water may result from the presence of natural metallic ions (iron and manganese), humus and peat materials, algae and industrial wastes. True colour is the colour of water with no suspended material present.
Composite sample	A sample made up of component samples or collected at more than one location.
Contaminant	Biological (e.g. bacterial and viral pathogens) and chemical introductions capable of producing an adverse effect in biota.
Cyanobacteria	A division of photosynthetic bacteria that can produce toxins, formerly known as blue–green algae.
Cyanotoxin	Toxin produced by some cyanobacteria.
Cyst	A resting spore of many algae and protozoa.
Detection limit	The smallest concentration or amount of a substance that can be reported as present with a specified degree of certainty by definite complete analytical procedure.
Diurnal	Daily.
Dissolved oxygen	The amount of oxygen dissolved in water.

Environmental flow	Water released from reservoirs aimed at improving and maintaining the ecological health of the river downstream.
Epilimnion	The warmer upper layer of water in a stratified lake.
Eutrophic	Water bodies rich in mineral and organic nutrients that promote a proliferation of plant life.
Hardness	A measure of the concentration of calcium and magnesium ions in water, frequently expressed as mg/L calcium carbonate equivalent (CaCO ₃).
Hypolimnion	The colder lower layer of water in a stratified lake.
IFA	A presumptive test to detect <i>Giardia</i> cysts and <i>Cryptosporidium</i> oocysts by microscopy after staining with immuno-fluorescent antibodies
Indicator	A parameter that can be used to provide a measure of the quality of water or the condition of an ecosystem.
Median	The value of the middle item when the data are arranged in an increasing or decreasing order of magnitude.
Metal	Certain opaque, fusible, ductile, and typically lustrous substances that yield basic oxides and hydroxides that generally occur in trace amounts in living organisms. Can become toxic at higher concentrations.
Nutrients	Compounds required for growth by plants and other organisms. Major plant nutrients are phosphorus and nitrogen.
Oligotrophic	Water bodies with low primary productivity, the result of low nutrient content.
Oocyst	Dormant but resistant phase of the life cycle of some protozoa.
Parameter	A measurable or quantifiable characteristic or feature.
Pathogens	Disease-causing organisms, such as bacteria and viruses.
Pesticide	A chemical that is toxic to pests.
pH	A measure of the degree of acidity or alkalinity, expressed on a logarithmic scale of one to 14 (one is most acid, seven neutral and 14 most alkaline).
Physicochemical	Refers to the physical (e.g. temperature, electrical conductivity) and chemical (e.g. concentrations of nitrate, mercury) characteristics of water.

Reservoir	An artificial body of water, often behind a dam.
Runoff	The portion of precipitation that flows towards streams, either above or below ground, often carrying dissolved or suspended material.
Sediment	Soil or other particles that settle to the bottom of lakes, rivers, and other waters.
Special Area	Areas of unspoilt bushland close to reservoirs that act as a buffer zones to help stop pollutants from entering reservoirs.
Stratification	Arrangement of layers, especially of water having different physico-chemical properties in lakes.
Thermal stratification	The formation of distinct layers in lakes based on temperature, usually most pronounced during the summer months.
Thermocline	A region of rapidly changing temperature in a lake, found between the epilimnion and hypolimnion.
Thermotolerant coliforms	Bacteria used as a primary indicator of sewage pollution. Thermotolerant coliforms may in some instances include bacteria of environmental rather than faecal origin.
Toxin	A poisonous substance of biological origin.
Turbidity	A measure of the amount of suspended material (usually fine clay or silt particles) in water and thus the degree of scattering or absorption of light in the water.
Trophic status	Categorisation based on the level of nutrient enrichment in a lake which could lead to algal growth e.g. oligotrophic (low mineral and nutrient concentrations), eutrophic (high mineral and nutrient concentrations).
Water column	The region of water between the surface and bottom of a lake or river.
Water filtration plant	A treatment plant that improves water quality by removing impurities through filtration.
Water quality benchmark	Scientific data evaluated to derive the recommended quality of water for various uses.

12 Acronyms

ADWG	Australian Drinking Water Guidelines
ASU	Areal standard unit (a measure of cyanobacteria)
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AusRivAS	Australian Rivers Assessment System
CFU	Colony forming units (a measure of microorganisms)
EPA	Environment Protection Authority
<i>E. coli</i>	Escherichia coli
GAM	General Additive Model
IFA	Immuno-fluorescent antibody
LOR	Limit of Reporting
mg/L	Milligrams per litre
mm	Millimetres
ML	Megalitre (one million litres)
NHMRC	National Health and Medical Research Council
NTU	Nephelometric turbidity units
QA/QC	Quality assurance and quality control
RWQIRP	Raw Water Quality Incident Response Plan
µg/L	Micrograms per litre
SCA	Sydney Catchment Authority
SCARMS	SCA Reservoir Management System
WFP	Water filtration plant