2007 Audit of the Sydney Drinking Water Catchment

Report to the Minister for Climate Change, Environment and Water NSW Government

Department of **Environment & Climate Change** NSW

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NSW Government

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Executive Summary

The *Sydney Water Catchment Management Act 1998* requires that an audit of the state of the land in the Sydney drinking water catchment (the Catchment) be undertaken every two years, and that a report on that audit be submitted to the Minister responsible for the Sydney Catchment Authority (SCA). The Department of Environment and Climate Change (DECC) was the nominated agency to undertake the 2007 Audit, covering the period from 1 July 2005 to 30 June 2007. The Audit's terms of reference were to:

- audit and report on the Catchment consistent with current methods used for the purpose of *New South Wales State of the Environment* (SoE) reporting, focusing on the priority sub-catchments
- as part of the audit, consult with stakeholders within and outside the Catchment to seek information and data that may assist with the audit and to seek comments relating to the state of the Catchment.

In this Audit, consistency with current methods for SoE reporting was achieved by using the 'Pressure-State-Response' (PSR) model of environmental reporting. The same 16 indicators used in previous audits were used again to quantify and simplify the complex natures of environmental states and pressures and their interactions, under four broad themes: raw water quality; managing water resources; land condition; and ecosystem health. Using the same indicators also allows an analysis of trends in the state of the Catchment. The Auditor assessed the progress made on recommendations in the 2005 audit report and the findings of this Audit, and developed a set of recommendations for the 2007 Audit report.

The Catchment is split into 28 sub-catchments of which nine have been assessed as priorities for SCA. For the first time, this Audit includes information compiled on a sub-catchment basis, to highlight the condition of individual sub-catchments and the pressures on them.

Agriculture and sewage treatment plants (STPs) are major sources of nutrient loads in the Catchment. The total nutrient contribution from STPs has decreased since the 2005 Audit period. The Kangaroo River, Mulwaree River, Wingecarribee River, Upper Coxs River, Wollondilly River, Upper Wollondilly River and Reedy Creek sub-catchments had the greatest nutrient load export potential for either phosphorus or nitrogen or both. The Auditor recommends continuing action to reduce nutrient loads and improved environmental performance at the STPs. There are also a number of villages in the Catchment that have no sewerage service and these may contribute nutrients to the Catchment if they are not appropriately managed.

Quality requirements for raw water from the SCA's storages supplied to water filtration plants were generally met to the satisfaction of Sydney Water Corporation and the NSW Department of Health. There was a decrease in the exceedence of the Bulk Water Supply Agreement for algae, turbidity, colour and pH parameters compared to the 2005 Audit period. Raw water supplied to the Kangaroo Valley (Kangaroo River sub-catchment) and Wingecarribee (Wingecarribee River sub-catchment) filtration plants had the most exceedences of quality requirements.

The incidence of toxic blue-green algae (cyanobacterial) in the water storages decreased slightly compared to the 2005 Audit period. The incidence of total cyanobacteria increased slightly compared to the 2005 Audit period, and there was continued presence of cyanobacterial indicating high levels of nutrients in some parts of the Catchment. There were incidences of toxic blue-green algae in Lake Yarrunga (Kangaroo River sub-catchment), Wingecarribee Reservoir (Wingecarribee River sub-catchment), and Lake Burragorang during the 2007 Audit period. In August 2007, outside the Audit period, an algal bloom developed and has since persisted in the Lake Burragorang storage, activating the SCA's short-term storage management procedures which are maintaining the quality of raw water supplied to the water filtration plants. Presence of pathogens in the storages remained low where sampling occurred. There was a continued presence of pathogens at a number of sites in the Catchment requiring further investigation, and the absence of pathogen monitoring in certain sub-catchments was noted, prompting a recommendation to undertake such monitoring in the Kangaroo River sub-catchment.

The licensed environmental flow releases from the water storages were reduced in the 2007 Audit period because of the drought and the consequent low levels of the water storages. The transfer of large volumes of

bulk water from the Wingecarribee Reservoir into the local Upper Nepean tributaries and the Wingecarribee River may have affected the health of those waterways.

The Upper Coxs River, Upper Wollondilly River, Wingecarribee River, Wollondilly River, and Kangaroo River sub-catchments were identified as areas affected by surface water extractions in the 2007 Audit period. The greatest number of groundwater bores are located in the Wingecarribee River sub-catchment. The Kangaroo River, Mulwaree River, Wollondilly River and Upper Wollondilly River sub-catchments also have a large number of groundwater bores.

The number of development applications submitted to the SCA for review and concurrence decreased during the 2007 Audit period. Large areas of agriculture and increased urbanisation and rural residential development can put pressure on the water quality in the Catchment, unless best management practices are adopted. The SCA's re-assessment of over 1000 identified sites of pollution and potential contamination, showed a decrease in the number of sites that are in the very high, high and medium risk categories. The majority of the sites in the higher categories of assessed pollution and contamination risk are located in the Kangaroo River, Werriberri Creek and Wingecarribee River sub-catchments.

Active gully erosion has been observed in only a small percentage of the Catchment, but local impacts can be severe and local remediation action is required. Eleven percent of the Catchment has very high or high estimated rill or sheet soil erosion, but only a small area of the Catchment is susceptible to or experiencing salinity issues.

The percentage of locations where water quality parameters exceeded ANZECC guideline values for aquatic ecosystem protection was higher in the 2007 Audit period than in the 2005 Audit period for seven out of the 12 parameters tested. This represents a deterioration in water quality across the Catchment. The number of locations where ANZECC water quality guideline values were exceeded increased for physical and toxicant parameters, and remained high for nutrient parameters compared to the 2005 Audit period. Degraded water quality was found in approximately half of the 28 sub-catchments, including the Kangaroo River, Werriberri Creek, Wingecarribee River, Grose-Blue Mountains, Lake Burragorang, Nattai River and Upper Nepean River sub-catchments. The Auditor considers it likely that a number of other sub-catchments have degraded water quality, because of identified pressures in these sub-catchments. However, there are no current water quality monitoring points in these sub-catchments, prompting an Audit recommendation to establish monitoring programs in all sub-catchments.

There were fewer water bodies where analysis of macroinvertebrate assemblages produced 'similar to reference' ratings compared to the 2005 Audit period. Macroinvertebrate assemblages at 39 per cent of the sampled locations in the Catchment were found to be 'significantly impaired' and two per cent of all sampled locations had a 'severely impaired' rating. The invasion of introduced fish species is problematic throughout the Catchment, indicating a level of disturbance to native species, flows or riparian vegetation structure. Fish populations with low or no endemic species, suggesting a potentially disturbed water body, were found in the Mulwaree River, Werriberri Creek, Mid Coxs River and Wollondilly River sub-catchments.

Riparian zones outside the Special Areas around the water storages were under variable pressure, due to little to no standing vegetation cover, stock access, and the presence of exotic species. The state of riparian and native vegetation varied across the Catchment. Native vegetation covered approximately 50 per cent of the Catchment. In broad terms, the majority of the sub-catchments adjacent to water storages had a good cover of vegetation. Only the Mulwaree River, Upper Wollondilly River, Braidwood Creek and Reedy Creek sub-catchments in the upper reaches of the Catchment had a poor cover of vegetation. Approved land clearing resulting in loss of vegetation remained low during the 2007 Audit period.

The Catchment was officially declared as drought-affected for approximately three quarters of the 2007 Audit period. Where relevant, the Auditor interpreted the influence of the drought when reporting findings and implications against relevant indicators by referring in the report to drought or low-flow conditions. Climate change may cause changes in average temperature, rainfall and evaporation in the Catchment. These changes will have long-term consequences for the Catchment, but the impacts are more likely to be felt through extreme weather events. Projections suggest that there will be more hot days, bushfires, droughts and intense storms. Adaptation to climate change and the management responses required are continuing challenges for land and water managers/agencies in the Catchment.

From the 16 indicators and available data that was assessed in this Audit report the sub-catchments under the most pressure are the Kangaroo River, Wingecarribee River, Mulwaree River and Wollondilly River. The

Auditor found that there were policies, plans and strategies in place, with both short- and long-term actions in progress. Gaps in monitoring or improvements necessary in responses to these issues are addressed in the Audit recommendations. Some recommendations are carried over or a revision of a recommendation from the 2005 Audit. A list of Auditor's 2007 recommendations, including those carried over or revised from the 2005 Audit is provided below.

Recommendations

Raw water quality

1	The operators and regulator(s) of the sewage treatment systems in the Catchment should continue efforts to reduce current levels of nutrient loads discharged into the Catchment.	New
	The SCA focus its programs for nutrient reduction from diffuse sources on the Wingecarribee River (priority), Wollondilly River (priority), and Mulwaree River (priority) sub-catchments, and encourage other organisations undertaking related programs to focus on these same sub-catchments where possible.	2005 Rec. 5 Carried over
	The SCA identify the cause of exceedence of the Bulk Water Supply Agreement for turbidity, pH and algae at water filtration plants.	2005 Rec. 6 Carried over
2	The SCA should continue the process of understanding the causes of the 'high' incidences of algae in the water storages of the Kangaroo River (priority), Wingecarribee River (priority) and Lake Burragorang sub-catchments, to help ensure that specific management strategies are in place for the short, medium and long term in each sub-catchment.	New (Revised 2005 Rec. 7)
3	The SCA should investigate the causes of the continuing presence of pathogens in the Nattai River (Gibbergunyah Creek), and the Wollondilly River, Mid Coxs River and Werriberri Creek (priority) sub-catchments.	New (Revised 2005 Rec. 8)
4	The SCA should undertake sampling for the presence of pathogens in the Kangaroo River (priority) sub-catchment.	New

Managing water resources

	The DWE undertake research into the impact of different levels of water extraction and harvesting of water in farm dams on flow regimes and ecosystem health within the Catchment, focusing on the sub-catchments most under pressure from water extraction and water harvesting.	2005 Rec. 9 Carried over
	The DNR require groundwater extraction volume metering and reporting with a priority for implementation on licences in the Southern Highlands, Kangaroo River (priority), Werriberri Creek (priority) and Wingecarribee River (priority) sub-catchments.	2005 Rec. 11 Carried over
	The DNR give consideration to locating new monitoring bores in the Southern Highlands, Kangaroo River (priority), Werriberri Creek (priority) and Wingecarribee River (priority) sub-catchments.	2005 Rec. 12 Carried over
5	DWE should work with stakeholders to complete a Water Sharing Plan that covers the Catchment as soon as practicable.	New

Land condition

	The SCA and DECC prepare a detailed land-use map at five-year intervals. The resolution and categorisation should be sufficient so that change from the previous map can be determined.	2005 Rec. 16 Carried over
	The SCA develop pollution prevention or rehabilitation programs at sites identified as very high, high and medium risk to water quality, in consultation with relevant agencies, operators and landholders.	2005 Rec. 18 Carried over

	DECC and DWE develop systems in consultation with the SCA for recording the location, nature and extent of actual cases of soil erosion and land salinity in the Catchment.	2005 Rec. 19 Carried over
6	The SCA, DECC and CMAs should undertake programs that address soil erosion and salinity in the areas with identified and observed risk, and integrate them with other programs for riparian and vegetation management where possible.	New (Revised 2005 Rec. 20)

Ecosystem health

7	The SCA should investigate the reasons and drivers for the decline in both water quality and macroinvertebrate health in those sub-catchments where declines have been documented.	New
8	The SCA should review its water quality and macroinvertebrate monitoring program to ensure that appropriate integrated ecosystem monitoring is undertaken in all sub-catchments.	New (Revised 2005 Rec. 21 and 22)
9	The SCA should undertake follow-up monitoring at macroinvertebrate monitoring locations that have significantly impaired or severely impaired AusRivAS ratings.	New (Revised 2005 Rec. 23)
	The DPI, in consultation with SCA, develop a fish community monitoring program for the Catchment to assist the management of aquatic ecosystem health.	2005 Rec. 24 Carried over
	DECC and SCA jointly undertake vegetation condition mapping of areas outside the Special Areas.	2005 Rec. 25 Carried over
	The SCA examine the potential for, and benefits of, integrating ecosystem water quality, macroinvertebrate, fish (when developed) and riparian vegetation condition monitoring programs	2005 Rec. 3 Carried over

General

10	The frequency of the Audit should be changed to every three years, instead of two years, from 2009 to align with State of Environment (SoE) and Monitoring, Evaluation and Reporting (MER) timeframes.	New (Revised 2005 Rec. 1)
11	Opportunities for the development of common or complementary indicators between the Audit SoE and MER reporting processes should be examined.	New
12	The SCA, DECC and CMAs should work together to establish a spatial information system to track and record information on all on-ground works being undertaken or funded by government for the purposes of water quality and ecosystem health management in the Catchment.	New (Revised 2005 Rec. 2)

Chapter 1
Introduction

1.1 The Sydney Water Catchment Management Act 1998 (the Act)

Section 42 of the *Sydney Water Catchment Management Act 1998* (the Act) requires an audit of the state of the land of the Sydney drinking water catchment area (the Catchment) be undertaken every two years, and that a report on this audit be submitted to the Minister responsible for the Sydney Catchment Authority (SCA). Section 42 of the Act also requires that the Minister nominate a person other than the SCA to conduct the audit and prepare the audit report.

The Minister nominated the Environment Protection Authority (EPA) to undertake the 2003 Audit. The EPA's successor organisations, the Department of Environment and Conservation (DEC) and the Department of Environment and Climate Change (DECC), undertaken the 2005 Audit and now the 2007 Audit respectively.

1.2 Overview of the Audit

The purpose of the 2007 Audit is to provide information to all stakeholders about the state of the Catchment during the period from 1 July 2005 to 30 June 2007. Information is provided on the indicators used to assess the pressures on and the state of the Catchment, and about changes in the state of the Catchment over time, by identifying trends in selected indicators where possible. Information from the 2007 Audit, and past audits, can be used to guide land managers and the community to make decisions about the management of the Catchment.

This is the fifth audit conducted under section 42 of the Act, with previous audits undertaken in 2005, 2003, 2001 and 1999. The Terms of Reference originally provided by the Minister for the 2003 Audit were used in 2005 and now again in 2007, namely:

- audit and report on the catchment consistent with current methods used for the purpose of *New South Wales State of the Environment* reporting, focusing on the priority sub-catchments
- as part of the audit, consult with stakeholders within and outside the catchment to seek information and data that may assist with the audit and to seek comments relating to the state of the catchment.

1.3 The Sydney drinking water catchment (the Catchment)

The Sydney drinking water catchment (the Catchment) collectss and stores up to 2.6 million megalitres of water to supply Sydney, the Blue Mountains, the Illawarra and parts of the Shoalhaven area with between an average of 1,000 and 1,500 megalitres of water every day.

The Catchment covers part of the hydrologic catchments of the Hawkesbury-Nepean, Shoalhaven and Woronora rivers and extends over 16,000 square kilometres. The Catchment extends from north of Lithgow on the Coxs River, from the head of the Shoalhaven River in the south near Cooma, and from the Woronora River in the east to the source of the Wollondilly River west of Goulburn (Map 1.1). The Catchment is split into 28 sub-catchments. For the purposes of the audit, the Catchment also includes the hydrologic catchment of the Prospect Reservoir in western Sydney.

Priority sub-catchments

The Terms of Reference require the audit to focus on the priority sub-catchments. The Sydney Catchment Authority (SCA) developed a methodology to identify the priority sub-catchments by assessing the water quality, risk to the SCA reservoir water quality, and stream health. The 2007 Audit considers that this was an appropriate approach, and has adopted this method as the focus for some aspects of the audit process.

The priority sub-catchments are:

- Kangaroo River
- Mulwaree River
- Werriberri Creek
- Wingecarribee River
- Lower Coxs River
- Mid Coxs River
- Upper Coxs River
- Wollondilly River
- Upper Wollondilly River

1.4 Multiple barrier approach to drinking water quality management

The management of drinking water quality in the Catchment uses a multiple barrier approach. The strength of the multiple barrier approach is that a failure of one barrier may be compensated by effective operation of the remaining barriers, minimising the likelihood of contaminants passing through the entire treatment system and being present in sufficient amounts to cause harm to consumers.

Traditional preventive measures are incorporated as or within a number of barriers, including:

- catchment management and source water protection
- detention in protected reservoirs or storages
- extraction management
- coagulation, flocculation, sedimentation and filtration
- disinfection
- protection and maintenance of the distribution system.

Catchment management

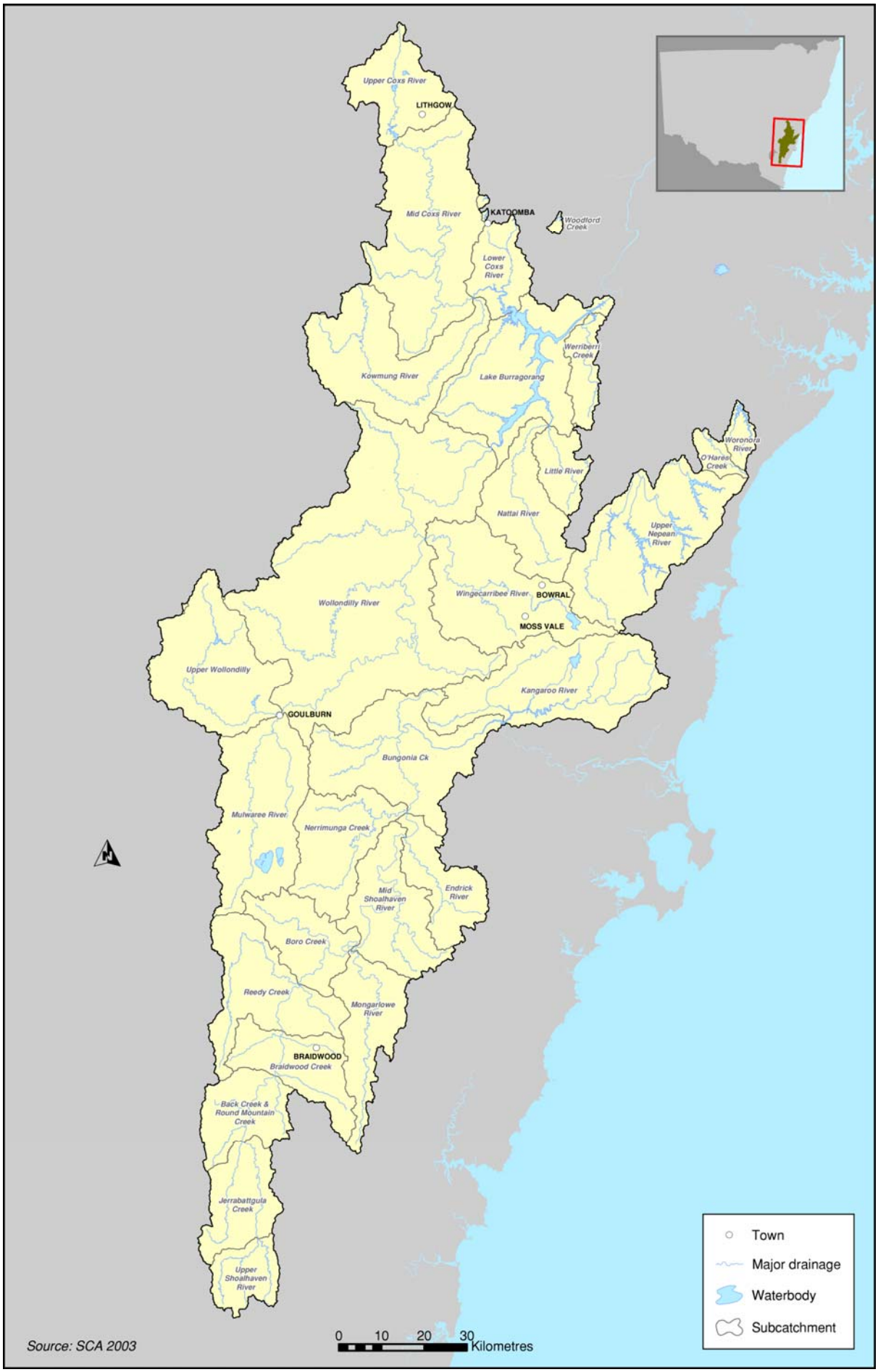
Catchment management provides the first barrier for the protection of water quality. By decreasing contamination of source water, the amount of treatment and quantity of chemicals needed is reduced. There are a number of agencies that are responsible for aspects of catchment management in the Catchment, these include the Sydney Catchment Authority (SCA), the Department of Water and Energy (DWE), the Department of Environment and Climate Change (DECC), Catchment Management Authorities (CMAs) and councils. The roles and responsibilities of these and other agencies are outlined in Appendix B. The SCA seeks to provide leadership in catchment protection through a set of tools including regulatory powers, policy development, inter-agency cooperation, research, community education and funding for catchment enhancement works. The SCA operates as an owner, regulator and partner in the management of catchment lands. The Catchment has Special Areas around the water storage areas where access and usage are restricted, and outer catchment areas where land uses such as urbanisation, mining, agriculture and industrial activities are permitted.

Storage and extraction management

The detention of water in reservoirs can reduce the number of faecal microorganisms through settling and inactivation and allow other suspended material to settle. Where a number of water sources are available, there may be flexibility in the selection of water for treatment and supply. Within a single water body, selective use of multiple extraction points can provide protection against localised contamination either horizontally or vertically through the water column. The SCA's primary activities in storage management are the selection of water from different storages and from different levels in the storages to meet bulk water quantity and quality requirements, destratification of storages where necessary, and monitoring water quality for a range of parameters.

Delivery system management

Effective maintenance procedures to repair faults and burst mains that prevent contamination, appropriate security to prevent unauthorized access to, or interference with water storages should be in place. Pipes need to be monitored for corrosion and the growth of biofilms should be minimized. The SCA has developed system management plans and standard operating procedures for the safe operation and maintenance of assets such as its reservoir off-takes, canals and pipelines.



Map 1.1: Sydney drinking water catchment

Chapter 2
Audit Methodology

2.1 Overview

The 2007 Audit Terms of Reference require that current methods for *New South Wales State of the Environment* (SoE) reporting are used. The main assessment tool in SoE reporting is the 'Pressure-State-Response' (PSR) model, and this model has been used in this and previous Audits.

Pressure-State-Response model

The Pressure-State-Response (PSR) model identifies the cause-effect chains that help us understand and scientifically analyse environmental resource use and problems. The PSR approach assumes that human activities exert pressures on the environment which can induce changes in the state of the environment. Society then responds to changes (in pressure or state) with environmental/economic policies and programs to prevent, reduce or mitigate pressures and/or environmental damage. In this model, indicators are an essential source of information about environmental systems. An indicator quantifies and aggregates data that can be measured and monitored to determine the pressure or state, and to assess whether change is taking place. Accordingly, indicators are selected to provide information about the functioning of a specific system to support decision making and management (Figure 2.1).

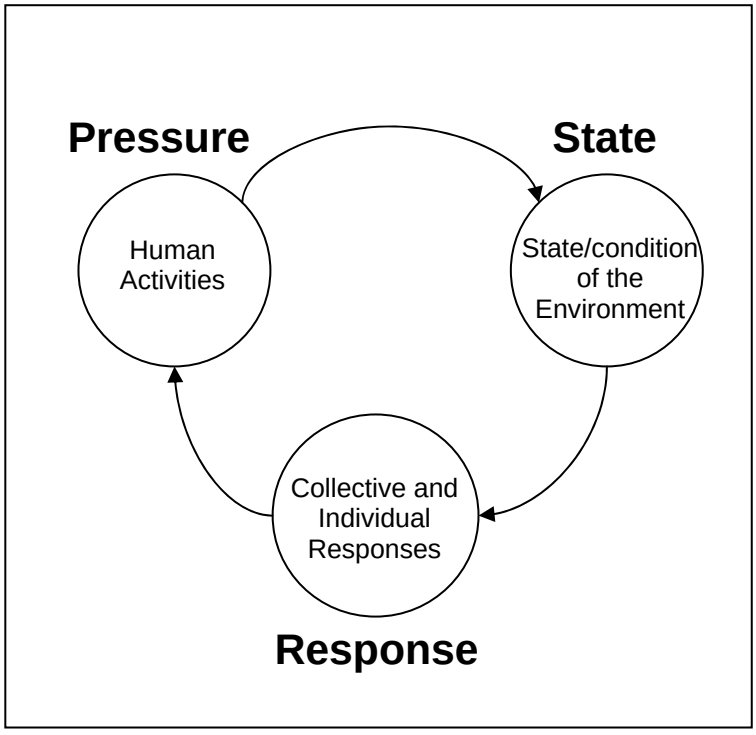


Figure 2.1: Simplified representation of the Pressure-State-Response model

Audit indicators

The 2003 and 2005 audits used a set of 16 indicators chosen to provide an understanding of the state of water quality and overall ecosystem health, and to measure environmental pressures in the Catchment.

To simplify understanding of the complex nature and diversity of issues in the Catchment, the indicators were grouped according to four broad themes: Raw Water Quality; Managing Water Resources; Land Condition; and Ecosystem Health. The full list of audit indicators is presented in Table 2.1.

Table 2.1: 2007 Audit indicators

Theme	Indicator
Raw Water Quality	Nutrient Load
	Raw Water Quality at Water Filtration Plants
	Algal Blooms
	Pathogens
Managing Water Resources	Surface Water Extraction
	Groundwater Extraction
	Water for the Environment
Land Condition	Changes in Land Use
	Sites of Pollution and Potential Contamination
	Soil Erosion
	Dryland Salinity
Ecosystem Health	Ecosystem Water Quality
	Macroinvertebrates
	Fish
	Riparian Vegetation
	Native Vegetation

The 2007 Audit has adopted these indicators because:

- this is consistent with the Review of the Catchment Audit Framework undertaken by the Sustainable Investment Research Institute in 2003
- it enables direct comparison with the 2003 and 2005 Audit results to identify trends
- the indicators remain relevant for describing the pressures on, and the state of the Catchment
- the indicators are considered to be readily understandable by resource management organisations, land managers and the general community.

2.2 Arrangements for the Audit

Agreement with the SCA

A written agreement was negotiated between the SCA and DECC for the conduct of the Audit. The agreement defined the roles of the SCA as the agency responsible for the administration of the Act, and of DECC as the nominated Auditor in accordance with Section 42 of the Act. The agreement documented the Terms of Reference, an itemised budget and key milestones for the Audit, the obligations and undertakings of the parties that ensured the successful completion of the Audit, and the primary points of contact within both parties.

The Audit Team

The Auditor was Dr Klaus Koop (DECC Director Environment and Conservation Science). The Auditor was supported by a project team assembled for the duration of the audit. Team members were:

Project Manager: Neale Philip

Senior Project Officer: Dr Sonia Claus

Project Officers: Alex Carthey and Eren Delgado.

Progress of the 2007 Audit was guided by a DECC internal steering committee, consisting of Klaus Koop (chairman), Stella Whittaker (Director Environmental Policy) and Michael Wright (Director Reserve and Wildlife Conservation).

The Audit report

This Audit report was submitted to the Minister in November 2007. In accordance with Section 39 of the Act, the Audit report was also laid before both Houses of Parliament within the specified one month of being submitted to the Minister. The Audit Report was also made available on the DECC's and SCA's websites, and copies were mailed to interested stakeholders.

2.3 Conduct of the Audit

Information gathering

The primary data and information sources for the 2007 Audit were the SCA, DECC, the catchment management authorities (CMAs), the Department of Water and Energy (DWE) and the Department of Primary Industries (DPI), because these agencies have responsibilities as resource and catchment managers. The 2007 Audit also sought information from these agencies on the nature and extent of actions undertaken in response to the recommendations made in the 2005 Audit report.

The 2007 Audit recognised the potential breadth of knowledge, information and data that may also be available from other stakeholders in the Catchment. Invitations to provide information and submissions were circulated via individual letters and general press advertisements throughout the Catchment. This was achieved by:

i) directly writing to 66 stakeholders, including relevant government agencies, CMAs, local government, industry associations, Local Aboriginal Land Councils and other non-government organizations
ii) inviting submissions from the general public through notices in *The Sydney Morning Herald, Daily Telegraph, Koori Mail* and 21 regional and local newspapers.

The newspaper notice text was similar to the written stakeholder invitations, and is reproduced in Figure 2.2.

advertisement

Audit of Sydney Water Catchment
In accordance with the Sydney Water Catchment Management Act the Minister for Climate Change, Environment and Water has commissioned the Department of Environment and Climate Change (DECC) to undertake an audit of Sydney's drinking water catchments. The audit is undertaken every two years to provide a snapshot of the health of the catchment.
This audit will use a *State of the Environment* 'pressure-state-response' model, focusing on the priority sub-catchment within the Sydney Water catchment area. The audit will be assessing the condition of the catchment using indicators relevant to raw water supply, managing water resources, land condition and ecosystem health.
DECC is inviting interested parties to make a submission presenting any information or data that may assist the conduct of the audit and provide comments relating to the state of the catchment.

Please send submissions to:
Sydney Water Catchment Audit
NSW Department of Environment and Climate Change
PO Box A290 Sydney South NSW 1232
or email them to: SWCA2007@environment.nsw.gov.au

The closing date for the receipt of submissions is 3 September 2007.
Inquiries regarding the audit and its terms of reference can be made to Neale Philip on (02) 9995 5624.

Figure 2.2: Notice inviting submissions

Twenty seven stakeholders responded to the invitation, and 16 submissions were subsequently received. The 16 submissions comprised nine from State agencies, one from local government, two from Catchment Management Authorities, and four from individuals/groups. The Audit Team acknowledged all submissions in writing and has used the information and data provided. Individuals and organisations that provided a submission are listed in Appendix A.

Aboriginal communities in the Catchment

The 2007 Audit and the 2005 Audit before it recognised that Aboriginal communities in the Catchment were stakeholders in the process for a range of reasons. There is Aboriginal presence in the Catchment, both past and present. The Blue Mountains National Park, Nattai Conservation Area and other reserves around the Catchment are known to contain some of the most culturally significant sites of Aboriginal occupation of the land. Parts of the Catchment are Country for the Deerubin, Dharrawal, Pejar, and other Aboriginal peoples. Aboriginal communities own significant tracts of land in the Catchment.

In 2005 and 2007, the Auditor wrote to the NSW Aboriginal Land Council, extending an invitation for them to make a submission. The 2007 Auditor also extended the invitation to five local Aboriginal land councils in the Catchment. The NSW Aboriginal Land Council responded to the 2005 invitation, by suggesting that cultural indicators be added into the Audit's scope. That suggestion was not accepted, however, because it is not consistent with the requirements of the Act. The 2007 invitation to make a submission on the existing Audit indicators did not receive any responses from any of the land councils.

The Auditor regrets that the current approaches have not successfully elicited the Aboriginal communities' views on the state of the land of the Catchment under the existing Audit Terms of Reference. The opportunity to add value to the Audit by engagement and consultation of Aboriginal stakeholders has been lost for another two years.

The Auditor has since reviewed the current Audit practice and concluded that the 2007 invitations were insufficient to satisfy new guidelines for effective engagement of Aboriginal communities in government processes (DECC, in press). These guidelines were prepared as a response to Federal and State Government initiatives to increase the level of Aboriginal participation in decision making and to address Indigenous disadvantage.

An effective engagement process is one that has:

- researched which Aboriginal people and organisations the Audit should engage with
- made contact with and established a level of trust, confidence and clarity on what benefits will ensue from the engagement process for the Aboriginal communities and for the Audit
- created culturally appropriate engagement activities
- addressed issues of intellectual property rights and confidentiality where appropriate
- established critical points for feedback throughout the process
- recognised the costs and time associated with effective engagement.

The Auditor notes that the current Audit timeframe is too short for this level of Aboriginal community engagement. The Auditor is aware that the SCA, DECC and the CMAs in the Catchment have officers and programs whose core businesses include effective engagement of Aboriginal communities on a range of government activities. The Auditor believes that a communication and engagement package should be developed along the above lines at an early stage for future audits.

Catchment inspections

The Audit Team undertook catchment inspections in August and September 2007 in order to view some of the specific localities and premises that represented known issues in the Catchment. Officers from the SCA, DECC and/or the Hawkesbury-Nepean CMA (H-N CMA) accompanied the Audit Team and provided expert advice on the issues. Issues of particular interest to the Audit team included:

- point source pollution and/or remediation (e.g. sewage treatment plants, mines, erosion sites, rehabilitation sites)
- creek bed cracking (in areas where longwall mining has occurred)
- land-use change.

The Audit Team focused on the identified priority sub-catchments, when it undertook the Catchment inspections at the following locations:

- Upper and Middle Coxs River and Farmers Creek around Lithgow
- Werriberri Creek near Lake Burragorang
- Mulwaree River, Wollondilly and Wingecarribee Rivers around Goulburn
- Nepean Dam, Wingecarribee River and Reservoir, Kangaloon Borefield in the Southern Highlands
- Kangaroo River
- Waratah Rivulet (Woronora River).

The outcomes and findings from the inspections are incorporated into case studies and the following chapters of this Audit report.

Analysis and interpretation

Information and data from the submissions were compiled and catalogued, and data identified for later analysis within their appropriate theme(s) and indicator(s) (Table 2.1). Where relevant, case studies were identified to highlight issues, utilising information provided by stakeholders in their submissions and from observations made during catchment inspections.

Where data were available, findings from the 2007 Audit were compared to those from the 2003 and 2005 audit periods, so that changes in states and pressures could be identified and evaluated. This information was then used to describe how the state of the Catchment had changed since the previous audits, and which pressures might be implicated in that change. For the first time, the 2007 Audit has compiled and presented information on a sub-catchment basis, to highlight the state of individual sub-catchments and the pressures on them.

During the 2007 Audit period (1 July 2005 to 30 June 2007), the Catchment was officially declared as drought-affected for approximately three quarters of the period (Table 2.2). Where relevant, the 2007 Audit interpreted the influence of the drought when reporting findings and implications against relevant indicators, by referring in the report to drought or low-flow conditions.

Table 2.2: Drought declarations in Rural Lands Protection Board (RLPB) areas in the Catchment during the 2007 Audit period

Area	Month											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Southern Highlands / Warragamba areas (Moss Vale RLPB)												
2005-06												
2006-07												
Lithgow area (Central Tablelands RLPB)												
2005-06												
2006-07												
Goulburn area (Goulburn RLPB)												
2005-06												
2006-07												

Source: NSW Department of Primary Industries website

Legend:

In drought

Marginal

Satisfactory

Varies across sub-catchments

or

The drought-declared status of the Catchment in the 2005 Audit period was also retrospectively examined for comparison with the 2007 Audit period. The drought situation in the northern half of the Catchment (Moss Vale and Lithgow RLPBs) was worse in the 2007 Audit period (average 16 of 24 months in drought) than in the 2005 period (average 9.5 of 24 months in drought), and it was better in the southern half of the Catchment (Goulburn RLPB) in the 2007 period (18 of 24 months in drought) than in the 2005 period (23 of 24 months in drought).

Future directions in the collection and analysis of data for each indicator was highlighted and if required resulted in a recommendation. The actions and responses to the pressures identified in each theme were listed but no assessment of the effectiveness of these actions and responses was made. Any gaps in the actions and responses that are evident from the findings and implications were also noted in each theme.

The assessment of progress on the 2005 Audit recommendations and the findings of this Audit led to the development of a set of 2007 Audit Recommendations, which are presented in Chapter 9 of this report.

Chapter 3
Raw Water Quality

Key Points

	Indicator	Status of Indicator
3.1	Nutrient load	Agriculture and sewage treatment plants (STPs) are major sources of nutrients in the Catchment. The total nutrient load discharged from STPs decreased compared to the 2005 Audit period.
3.2	Raw water quality requirements for water filtration plants	Raw drinking water quality generally meets the requirements of Sydney Water Corporation and NSW Health. There was a decrease in the exceedence of the Bulk Water Supply Agreement for algae, turbidity, colour and pH compared to the 2005 Audit period.
3.3	Algal blooms	The incidence of toxic cyanobacteria blooms decreased slightly compared to the 2005 Audit period. The incidence of total cyanobacteria blooms increased slightly compared to the 2005 Audit period. There was continued presence of cyanobacteria blooms indicating high levels of nutrients in some parts of the Catchment.
3.4	Pathogens	There are continued occurrences of *Cryptosporidium* and *Giardia* at Gibbergunyah Creek. *Cryptosporidium* and *Giardia* were present at a number of sites in the 2007 Audit period where there was no presence in the 2005 Audit period.

Raw water quality is an essential theme for an audit of a drinking water catchment as it represents the end product of the catchment management approach to water supply. Raw water quality is a function of the inherent geological conditions and in-stream processes, combined with land use, land and catchment management practices and climatic conditions such as drought. This chapter examines:

- nutrient loads, as pressures on raw water quality can result from both point and diffuse source nutrient loads released into waterways from the Catchment
- state of raw water quality as measured by the presence and severity of algal blooms and pathogens in the water storages, and the quality of the raw water delivered to the water filtration plants.

Pressures in the Catchment

Raw water in the Catchment is generally of good quality and meets most applicable guidelines. However, there are significant pressures on water quality in the Catchment from point and diffuse sources of pollution. Point sources of pollution include discharges from sewage treatment systems (STSs)*, and other licensed activities such as mining. Diffuse sources include urban stormwater and rural runoff. Pollution from both point and diffuse sources is driven by land use, intensity of use and management practice.

Population growth in urban areas increases stormwater runoff and puts pressure on wastewater management systems often resulting in the need for upgraded infrastructure. Population growth in rural areas can result in increased on-site sewage treatment that, if not well managed, can add to the diffuse pollution loads. Population growth can also drive the intensification of land use, which can increase land clearing, runoff and ultimately increase risk of impact on the quality of the raw water supply.

The performance of local government and Sydney Water STSs in the Catchment is variable, with some operating over capacity and others approaching capacity. Pollution reduction and wastewater re-use programs in STSs, and their sewage treatment plants (STPs) in particular, have great potential to reduce the amount of pollution and nutrients reaching waterways in the Catchment. Improved urban stormwater management will also have a positive effect on water quality.

There are large areas of agriculturally productive land in the Catchment which have had much of the native vegetation removed. Runoff from agricultural land can carry large amounts of sediment and nutrients into rivers and creeks. The amount of material washed into waterways is increased in areas of bare soil or reduced riparian vegetation. Rural runoff can also contain pesticides, and pathogenic material from areas with livestock. The condition and role of native vegetation in protecting the water supply is dealt with in Chapter 6.

Pollution and contamination from industrial and commercial sites in the Catchment can also impact on raw water quality. These are dealt with in Chapter 5.

3.1 Nutrient load

Background

Small amounts of nutrients are required for plant growth. However, in large amounts, nutrients can cause excessive algal growth in waterways. Excessive algal growth can disturb natural ecosystem processes and affect the health of waterways.

Nutrient loads result from a complex relationship between catchment and input sources, including natural inputs from inherent geological features and soil types, diffuse sources such as runoff from agricultural and urban areas, and point sources such as STPs. The main human-induced sources of nutrients in rivers include runoff from urban areas, erosion and runoff from grazing and cultivated land, tail water from irrigation areas, river and stream bank erosion and point source discharges.

Point sources of nutrients include STP discharges and other industrial discharges. Nutrient point sources have potential to cause severe long-term impacts on water quality and ecosystem health because they are commonly continuous sources of nutrients, rather than intermittent inputs during rainfall events. Rivers that receive large volumes of STP effluent may be prone to eutrophication and algal blooms.

The relative nutrient contribution of different point and diffuse sources needs to be understood to guide response programs. Catchment modelling for nutrient loads can provide valuable information on potential hot spots. This audit examines:

- nutrient load modelling to understand locations of high diffuse nutrient export
- sewage management as a primary indicator of point sources of nutrients in the Catchment.

* An STS represents the combination of pipes (or sewers), pumping stations, treatment plant and other works that collect, transport, treat and dispose of sewage from an area. The sewers collect sewage from individual properties and transport it via larger sewers and sewage pumping stations for treatment at the sewage treatment plant (STP).

STSs have designed overflow points in the pipe networks to release sewage to the environment to prevent sewer overflows into houses and other properties where it may cause an immediate public health issue. In dry weather, sewer overflows occur because of:

- chokes, blockages or excess flow in a sewer pipe where the overflow is from a design overflow point
- pipe defects where sewage leaks to ground and surface waters.

In wet weather, sewer overflows occur because of excess flow in the sewerage system caused by:

- infiltration of water to the system through defects in the system, and in privately owned sewer pipes
- illegal stormwater connections to the sewer.

At the STP, sewage may bypass one or more of the treatment processes due to an equipment failure or an exceedence of the hydraulic capacity of a process in the STP. Sewer overflows and STP bypasses are of concern; sewage overflows discharge raw sewage, while STP bypasses discharge partially treated sewage and this can be in large volumes.

A number of villages in the Catchment have no sewerage service and are served by on-site effluent management systems such as septic tanks. Unsewered villages have been identified as key sources of potential pollution threats to drinking water quality.

This audit report presents the same nutrient export data as used for the 2003 and 2005 audits. The 2003 data were used to estimate annual nutrient loads for each sub-catchment based on extrapolating nutrient export rates for land use types from other studies. The Auditor acknowledges there were limitations associated with the 2003 nutrient modelling approach, however, no new data are available.

The sewage management components examined for this audit are:

- phosphorus and nitrogen loads discharged from STPs in the Catchment
- STP non-compliance with Environment Protection Licence effluent quality and monitoring requirements
- number of sewer overflows from STSs and bypasses of STPs
- equivalent population estimates for unsewered villages.

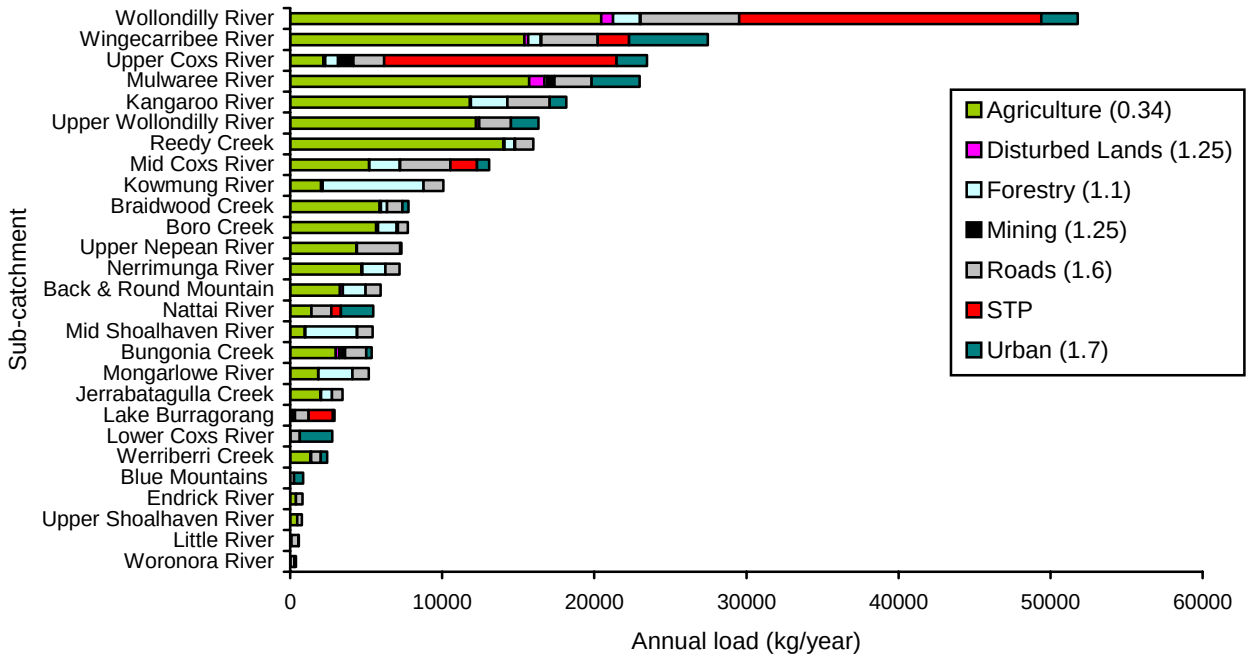
Findings

There has been no new assessment of nutrient loads from the Catchment since the 2003 Audit period. Using the results of the 2003 L-THIA modelling, Figures 3.1 and 3.2 present estimates of annual phosphorus and nitrogen export potential due to human activity from each sub-catchment for 7 land use categories (i.e. in excess of exports from natural land cover).

Agriculture was estimated to be the largest source of phosphorus and nitrogen in the Catchment. STPs were also a significant contributor of phosphorus and nitrogen in the Wollondilly River (priority) and Upper Coxs River (priority) sub-catchments. The sub-catchments with the greatest export potential of phosphorus loads were Wollondilly River (priority), Wingecarribee River (priority), Upper Coxs River (priority), Mulwaree River (priority) and Kangaroo River (priority) sub-catchments (Figure 3.1). The sub-catchments with the greatest export potential of nitrogen loads were Wollondilly River (priority), Mulwaree River (priority), Wingecarribee River (priority), Upper Wollondilly River (priority) and Reedy Creek sub-catchments (Figure 3.2).

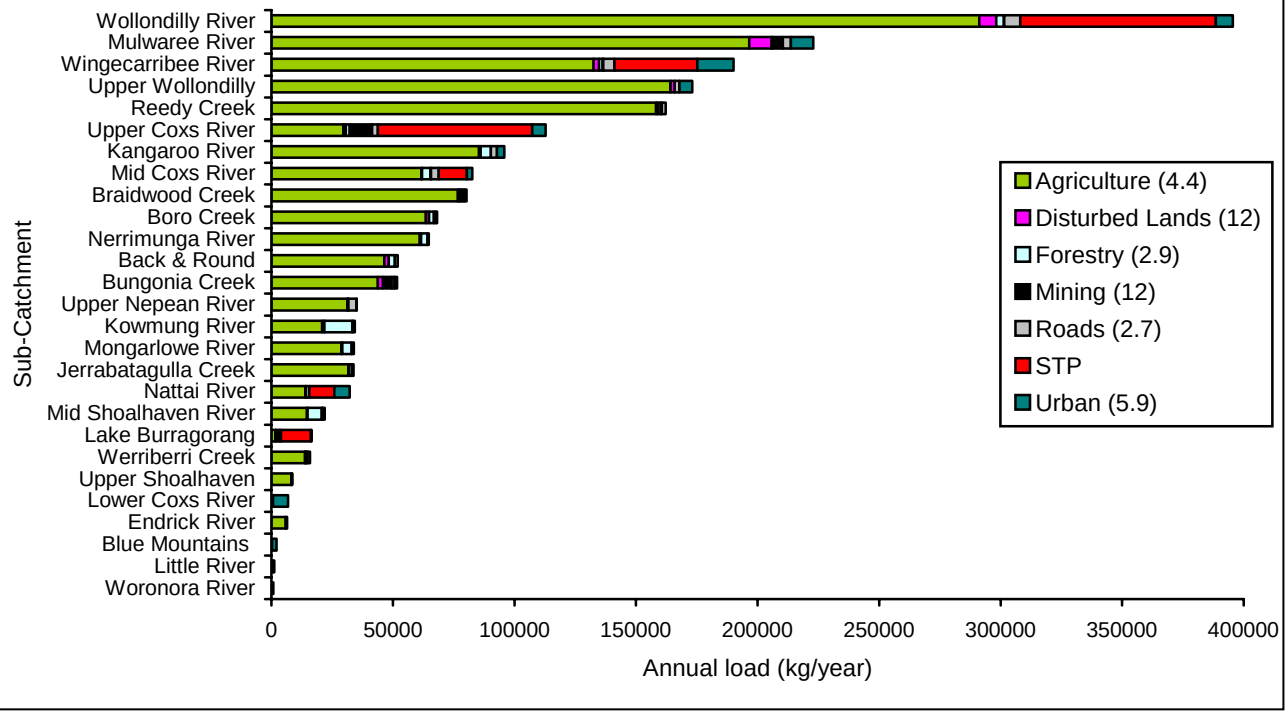
The generation rates of phosphorus were greatest in agricultural areas particularly in the Reedy Creek and Mulwaree River (priority) sub-catchments (Map 3.1). The generation rates of nitrogen had similar hot spots to phosphorus, however there were also hot spots of nitrogen generation in urban areas (Map 3.2). In addition to the Reedy Creek and Mulwaree River (priority) sub-catchments, the Upper Wollondilly River (priority) and Wingecarribee River (priority) sub-catchments were important for nitrogen generation.

Figure 3.1: Export potential of phosphorus loads (kg/year) due to human activity for all sub-catchments. Value in parentheses is the export rate (kg/ha/year).

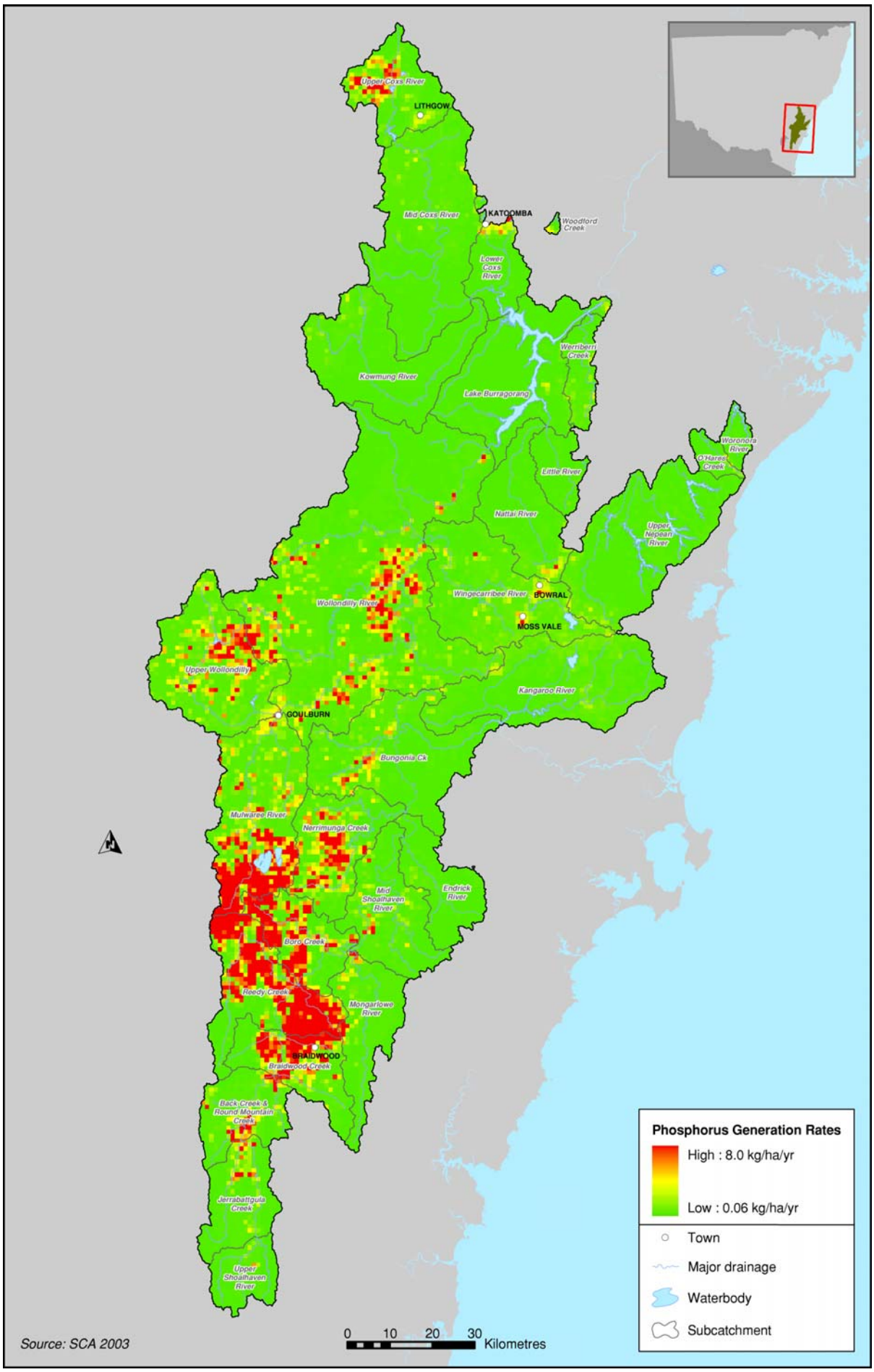


Source: SCA 2003

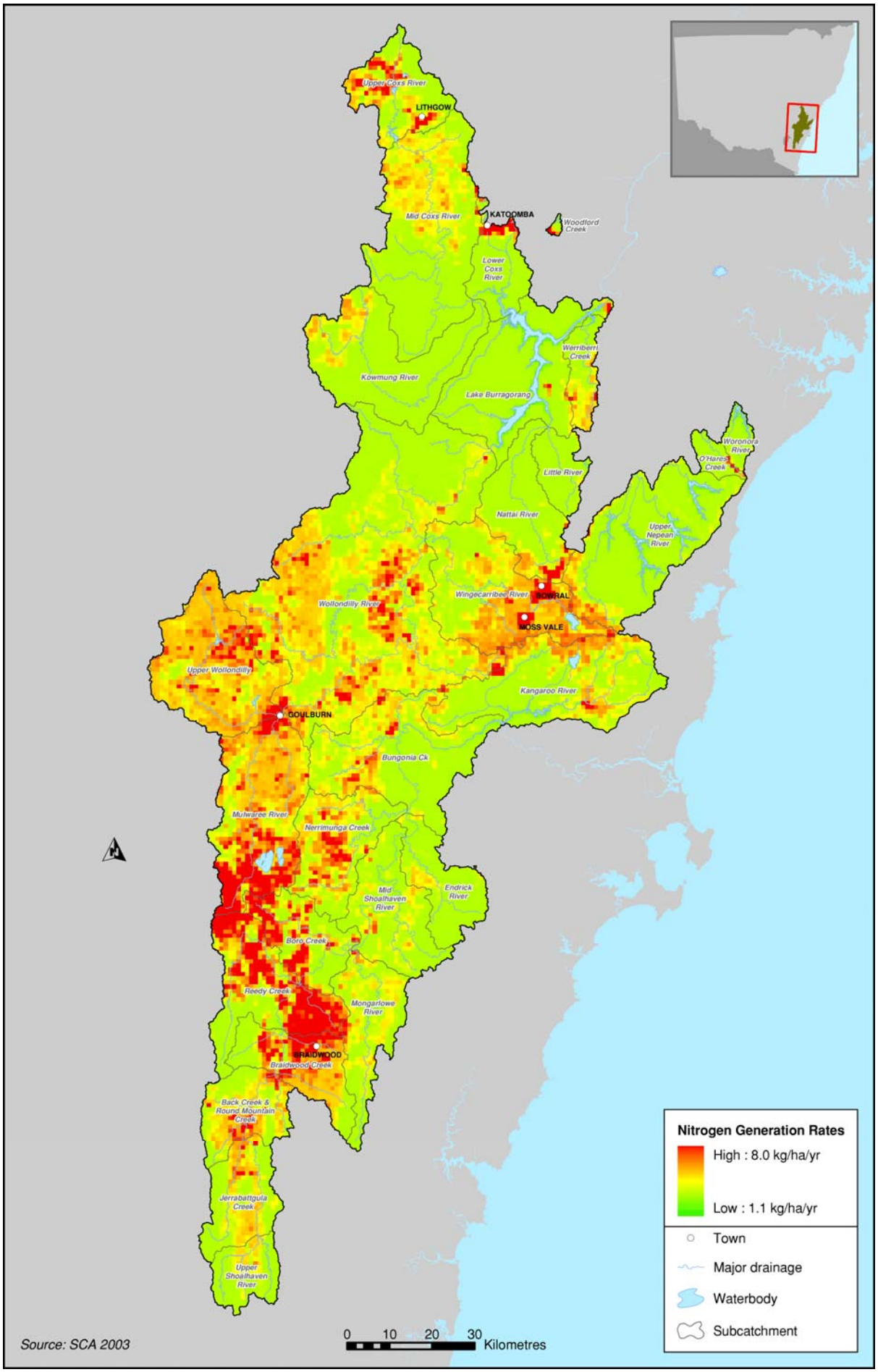
Figure 3.2: Export potential of nitrogen loads (kg/year) due to human activity for all sub-catchments. Value in parentheses is the export rate (kg/ha/year).



Source: SCA 2003



Map 3.1: Modelled annual phosphorus export (kg/ha/year) due to human activity for all sub-catchments in the Sydney drinking water catchment



Map 3.2: Modelled annual nitrogen export (kg/ha/year) due to human activity for all sub-catchments in the Sydney drinking water catchment

Sewage treatment systems

There are currently 14 sewage treatment systems (STSs) with sewers and/or STPs in the Catchment: Bowral; Lithgow; Moss Vale; Bundanoon; Goulburn; Warragamba (now Wallacia); Berrima; Braidwood; Braemar (Mittagong); Wallerawang; Mount Victoria; The Oaks/Oakdale (part of West Camden STS); Blackheath; and Winmalee.

Blackheath, Warragamba (now Wallacia), West Camden and Winmalee STPs discharge treated effluent outside of the Catchment, however overflows from their reticulation systems can occur in the Catchment. The effluent from the remainder of the STPs is discharged directly into waterways in the Catchment, except from the Goulburn STP where the effluent is discharged to land in effluent irrigation systems. The original Mittagong STP was decommissioned in 2001 and replaced by a new STP at nearby Braemar, although the discharge point remained unchanged. The new Bowral STP was commissioned in the 2007 Audit period.

The STPs discharging into the Catchment are operated by the relevant local councils and Sydney Water. DECC regulates the environmental performance of the STPs under the *Protection of the Environment Operations Act 1997* (POEO Act). The council operators of the Bowral, Braemar (Mittagong), Lithgow, Moss Vale, Bundanoon and Goulburn STSs are required to collect data on phosphorus and nitrogen loads from the STPs as part of the load-based licensing scheme under the POEO Act. This data has been used to compare phosphorus and nitrogen loads discharged from STPs in the Catchment (Figures 3.3 and 3.4).

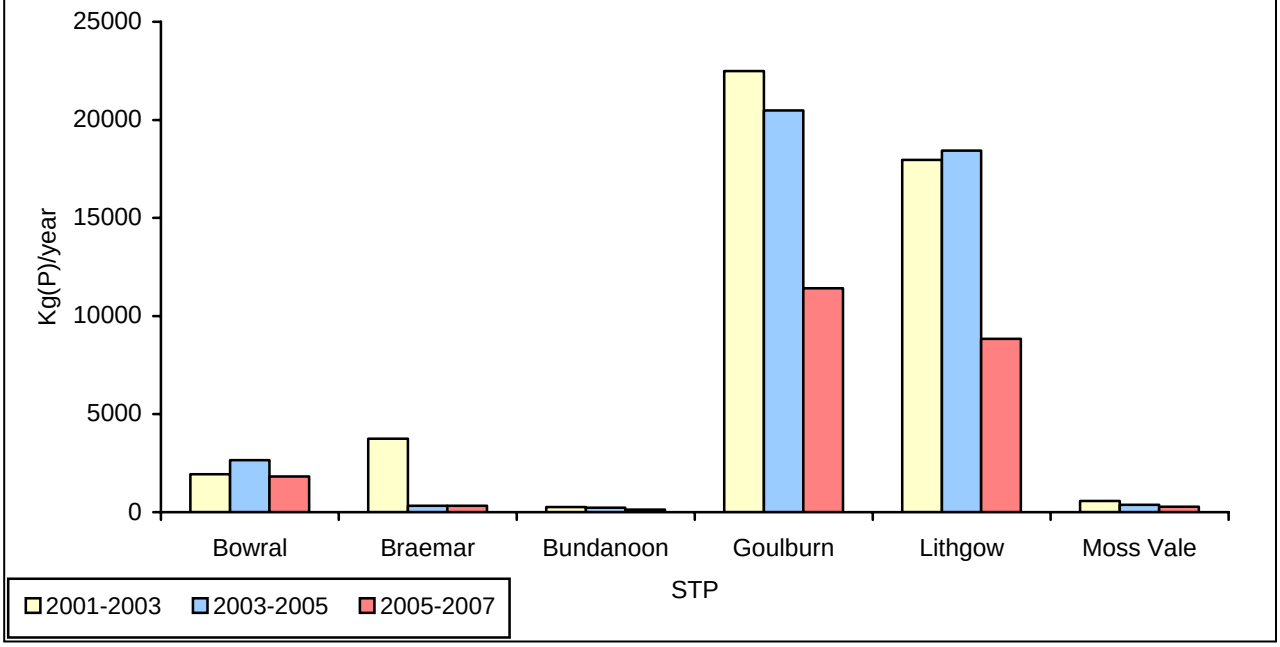
The **total phosphorus** load discharged by STPs in the Catchment decreased during the 2007 Audit period compared to the 2005 Audit period, with a major of the decrease occurring at the Lithgow and Goulburn STPs. The Goulburn and Lithgow STPs, however, generated the greatest load of phosphorus. During the 2007 Audit period, phosphorus loads from Bowral STP also decreased. The phosphorus load from Braemar, Bundanoon and Moss Vale remained relatively unchanged during the 2007 Audit period compared to the 2005 Audit period (Figure 3.3).

The **total nitrogen** load discharged by STPs in the Catchment decreased slightly during the 2007 Audit period compared to the 2005 Audit period. The nitrogen load discharged, however, by Braemar, Goulburn, Lithgow and Moss Vale STPs increased during the 2007 Audit period compared to the 2005 Audit period. The nitrogen loads from Bundanoon and Bowral STPs decreased during the 2007 Audit compared to the 2005 Audit period. After the previous three years of increases by 10 per cent per year, Bowral STP had a recent upgrade completed in 2006 resulting in a decrease in the amount of nitrogen discharged (Figure 3.4).

The STS Environment Protection Licences covering the STPs in the Catchment also impose effluent concentration and load limits and effluent and system monitoring requirements. Table 3.1 summarises the limit and monitoring non-compliances of STPs in the Catchment during the 2007 Audit period. Bowral STP continued to have incidences of non-compliance, although it has improved since the 2005 Audit period due to its recent upgrade. Goulburn STP's level of non-compliance improved in the 2007 Audit period. Lithgow STP did not improve during the 2007 Audit Period with the same number of non-compliances since the 2005 Audit period. All other STPs had improved compliance with licence limit and monitoring requirements in the 2007 Audit period.

There are also eight small package STPs in the Catchment that are not licensed by DECC and are regulated by councils. There was no information available to indicate the effectiveness of the environmental management of these plants.

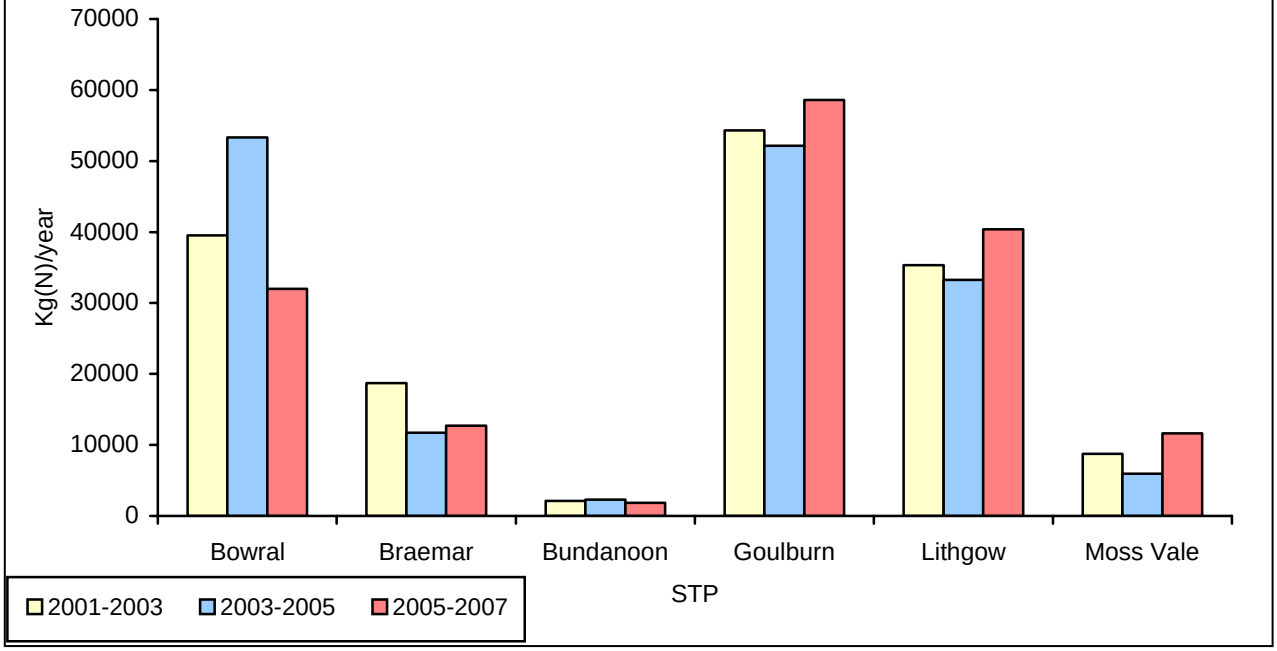
Figure 3.3: Load of phosphorus (kg/year) discharged from STPs, for the 2003, 2005 and 2007 Audit periods.



Source: DECC 2007

Note: The majority of the Goulburn STP effluent in 2003-2005 and 2005-2007 was irrigated and is not discharged to water.

Figure 3.4: Load of nitrogen (kg/year) discharged from STPs, for the 2003, 2005 and 2007 Audit periods.



Source: DECC 2007

Note: The majority of the Goulburn STP effluent in 2003-2005 and 2005-2007 was irrigated and is not discharged to water.

Table 3.1: Number of effluent and monitoring non-compliances of licensed STPs during the 2007 Audit period

STP		PH	Discharge	BOD Load	Total P	Total N	TSS	Oil & grease	Faecal coliforms	Monitoring	Sludge Storage	Volume Limit
Berrima	2003-04	2X	X									
	2004-05	2X										
	2005-06	X								X		
	2006-07	X										
Bowral	2003-04	2X	X	X	X		X			X		
	2004-05	X		2X	X	X	2X			X		
	2005-06						2X			2X		
	2006-07	X			X	X		X				
Braemar	2003-04		9X		X	X						
	2004-05											
	2005-06									3X		
	2006-07	X			X	X						
Braidwood	2003-04		X	2X			4X					
	2004-05						2X			X		
	2005-06			X			X					X
	2006-07						X					5X
Bundanoon	2003-04	X	X							X		
	2004-05											
	2005-06									X		
	2006-07											
Goulburn	2003-04						2X			X		
	2004-05											
	2005-06						X			5X		
	2006-07											
Lithgow	2003-04	X						2X				
	2004-05	X			X	X	X		X		X	
	2005-06			X	X	X	X		X			
	2006-07	X			X	X	X		X			

Source: DECC 2007

Note: * non-compliance data not available until December 2007.

Table 3.1: Effluent and monitoring non-compliances of licensed STPs during the 2007 Audit period (Continued)

STP		PH	Discharge	BOD Load	Total P	Total N	TSS	Oil & grease	Faecal coliforms	Monitoring	Sludge Storage	Volume Limit
Moss Vale	2003-04		X							X		
	2004-05											
	2005-06									X		X
	2006-07					X						
Mt. Victoria	2003-04									4X		
	2004-05											
	2005-06											
	2006-07									3X		
Wallerawang	2003-04	3X		5X	10X	8X			7X			
	2004-05											
	2005-06				X	X			X			
	2006-07*											
Warragamba	2003-04		X							X		
	2004-05											
	2005-06									X		X
	2006-07											

Source: DECC 2007

Note: * non-compliance data not available until December 2007.

Sewer overflows

The total number of sewer overflows from all STSs in the Catchment increased from 23 during the 2003 Audit period to 28 for the 2005 Audit period to 70 for the 2007 Audit period. The STSs that had the most sewer overflows during the 2007 Audit period, were Bowral with 21, Braemar with 14 and Lithgow with 11 (Table 3.2).

The data produced in Table 3.2 is sourced from the SCA and DECC, and the Auditor understands that the recorded overflows are consistently measured and reported, enabling comparisons of performance across the STSs. The Auditor is aware that new data on sewer overflow performance are now reported to DECC for STSs operated by Wingecarribee Shire Council in particular. The new overflow data result from the delivery from 2005 and 2006 onwards of a 2003 Pollution Reduction Program on Council STS licences requiring investigations of sewer overflows. This is providing an improved understanding of STS performance. In the case of these Wingecarribee Shire Council STSs, the new data show apparent increased incidences of sewer overflows since 2005, which the Auditor believes may arise from the use of the new standard of assessment and reporting, rather than a demonstration of deterioration in overflow performance. Consequently, the Auditor has not incorporated the new data from Wingecarribee Shire STSs in Table 3.2 for this audit. The Auditor anticipates that DECC (as the STS regulator) and/or councils (as the operators) will be able to provide the next Audit with consistent new data for all STSs in the Catchment.

Sewage flows can also bypass the treatment plant processes when the flow rate exceeds the hydraulic design capacity of the treatment plant. The total STP bypasses decreased from 12 for the 2005 Audit period to nine for the 2007 Audit period. The most STP bypasses occurred at Mt Victoria and Bowral STPs (Table 3.2). The Bowral STP bypasses occurred prior to its upgrade in the 2007 Audit period.

Table 3.2: Number of discharges of untreated or partially treated sewage from licensed STSs for the 2003, 2005 and 2007 Audit periods

	2001-2003		2003-2005		2005-2007	
Licensed STS	**Bypass**	**Overflow**	**Bypass**	**Overflow**	**Bypass**	**Overflow**
Berrima		1		1		4
Bowral	4	1	3	10	3	21
Braidwood		2		1		1
Bundanoon				1		5
Goulburn		9		12		1
Lithgow						11
Braemar (Mittagong)		4		3	1	14
Moss Vale	1	1				6
Mt Victoria		5	8		4	7
Wallerawang			1		1	
Total	5	23	12	28	9	70

Source: DECC 2007 and SCA 2007

Other potential sources

During the 2007 Audit period there were six sites in the Catchment where biosolids were applied to land and 12 sites where effluent was irrigated. During the 2005 Audit period, there were 12 sites where biosolids were applied to land and 16 sites where effluent was irrigated. There were no data available to indicate the effectiveness of environmental management of these sites. There is, however, detailed environmental guidance available for these activities and their impact is expected to be relatively low. The locations of potential nutrient sources in the Catchment are indicated in Map 3.3.

Unsewered villages

The number of unsewered villages remained unchanged from the 2005 Audit period. The largest remaining unsewered villages are Buxton in the Little River sub-catchment with an estimated equivalent population (EP) of 1,957 and Robertson in the Wingecarribee River (priority) sub-catchment with an EP of 1,507 (Table

3.3). The unsewered villages at Kangaroo Valley and Medlow Bath have high peak season equivalent populations. Investigations are currently being undertaken to sewer Buxton, Robertson, Kangaroo Valley, Medlow Bath and Taralga (see Action and Responses section of this chapter).

The towns of Goulburn, Marulan, Mount Victoria, Woodford and Blackheath are serviced by STPs, however there remain a significant number of residences that have on-site systems. The SCA also owns a number of unsewered houses within the Upper Nepean River sub-catchment at the Cordeaux, Cataract, Avon and Nepean Dams. The majority of these houses are now connected to new pump out systems which are regularly maintained.

Table 3.3: Equivalent population (EP) estimates of unsewered villages in the Catchment

Sub-catchment	Village	EP estimate 2001	EP estimate 2003	EP estimate 2005
Bungonia Creek	Tallong	ND	108	114
Endrick River	Nerriga	ND	ND	ND
Kangaroo River	Burrawang	235	268	301
Kangaroo River	Exeter	369	423	477
Kangaroo River	Fitzroy Falls	ND	ND	ND
Kangaroo River	Kangaroo Valley*	1320	1506	1692
Kangaroo River	Penrose	169	189	210
Kangaroo River	Wingello	264	303	342
Lake Burragorang	Nattai	ND	ND	ND
Lake Burragorang	Yerranderie and Quigtown	ND	ND	ND
Little River	Balmoral	165	192	219
Little River	Buxton	1509	1733	1957
Mid Coxs River	Hartley	ND	ND	ND
Mid Coxs River	Medlow Bath*	750	886	1022
Mongarlowe River	Mongarlowe	ND	ND	ND
Mulwaree River	Tarago	ND	105	111
Upper Nepean River	Kangaloon	ND	ND	ND
Upper Nepean River	Yerrinbool	927	1047	1167
Wingecarribee River	Robertson	1191	1349	1507
Wingecarribee River	Sutton Forest	218	249	280
Wollondilly River	Taralga	382	424	466
Total		**7499**	**8782**	**9864**

Source: CH2MHILL 2001 and SCA 2005

Notes: ND – Not Determined, but significantly below 200 EP

Reported Tallong and Tarago Population Growth data is sourced from Mulwaree Shire Council Settlement Strategy Report, November 2003

*Values quoted in table are peak summer loadings.

Map 3.3: Nutrient point sources in the Sydney drinking water catchment

Implications

Based on the 2003 L-THIA nutrient modelling for diffuse nutrient pollution, the sub-catchments with the greatest export potential of phosphorus loads are Wollondilly River (priority), Wingecarribee River (priority), Upper Coxs River (priority), Mulwaree River (priority) and Kangaroo River (priority) sub-catchments. The sub-catchments with the greatest export potential of nitrogen loads are Wollondilly River (priority), Mulwaree River (priority), Wingecarribee River (priority), Upper Wollondilly River (priority) and Reedy Creek sub-catchments.

Some individual STPs increased their nutrient load contributions to the Catchment, which need to be addressed through upgrades and improved performance. The load of phosphorus and nitrogen discharged from the Lithgow, Moss Vale and Braemar STPs produced non-compliances with their Environment Protection Licences. Current programs to reduce nutrients from sewage management systems are outlined in the Actions and Response section of this chapter.

Although there is no data to confirm this for the Catchment during the 2007 Audit period, it is likely that the effluent discharged from the STPs had a greater influence on ambient water quality in the current low flow conditions resulting from drought. The Auditor believes that operators and regulators should continue current programs to reduce nutrient contributions from STPs in the Catchment, and continue to work with the SCA to identify what further reductions would ensure ongoing protection of water quality. Addressing and avoiding non-compliances with licence limits on nutrient loads should also continue to be a priority for operators and regulators.

Recommendation 1: The operators and regulator(s) of the sewage treatment systems in the Catchment should continue efforts to reduce current levels of nutrient loads discharged into the Catchment.

The Bowral, Mount Victoria, Braemar (Mittagong) and Lithgow STSs are of concern with respect to sewer overflows. DECC imposed a Pollution Reduction Program on all STS operators to assess sewer system performance, and to identify priorities for minimising risk to the environment and public health from overflows and STP bypasses. The Bowral STP augmentation works were completed during the 2007 Audit period, with the installation of a new wet weather detention pond, to reduce bypasses of effluent flowing into the STP during storm events.

A large number of unsewered villages are located in the Kangaroo River (priority) sub-catchment. The Little River, Mid Coxs River (priority), Upper Nepean River and Wingecarribee River (priority) sub-catchments each have an unsewered village with an EP greater than 1,000 (Table 3.3).

These findings highlight that there are many potential point and diffuse sources of nutrients in the Catchment.

Future directions

High nutrient loads can cause excessive algal growth in waterways. Excessive algal growth can disturb natural ecosystem processes and affect the health of waterways. Figure 3.5 depicts the presence of algae in Lithgow STP's treatment ponds, which can contribute to the risk of algal blooms in the Catchment. A better understanding of the magnitude and pattern of delivery of nutrient loadings is required to further optimise management strategies to reduce nutrient loads and mitigate impacts.

Figure 3.5: Lithgow STP pond with algal growth
Source: DECC 2007

STSs need to be managed to protect water quality in the Catchment, including establishing clear strategies for upgrading and augmenting STPs and reticulation systems to accommodate anticipated growth. The strategies need to plan for a range of potential growth scenarios, include funding options and seek to minimise nutrient growth through treatment upgrades and effluent re-use opportunities.

Reduction in nutrient export from diffuse sources can be achieved through improved land use management practices as well as through specific riparian vegetation, erosion control and streambank stabilisation projects. Diffuse source nutrient control programs should therefore be integrated with programs for riparian management and erosion control to obtain multiple water quality, land management and ecosystem health benefits. This requires significant coordination across organisations and landholders that are involved in funding and managing these types of programs. DECC, SCA, CMAs and councils therefore need to be collaborating to ensure programs are complementary and target high priority areas and locations.

It is important that one organisation maintains an overview of the relationship between programs and encourages collaboration between organisations involved in nutrient management to seek efficient integration of programs for nutrient reduction in the Catchment. The Auditor considers that the SCA is best placed to fulfill this role because it has an overview of the whole Catchment and has a direct interest in the raw water quality outcomes that can be affected by high nutrient levels. Given this view, the SCA should:

- ensure its own nutrient reduction programs target areas of priority nutrient contribution where there is greatest scope for nutrient reduction by application of improved practice
- encourage other organisations to implement programs that can contribute to nutrient reduction in similar priority areas.

The SCA relies on a risk assessment methodology to prioritise nutrient reduction programs, having moved away from modelling of nutrient loads across the Catchment. The risk assessment methodology described in SCA's Water Quality Risk Management Framework addresses risks to bulk raw water quality in the SCA supply systems. It identifies hazards to bulk raw water quality and assesses the risk of events that cause these hazards. The Framework also identifies and evaluates the controls to be used in dealing with the hazards throughout the SCA system.

The Auditor notes that the SCA has not progressed nutrient modeling to the extent recommended by the 2005 Audit. The Auditor believes that the SCA's risk management approach needs to be complemented with modeling of catchment nutrient loads to ensure that catchment-sourced nutrient load risks continue to be appropriately assessed, prioritised and managed.

3.2 Raw water quality requirements for water filtration plants

Background

There are a number of Water Filtration Plants (WFPs) in the Sydney drinking water system operated by Sydney Water Corporation and local councils. WFPs are an important part of a multiple barrier approach to improve drinking water quality (see Section 1.4 of this report and SCA, 2003a). These barriers include catchment management, storage management, water filtration, distribution, and integrated water quality management. The level of contaminants in raw water supplied to 11 of the WFPs is monitored by SCA to optimise raw water quality supplied and to minimise treatment costs. Raw water in storages is not required to meet drinking water quality standards. However, the most cost effective provision of good drinking water is likely to be a balance between ensuring good quality raw water and the application of water treatment technologies at WFPs.

Bulk water supplied by the SCA to WFP operators is expected to meet site-specific raw water quality requirements for each WFP. The requirements for the Prospect, Warragamba, Orchard Hills, Macarthur, Nepean, Illawarra, Woronora, Cascade and Greaves Creek WFPs are detailed in the SCA's Bulk Water Supply Agreement (BWSA) with Sydney Water Corporation. The SCA also has a BWSA with Wingecarribee Shire Council and Shoalhaven City Council (Kangaroo Valley WFP) for their WFPs (Table 3.4).

The audit examined the level of exceedence of raw water quality parameters with the BWSA requirements for turbidity (NTU), colour (HU), manganese (mg/L), pH and algae (ASU/mL). These parameters were selected for their importance in the production of quality drinking water and in the effective operation of the WFPs. The Area Standard Unit (ASU) for algae indicates the potential for filtration blockage, and the measure is derived from cell count and average size for each species present.

Table 3.4: Bulk Water Supply Agreement (BWSA) water quality requirements at each water filtration plant (WFP), revised April 2006

WFP	Turbidity (NTU)		Colour (HU)		Manganese (mg/L)		pH		Algae (ASU/mL)	
	Old	New	Old	New	Old	New	Old	New	Old	New
Cascade	15	150	60	60	0.25	0.30	6.0 – 7.4	6.0 – 7.9	1000	2000
Greaves Creek	40	NA	60	NA	1.00	NA	4.4 – 9.2	NA	1000	NA
Illawarra	10	10	48	50	0.37	0.40	6.15 – 7.2	6.2 – 7.2	5000	5000
Kangaroo Valley	5	20	40	70	1.2	NA	6.5 – 8.5	5.5 – 8.5	1000	5000
Macarthur	60	60	40	40	0.35	0.35	5.72 – 7.65	5.7 – 7.7	500	500
Nepean	183	150	60	60	1.45	1.50	4.80 – 7.65	4.8 – 7.7	1000	2000
Orchard Hills Prospect Warragamba	40	40	60	60	1.40	1.40	6.27 – 7.87	6.3 – 7.9	1000	2000
Wingecarribee	5	5	40	70	1.2	1.2	5.5 – 8.5	6.5 – 8.5	1000	1000
Woronora	11	10	70	70	0.07	0.1	5.06 – 7.54	5.1 – 7.5	5000	5000

Source: SCA 2007

Note: All figures are maximum guideline limits, except for pH that is a range of guideline limits.

NA, not applicable.

SCA and Sydney Water signed a new BWSA in April 2006 in which some of the requirements were revised and a new BWSA with Shoalhaven City Council was signed in December 2006.

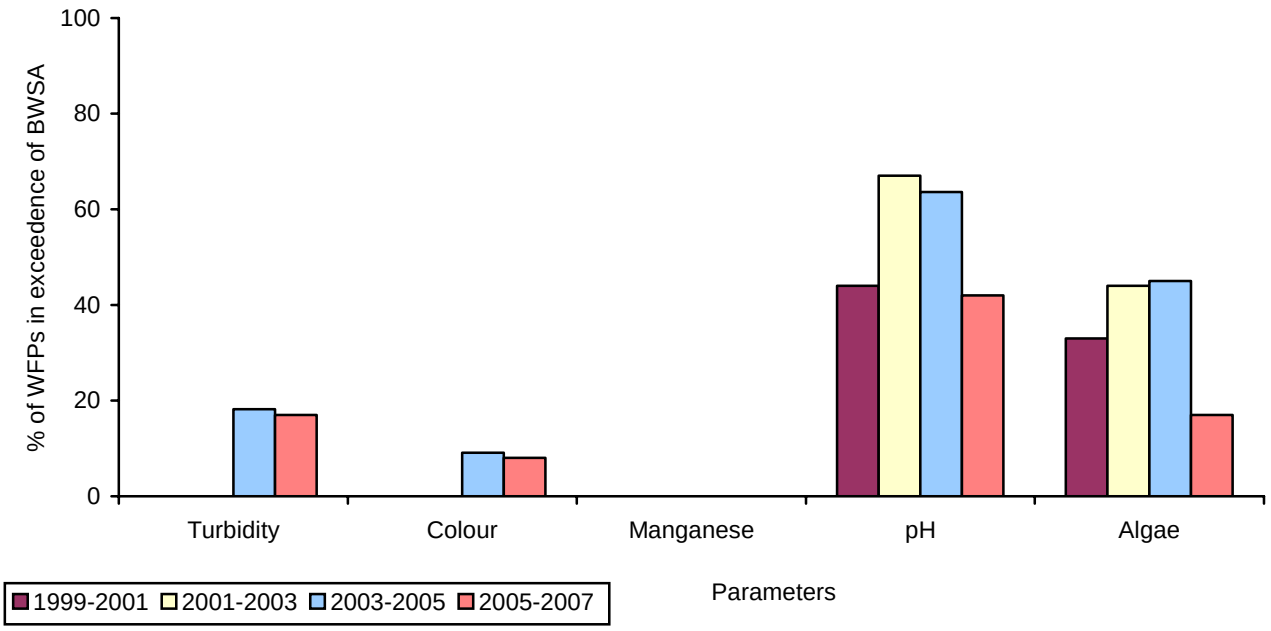
Findings

The number of WFPs at which raw water quality exceeded guideline values in the BWSAs decreased in the 2007 Audit period (Figure 3.6). Raw water quality, however, continued to exceed guideline values in the BWSA for turbidity, pH, and algae.

In the 2007 Audit period, raw water supplied to the Kangaroo Valley and Wingecarribee WFPs did not meet guideline values in the BWSA for turbidity and algae (Table 3.5). There was no manganese present in the raw water supplied to any of the Sydney Water Corporation WFPs in the 2007 Audit period (Table 3.5).

The NSW Department of Health advised the Auditor in its submission to the Audit that it was satisfied with the quality of raw water being delivered to the WFPs and with the resulting quality of drinking water produced by the WFPs.

Figure 3.6: Percentage of water filtration plants where raw water supplied exceeded BWSA guidelines for each parameter for the 2001, 2003, 2005 and 2007 audit periods



Source: SCA 2007

Implication

Exceedences of the BWSAs generally decreased in the 2007 Audit period, when compared to past Audit periods. In 2005, the Auditor recommended (2005 Recommendation 6) that the SCA identify the cause of exceedence of the BWSA for turbidity, pH and algae at water filtration plants. The SCA, Department of Health and Sydney Water subsequently concluded that the drought was responsible for the exceedences in the 2005 Audit period. Nonetheless, the persistent exceedences at the Kangaroo Valley and Wingecarribee WFPs suggest that there may be continuing issues in their respective (priority) sub-catchments. The storages supplying these WFPs were Tallowa Dam (Lake Yarrunga/Bendeela Pondage) and Wingecarribee Reservoir. The Auditor asserts that actions needed to identify the causes of the exceedences in the 2007 Audit period remain necessary.

Table 3.5: Percentage of samples collected in exceedence of the BWSA for each parameter at WFPs

WFP	Turbidity			Colour			Manganese			pH *			Algae		
	2003	2005	2007	2003	2005	2007	2003	2005	2007	2003	2005	2007	2003	2005	2007
Cascade	0	0	0	0	0	0	0	0	0	31	81	0	58	8	0
Greaves Creek	0	0	0	0	0	0	0	0	0	0	0	0	54	22	0
Illawarra	0	0	0	0	0	0	0	0	0	6	81	42	0	0	0
Kangaroo Valley	ND	29	32	ND	7	8	ND	0	0	ND	0	0	ND	60	28
Macarthur	0	0	0	0	0	0	0	0	0	11	16	17	3	2	0
Nepean	0	0	0	0	0	0	0	0	0	3	14	0	4	0	0
Orchard Hills	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0
Prospect	0	0	0	0	0	0	0	0	0	19	0	8	0	0	0
Warragamba	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0
Wingecarribee	ND	50	32	ND	0	0	ND	0	0	ND	0	0	ND	64	14
Woronora	0	0	0	0	0	0	0	0	0	2	8	4	0	0	0

Source: SCA 2007

Notes: Red indicates exceedence of the BWSA by > 75% of samples, orange 50–75% of samples and yellow 25–50% of samples.

* percentage of samples outside the guideline range

ND: No data – Kangaroo Valley and Wingecarribee were new plants for the 2005 Audit, Greaves Creek decommissioned in November 2005.

3.3 Algal blooms

Background

Algae are naturally present in waterways and they can reproduce rapidly to form a bloom under favourable environmental conditions such as high nutrient levels, reduced flow, high light penetration and warm temperatures. Most blooms do not last long, often disappearing within days or weeks. However, when conditions remain favourable, blooms can last months, especially if nutrient levels are high (CRCWQT, 2007a).

Algal blooms give rise to a number of problems in waterways and water storages, including changes in pH, reduction of light penetration and the smothering of habitat and deoxygenation of water. Lack of dissolved oxygen in water can result in the death of fish and other aquatic organisms. Algal blooms reduce the environmental values of water by limiting the potential uses of water resources for recreation and stock purposes and they increase the cost of treatment for human consumption. Algal blooms can also cause tainting of drinking water and disruption of filters and other operations.

Blue–green algae, or cyanobacteria, are of particular concern as some species produce toxins that may cause skin irritations, gastrointestinal disorders and in extreme cases of prolonged exposure can result in permanent organ damage or death (DEC, 2003). If the toxicity of the bloom is significant, the water becomes unusable for either drinking or other direct contact. Even at low concentrations some blue–green algae can cause strong tastes and odours in treated water. Few freshwater cyanobacterial species release toxins throughout their life cycle. However, toxins, organic matter and nutrients are released into the water from cells when they begin to die, or when cell walls are ruptured when passing through filtration devices at WFPs.

The ability of blue-green algae to use gas pockets to move within the water column gives them an advantage over the other microorganisms that compete for the same food. However, their gas pockets cannot keep them afloat in a turbulent water column, lessening their competitive advantage and so reducing the growth rate of the population. These gas pockets are the reason that turbulence is an important factor in determining whether a bloom will form or not. Waters that flow slowly with low turbulence (such as regulated rivers, dams, or water storages) are at particularly high risk of algal blooms. Nutrient levels, while important, do not trigger a bloom alone, but they do determine how large it becomes (CRCWQT, 2007a).

The National Health and Medical Research Council (NHMRC & ARMCANZ, 1996) drinking water guidelines identify three levels of algal presence:

- Low (< 2,000 cells/mL)
- Medium (2,000 to 15,000 cells/mL)
- High (> 15,000 cells/mL).

The revised NHMRC guidelines (2004) identify greater than 2,000 cells/mL as an alert and 6,500 cells/mL as a major incident.

The Audit used the NHMRC 1996 drinking water guidelines to assess algal blooms and for comparison with the findings of the 2003 and 2005 Audit periods. There are other algal benchmarks in use in the Catchment. For instance:

- the NSW State Algal Coordinating Committee (SACC) specifies that recreation on water bodies should not be permitted when toxic cyanobacterial counts exceed 50,000 cells/mL, total cyanobacterial biovolume exceeds 4mm^3 cells/mL or a visible scum persists in the area
- the SCA's Cyanobacterial Response Plan states that NSW Health will be alerted when known toxigenic cyanobacterial counts exceed 2,000 cells/mL in drinking water, or 5,000 cells/mL in recreational water, and water users (Sydney Water, Shoalhaven City Council and Wingecarribee Shire Council) and other stakeholders should be notified if the cyanobacterial counts exceed 6,500 cells/mL in drinking water, or 50,000 cells/mL in recreational water.

The frequency of the SCA's sampling for algal presence varies from site to site. Sites are sampled weekly, fortnightly or monthly. Some sites are sampled more regularly in summer and *ad hoc* samples are also collected if an algal bloom is detected.

Findings

*The total incidences of **toxic cyanobacteria*** which contained greater than 2,000 cells/mL decreased slightly during the 2007 Audit period, compared to the 2005 Audit period (Figure 1 and Table 1 in Appendix C).

Incidences of toxic cyanobacteria decreased at Bendeela Pondage [B*], Fitzroy Falls [E*], Lake Fitzroy [F*], Lake Greaves [G*], Lake Nepean at 300m [I*] and Bendeela picnic area [J*], Wingecarribee Lake [X*] (Map 3.4).

Increases in the incidence of toxic cyanobacteria occurred at Lake Yarrunga at Kangaroo and Yarrunga Junction [L*], Lake Yarrunga at Kangaroo River [N*], Lake Burragorang at 500m [Q*], Lake Burragorang at 14km [R*], Oberon pipeline [AB*], Lake Burragorang at Butchers Creek [AM*] and Wingecarribee River [EH*] (Map 3.4).

*The total incidences of **total cyanobacteria*** which contained greater than 2,000 cells/mL increased slightly during the 2007 Audit period, compared to the 2005 Audit period (Figure 2 and Table 2 in Appendix C).

Decreases in the incidence of total cyanobacteria occurred at Lake Avon [A*], Bendeela Pondage [B*], Lake Greaves [G*], Lake Lower Cascade [H*], Lake Nepean [I*], Bendeela picnic area [J*], Lake Yarrunga at Kangaroo and Yarrunga Junction [L*], Lake Yarrunga at Kangaroo arm [O*], Lake top Cascade at 100m [P*], Lake Burragorand at 500m [Q*] and Lake Burragorang at 14km [R*].

Increases in the incidence of total cyanobacteria occurred at Lake Cataract [C*], Lake Cordeaux [D*], Lake Yarrunga at 100m [K*], Lake Yarrunga at Shoalhaven River [M*], Lake Yarrunga at Kangaroo River [N*], Lake top Cascade at 100m [P*], Lake Woronora [Y*], Oberon pipeline [AB*], and Lake Prospect [AF & AG*].

Constant high levels of total cyanobacteria were recorded at Fitzroy Falls [E*], Lake Fitzroy Falls [F*], Lake Burragorang [S*], Lake Burragorang at Wollondilly arm [V*] and Wingecarribee Lake at outlet [X*].

Sites which had a large number of incidences of total cyanobacteria during the 2005 Audit period, but were not sampled for the 2007 Audit period were Lake Burragorang at Wollondilly River [W*], Lake Nepean [AK*], and Lake Wingecarribee at Mid Lake [AL*]. The sites at Lake Burragorang at Kembula River [T*], Lake Burragorang at Coxs River [U*] and Lake Burragorang at Wollondilly River [W**] were dry during the 2007 Audit period.

During 2005-06, the Metropolitan and South Coast Regional Algal Coordinating Committee (RACC) issued blue green algal red alerts (> 50,000 cells/mL) for Farmers Creek, Pipers Flat Creek and Lake Wallace in the Upper Coxs River (priority) sub-catchment. Figure 3.7 shows Farmers Creek during a blue green algal red alert during the 2007 Audit period. In 2006-07, the RACC issued weekly red alerts for Farmers Creek continuously from April to June 2007 inclusive.

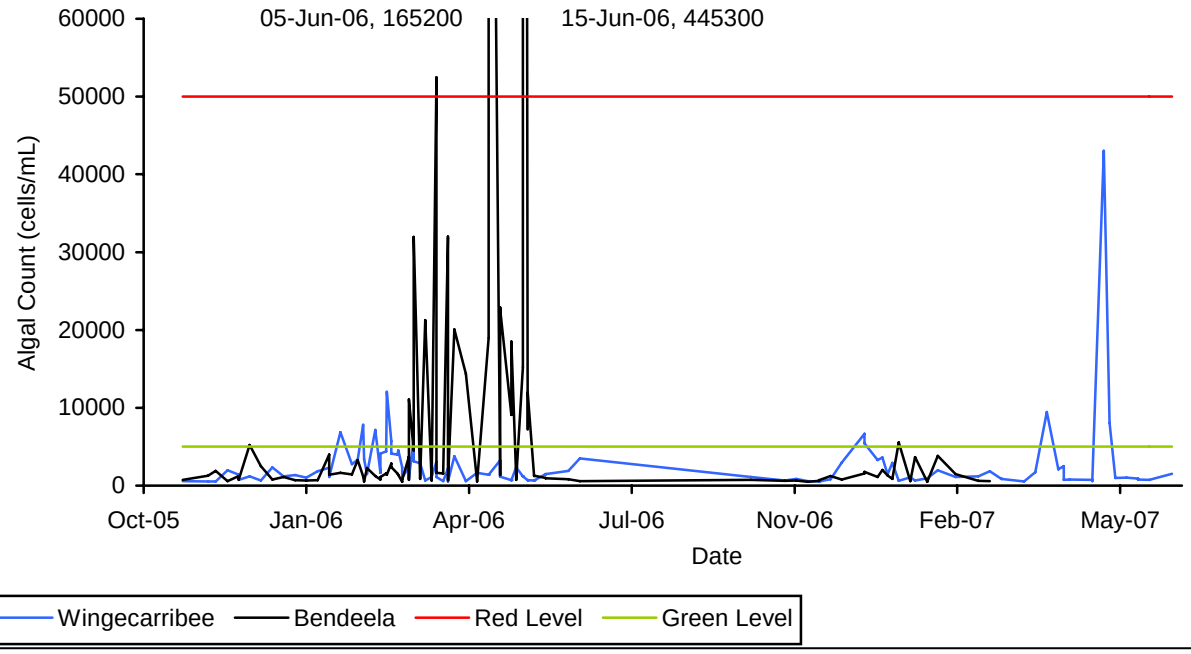
Two additional algal blooms occurred in the 2007 Audit period (Figure 3.8). The incident at Bendeela (Lake Yarrunga in the Kangaroo River (priority) sub-catchment) consisted of two red level alerts of greater than 50,000 cells/mL on the 5th and 15th of June 2006. The second incident at Wingecarribee Reservoir was classed as an amber level alert with greater than 40,000 cells/mL present on the 15 May 2007 (Figure 3.8).

* See Map 3.4 for locations of sampling sites and Table 10 in Appendix C for explanation of codes.

Figure 3.7: Algal bloom in Farmers Creek Lithgow, February 2006

Source: S. Tinsley from DWE (formerly DNR)

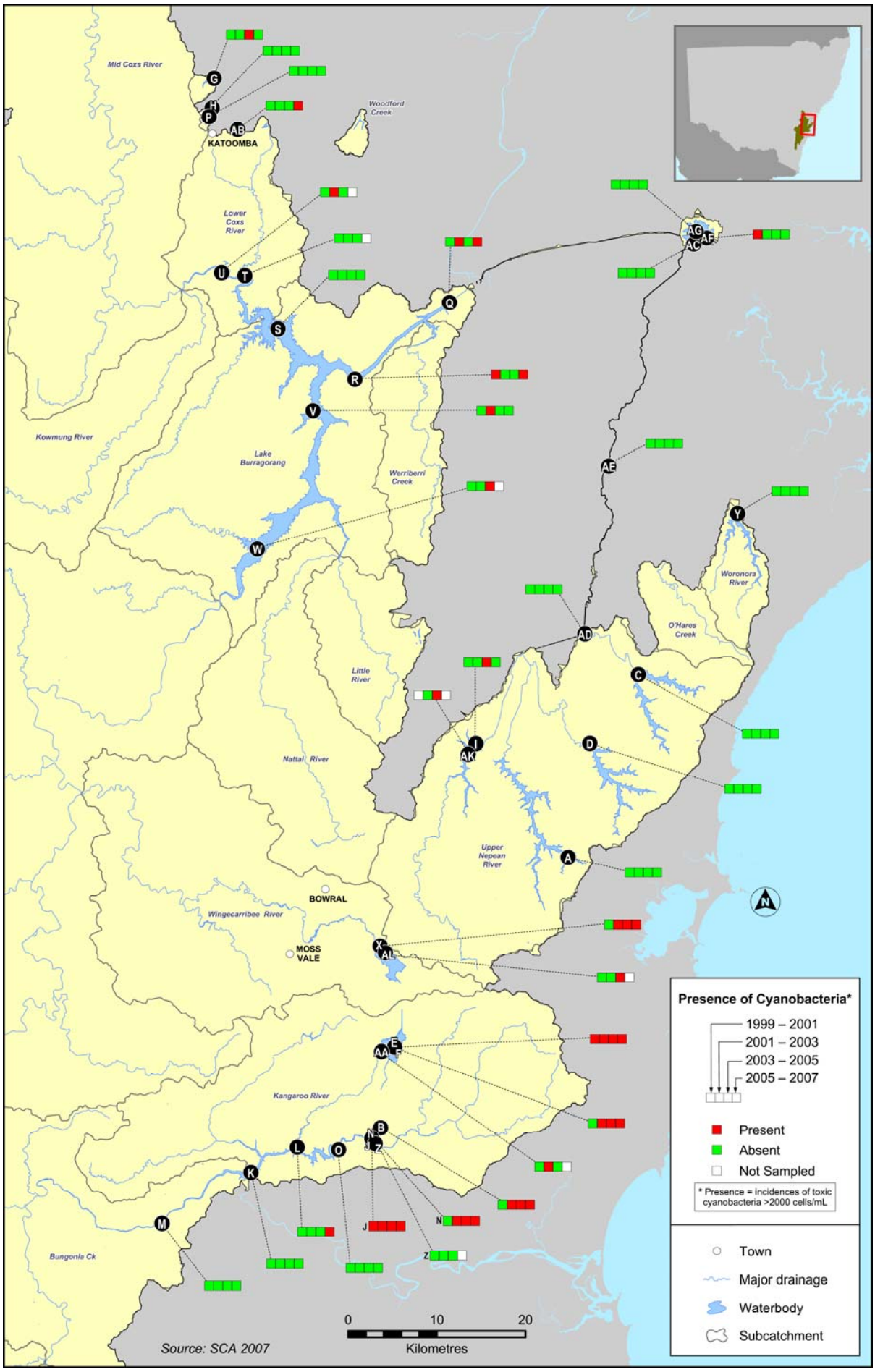
Figure 3.8: Algal incidences at Bendeela and Wingecarribee Reservoir during the 2007 Audit period



Source: SCA 2007

Note: Red level = major incident, >50,000 cells/mL, Green level = alert level,< 5,000 cells/mL. Amber level = minor incident, 5,000-50,000 cells/mL

In August 2007, outside the 2007 Audit period, an algal bloom developed over a large area of Lake Burragorang at Warragamba Dam. The dominant alga present on the surface of Warragamba Dam was a species of *Microcystis*, which is a non-toxic blue-green alga. The algal bloom in Warragamba Dam may have been triggered by nutrients being washed into the dam from the heavy rainfall in June/July 2007. Several algal monitoring sites in the Warragamba (Lake Burragorang) storage showed high percentages of total cyanobacteria in the 2007 Audit period, preceding the rainfall event. The increased nutrients combined with the warming of the surface waters in Lake Burragorang from the recent warm weather, would have promoted the algal growth. The numbers of *Microcystis* could increase in coming months if the warmer weather continues (SCA, 2007e).



Map 3.4: Toxic cyanobacteria presence with >2,000 cells/mL for the 2001, 2003, 2005 and 2007 Audit periods in the Sydney drinking water catchment

SCA has conducted tests on raw and treated water from Warragamba Dam and found that no impact on drinking water quality and no toxins have been found. The SCA has been drawing water from between 40 and 48 metres below the dam surface. The SCA has alternate sources of water that could be used if the quality of the water being supplied from Warragamba Dam were to change. SCA is also working closely with the scientific community to gain a better understanding of the cyanobacteria *Microcystis*.

Implication

The overall incidence of toxic cyanobacteria in the water storages decreased but the overall incidence of total cyanobacteria increased during the 2007 Audit period. The continued and increased incidences of total cyanobacteria with greater than 2,000 cells/mL at sampling locations in the Kangaroo River (priority), Wingecarribee River (priority) and Lake Burragorang sub-catchments are of concern.

Algal blooms are triggered in various ways depending on the nature of the waterway and antecedent conditions in the Catchment. Nutrient inputs from catchment sources are clearly important, but other factors, such as turbidity of the water, internal nutrient cycling (i.e. nutrients regenerated from sediments), temperature and stratification of the water are also important in triggering and maintaining algal blooms.

A number of management methods are available to manage blooms (CRCWQT, 2007a), including:

- physical controls, such as artificially mixing the water column to create turbulence
- minimising nutrient levels in water storages
- restricting light onto the water surface - for instance, covering tanks or dams
- taking water from different parts of the reservoir.

Future directions

The use of models can simulate management scenarios such as changes in nutrient loading or destratification via turbulence to enable predictions of the most appropriate management strategy and risk reduction that can be achieved. As an example, modelling of cyanobacterial growth in Myponga Reservoir South Australia suggests that the cyanobacterial population would be reduced by 75 per cent with a bubble plume aerator (CRCWQT, 2007c).

The best options for managing the impact of algal blooms on water quality and ecosystem health in each location can be developed when the processes responsible for triggering and maintaining algal blooms in the 'hot spots' are identified and understood. The key to understanding these processes may be the use of models.

The Auditor notes that as a first step, nutrient budgets (nitrogen, phosphorus and carbon) are being constructed by SCA to determine the relative contributions from sources, such as sewage, stormwater, agricultural runoff and erosion, as well as the in-stream stocks, such as sediment deposits, to the yield of nutrients reaching reservoirs. In addition, work is being undertaken to understand the cycling of these elements within the reservoirs themselves. This will enable the processes and systems that are contributing the most nutrients to be predicted. Tracing tools are being used to test the modelling aspects of the budget to provide an objective analysis. It has also been noted by SCA that it is important to provide a strong linkage with the erosion work, since this is a major factor in driving phosphorus budgets.

Most of the nutrient delivery takes place in association with major events such as floods. Therefore, it is important to understand the relationship between these natural processes and nutrient delivery. Nutrient budgets will be informed not only by tracing tools, but also with data from storm-event sampling programs.

In 2005, the Auditor recommended that the cause of the high incidences of algae be identified and management strategies be developed (2005 Recommendation 7). Based on the data from the 2007 Audit period it is clear that this work should continue to receive priority.

Recommendation 2: The SCA should continue the process of understanding the causes of 'high' incidences of algae in the water storages of the Kangaroo River (priority), Wingecarribee River (priority) and Lake Burragorang sub-catchments, to help ensure that specific management strategies are in place for short, medium and long term responses in each sub-catchment.

Reducing the risk of algal blooms in Lake Burragorang

To reduce the risk of further algal blooms in Lake Burragorang, the SCA needs to continue with the implementation of long-term strategies including:

- continue collecting the information (nutrient budgets, tracing tools, storm event sampling) that will identify the main sources of nutrients to the Catchment.
- rectification action planning needs to be completed so that the major sources of pollutants in the catchments and actions to reduce the pollutant loads or concentrations from existing land uses, developments and activities can be identified.
- continue to implement the Healthy Catchments Program (HCP) for the protection and remediation of water quality and catchment health issues.

It is noted, however, that after prolonged periods of drought the onset of rain will result in a flush of nutrients into waterways, increasing the risk of algal blooms.

3.4 Pathogens

Background

Cryptosporidium and *Giardia* are pathogenic micro-organisms which cause intestinal infections in humans. The micro-organisms are transmitted between humans by means of cysts which are found in excreted faecal material. Consumption of water containing cysts is the principal method of contracting the disease (Braidech and Karlin, 1985).

Sources of these micro-organisms include STPs, unsewered areas and native and domestic animals. Juvenile cattle and pigs, and adult and juvenile sheep have been found to shed the most *Cryptosporidium*. Kangaroos shed lower levels of *Cryptosporidium* than domestic animals (similar to adult pigs and cattle) (CRCWQT, 2007d).

There is potential for large amounts of pathogenic material, including *Cryptosporidium* and *Giardia*, to be mobilised during storm events to reach creeks, rivers and water storages. *Cryptosporidium* oocysts show relatively high mobilisation rates across land surfaces during rain events as well as moving as single colloidal entities within rivers and reservoirs, potentially moving through even the largest reservoirs within days (CRCWQT, 2007b).

The Audit examined the incidence of DAPI (4', 6-diamidino-2-phenylindole) positive *Cryptosporidium* oocysts and *Giardia* cysts in the Catchment during the 2007 Audit period and compared it to data from the 2001, 2003, and 2005 audit periods. Identification of positive oocysts/cysts was undertaken using DAPI staining technique that identifies the presence of intact characteristic internal structures. In particular, the Audit focused on locations where *Cryptosporidium* oocysts or *Giardia* cysts were present in more than five per cent of the samples collected at a location during the 2007 Audit period.

Findings

The total number of locations where ***Cryptosporidium*** oocysts were present in more than five per cent of samples, decreased from three sites during the 2005 Audit period to two sites for the 2007 Audit period.

The incidences of *Cryptosporidum* oocysts at Gibbergunyah Creek at Braemar (Mittagong) STP discharge point $^{(CD^*)}$ increased, in the low level range, from 15 per cent of total samples during the 2003 Audit period to 46 per cent during the 2005 Audit period. During the 2007 Audit period the incidences of *Cryptosporidium* decreased slightly to 40 per cent of the total samples. This site still has the greatest incidences of *Cryptosporidium* during the 2007 Audit period (Map 3.5 and Table 3 in Appendix C).

The other site with *Cryptosporidium* oocysts present was Wollondilly River at Jooriland $^{(CL^*)}$. The incidences of oocysts increased, in the low level range, from no samples during the 2005 Audit period to 7 per cent for the 2007 Audit period (Map 3.5 and Table 3 in Appendix C).

The presence of *Cryptospidium* oocyts at the Prospect WFP $^{(AH^*)}$ decreased , in the low level range, from 50 per cent of total samples during the 2005 Audit period to one per cent for the 2007 Audit period (Map 3.5 and Table 3 in Appendix C).

The number of locations where ***Giardia*** cysts were present in more than five per cent of samples, decreased from four sites during the 2005 Audit period to three sites during the 2007 Audit period.

The incidences of *Giardia* cysts at Coxs River at Kelpie Point (CA*) and at Werriberri Creek at Werombi (CM*) increased, in the low level range, from no samples during the 2005 Audit period to eight per cent and six per cent respectively for the 2007 Audit period (Map 3.5 and Table 3 in Appendix C).

Giardia cysts were detected in all samples taken, at Gibbergunyah Creek (CD*). However, it decreased from 19 per cent in the high level and 53 per cent in the medium level of total samples during the 2005 Audit period to no samples in the high level and 36 per cent in the medium level for the 2007 Audit period. There was, however, a slight increase in the low level range, from 23 per cent during the 2005 Audit period to 36 per cent for the 2007 Audit period (Map 3.5 and Table 3 in Appendix C).

The incidences of *Giardia* cysts decreased in the low level range at two locations. At Kedumba River at Maxwells Crossing (CC*) from five per cent of total samples during the 2005 Audit period to no samples for the 2007 Audit period; and at Wollondilly River at Jouriland (CL**) from seven per cent in 2005 to four percent during the 2007 Audit period (Map 3.5 and Table 3 in Appendix C).

Implication

There is continued incidence of *Cryptosporidium* and *Giardia* at Gibbergunyah Creek near the location of the Braemar STP discharge point. Gibbergunyah Creek is one of the few locations where monitoring for pathogens is undertaken in the Catchment away from the water storages. This site is monitored by SCA because Braemar STP is only 95 km from the raw water offtake at Lake Burragorang. It appears to have a persistent source of *Cryptosporidium* oocysts, having had more than five per cent of samples containing *Cryptosporidium* in the 2001, 2003, 2005 and 2007 Audit periods. The SCA identified in the 2005 Audit that the UV disinfection process at the Braemar STP had not been operating effectively. However, there were still incidences of *Cryptosporidium* and *Giardia* at Gibbergunyah Creek during the 2007 Audit period.

SCA stated in the 2005–06 Annual WQ Monitoring report "that the incidence of *Cryptosporidium* and *Giardia* at Gibbergunyah Creek are most likely as a result of the Braemar STP which is immediately upstream of the sampling location. No *Cryptosporidium* oocysts and *Giardia* cysts were detected at Nattai river at Smallwoods crossing (CF*), located about 35km downstream of Gibbergunyah Creek. This indicates that *Cryptosporidium* oocysts and *Giardia* cysts may die off and settle along the Nattai River".

In 2005, the Auditor recommended (2005 Recommendation 8) that the SCA investigate the source of *Cryptosporidium oocysts* at Gibbergunyah Creek and Prospect WFP and the source of *Giardia* cysts at Gibbergunyah Creek, Kedumba Creek, Wollondilly River at Jooriland and Murray's Flat, and develop a management response at each location to reduce the incidence of C*ryptosporidium* and *Giardia* oocysts and cyst presence. In response to this recommendation, SCA is undertaking a research project to look at the viability of *Cryptosporidium* in both the influent and effluent from the Braemar and Moss Vale STPs. This will assess the numbers of viable *Cryptosporidium* being discharged from these STPs.

Based on the data from the 2007 Audit period, the Auditor believes that further investigation into the cause of the persistent sources of pathogens is required.

Recommendation 3: The SCA should investigate the causes of the continuing presence of pathogens in the Nattai River (Gibbergunyah Creek), and in the Wollondilly River, Mid Coxs River and Werriberri Creek (priority) sub-catchments.

Studies have found that fully protected catchments have by far the highest water quality even during rain events (equivalent to over 99.9 per cent pathogen reduction compared to unprotected). This demonstrates the value of catchment protection and access exclusion policies. A critical finding for surface waters has been that impact is directly related to rainfall-induced runoff, and therefore sampling during relatively dry periods provides minimal indication of the level of pathogen risks. Intensive agricultural development in less than five per cent of a catchment area leads to a doubling in pathogen concentrations and risk. Even during baseline/small storm events, source water quality was heavily degraded in agricultural/urbanised catchments,

* See Map 3.5 for the location of sampling sites and Table 10 in Appendix C for explanation of codes.

highlighting the need to target data collection more on high runoff periods than dry weather periods. During the latter, water quality was relatively good (CRCWQT, 2007d).

The Kangaroo River (priority) and Woronora River sub-catchments are the only locations where raw water from a storage is supplied to a local WFP without monitoring for the presence of pathogens in the storage or its sub-catchment. The Auditor notes that there are recognised pathogen-generating activities in the Kangaroo River sub-catchment, yet the Lake Yarrunga (Tallowa Dam) storage and/or the Bendeela storage supplying raw water to the Kangaroo Valley water filtration plant are not monitored for the presence of pathogens. The Auditor believes that this situation should be addressed.

Recommendation 4: The SCA should undertake sampling for the presence of pathogens in the Kangaroo River (priority) sub-catchment.

Future directions

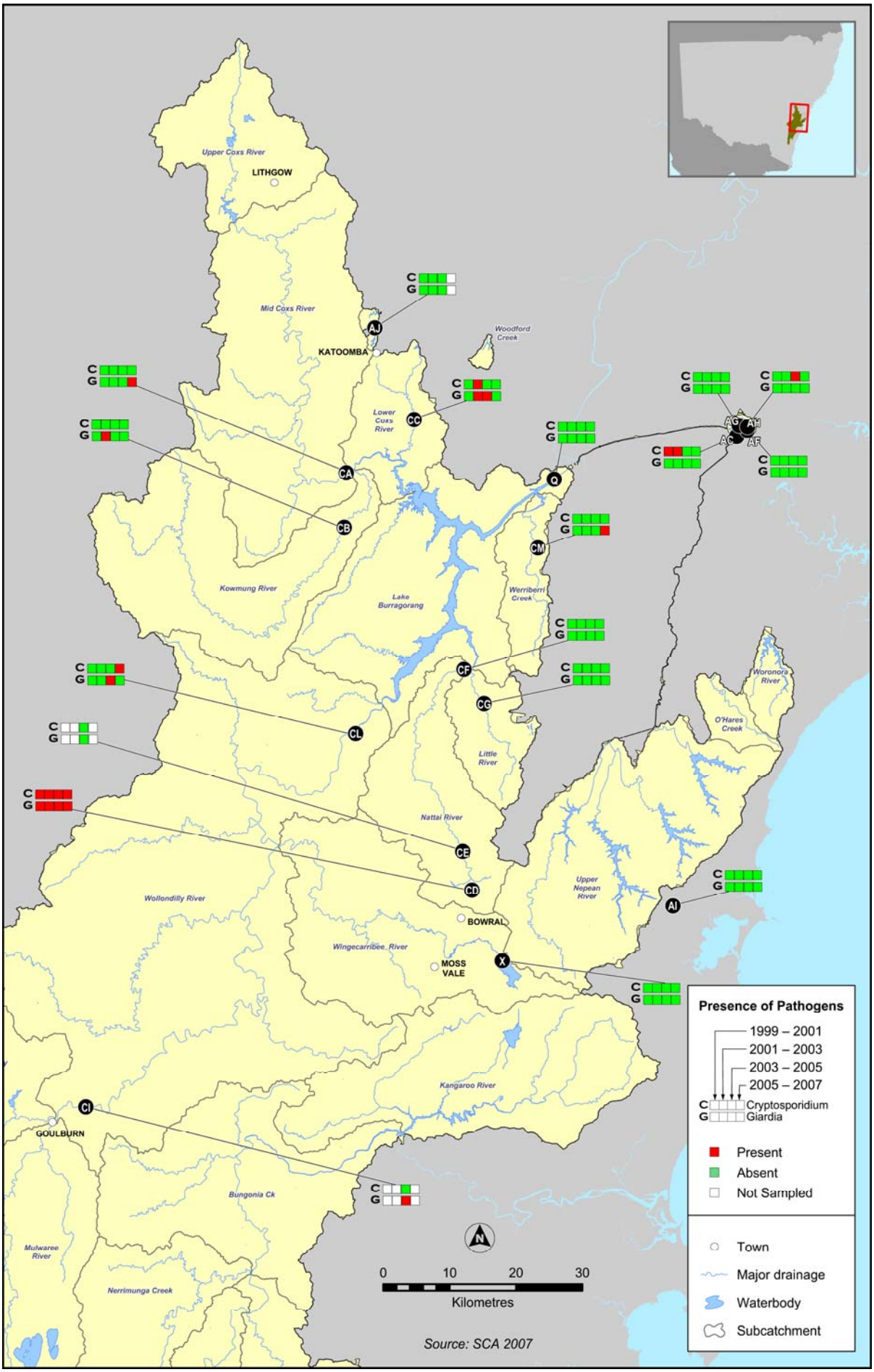
Cryptosporidium hominis and *Cryptosporidium parvum* are infectious to humans, *C. hominis* is specific to humans and *C. parvum* is specific to cattle but also infects humans. To assess the potential risk from *Cryptosporidium* in the Catchment it is necessary to quantify and identify the strains of *Cryptosporidium* that are prevalent in the Catchment. *Cryptosporidium* genotyping can be used to determine how many different types of strains are carried by host animals and humans. Genotypes of *C. hominis* and *C. parvum* that are prevalent in a Catchment may warrant subsequent testing using infectivity assays to assess their potential ability to cause human infections (CRCWQT, 2007b).

Predictive models for *Cryptosporidium* oocyst and other pathogens' transport may be helpful in investigating the source of *Cryptosporidium* oocysts and *Giardia* cysts in the Catchment. Elcom is a three-dimensional lake model that can be used to simulate the hydrodynamics, particularly the river inflow. The river inflow will move through the reservoir at a depth determined by the density (temperature and salinity) relative to the density of the reservoir. This model can be linked to an ecological model (Caedym) that describes particle settling and pathogen inactivation. The model can be used to predict where pathogens occur in the reservoir following a river inflow event (CRCWQT, 2007d). The SCA is currently running Elcom for Lake Burragorang, to predict where dirty water and therefore pathogens might occur in the reservoir following a large river inflow event.

When modelling the fate of pathogens in the environment, the inactivation rates must be appropriate for the temperature of the climate in question and the location of the river intrusion, as this is where the pathogens are most likely to be. Sampling in the reservoir should target the river intrusion to facilitate the best measure of pathogen risk.

It is also recommended that all domestic livestock be kept as far away from watercourses as possible, the actual distance required depending on what pathogens need to be controlled and on the local soil, climate, vegetation and slope factors. At the very least, newborn to juvenile animals should be kept separated from watercourses in barns/stockyards or distant paddocks. Collection, stockpiling (away from watercourses) and treatment of manure, particularly from juvenile animals will minimise the land deposition of highly contaminated faeces. Manure storage should aim to increase temperatures to maximise pathogen inactivation (CRCWQT, 2007d).

Current programs to investigate and reduce the incidence of pathogens are outlined in the Actions and Response section of this chapter.



Map 3.5: *Cryptosporidium* and *Giardia* presence in > 5% of samples for the 2001, 2003, 2005 and 2007 Audit periods in the Sydney drinking water catchment

Actions and Response

Response to issue

The primary responses to reducing contamination of the raw water supply are related to improving understanding of the relative contribution of nutrient sources and to reducing the amount of pollution entering waterways in the Catchment. Improving stream flow regimes, vegetation cover and riparian vegetation all contribute to reducing the impact of nutrients and pollution sources on raw water supply, and are dealt with in other sections of this Report. This section covers the major actions to manage and reduce pollution discharge to the rivers and streams in the Catchment. These actions include programs to:

- ***understand nutrient sources***
- ***reduce nutrients from sewage management systems***
- ***reduce pollution from diffuse point sources (agricultural and urban runoff)***
- ***investigate exceedences of the Bulk Water Supply Agreement***
- ***investigate and reduce the incidence of algae blooms***
- ***investigate and reduce the incidence of pathogens.***

Programs to understand nutrient sources

The SCA's Collaborative Research Program includes a number of projects to evaluate and enhance tools for understanding nutrient contribution, including:

- a Nutrient Source Budgeting project with the University of Western Sydney which aims to evaluate and enhance tools for nutrient budget construction and prioritisation of land uses and abatement actions to reduce nutrient loadings. Completed in 2006
- identification of major sediment and nutrient sources in Sydney's drinking water catchments with CSIRO. Due for completion in 2007
- cover crops to decrease phosphorus transport from agricultural soils with Australian National University. Due for completion in 2007
- impact on water quality by post-wildfire erosion and nutrient release with CSIRO. Completed in 2006
- nutrient generation from rural land and delivery to streams in the Sydney drinking water catchment with the University of Western Sydney. Due for completion in 2008.

Programs to reduce nutrients from sewage treatment systems

DECC regulates major point sources of water pollution using licences issued under the POEO Act. The licences include requirements for pollution control, monitoring, and reporting. DECC imposed **Pollution Reduction Programs (PRPs)** on all Council STS licences across the State, that required licensees to prepare a Sewer Overflow Investigations Report (PRP100) and an Incident Notification Protocol (PRP101). The Sewer Overflow Investigations Report identifies overflows from the sewerage system that pose a significant risk of harm to the environment or to public health and to assist in implementing management responses to reduce this risk. The Incident Notification Protocol ensures that incidents with public health and/or environmental consequences are reported to appropriate stakeholders in a timely manner. Other PRPs applying to licensed STS operators in the Catchment during the current audit period are listed in Table 3.6.

Table 3.6: STS PRPs during the 2007 Audit period

Licensed STS	PRP	Description
Bowral	PRP1	STP upgrade which will reduce nutrients loads being discharged. *Delivered*
Goulburn	PRP3	Evaluate options for sustainable effluent management, and implement preferred option. *Preferred option in construction*
Lithgow	PRP4	Install and operate Nitrification/Denitrification reactor at STP and decommission redundant tertiary ponds. *In planning (passed due completion date)*
Mount Victoria	PRP8	Sewer overflow abatement for dry and wet weather. *Delivered*
Warragamba	PRP7	Sewer overflow abatement for dry and wet weather. *Delivered*

Source: DECC 2007

The PRP4 for Lithgow STP was due to be completed in late 2006. The Auditor understands that the environmental regulator (DECC) is engaged with Lithgow City Council in actions to ensure that nutrient loads to the Catchment are reduced as soon as practicable. During the Audit period, Council had to terminate a load reduction agreement negotiated with DECC, and thus forego available financial benefits from reduced licence fees, because it could not deliver PRP4 in the agreed timeframe.

Installation and operation of on-site sewerage systems are regulated by local councils under a range of legislation including the *Local Government Act 1993*, the *Environmental Planning and Assessment Act 1979* and the POEO Act. There are approximately 18,000 on-site sewage management systems in the Catchment. The primary program for on-site sewage management systems is the **SepticSafe Program** which was introduced in 1998. SepticSafe is a statewide partnership between the NSW Government and local councils to deliver improved management of on-site sewage management systems by providing education, support and supervision to landowners, to enable them to manage their systems so that they operate in accordance with health and environmental performance standards.

The SCA's **Healthy Catchments Program** includes a **Sewerage Strategy**. There are a number of programs under the Sewerage Strategy including:

- Accelerated Sewerage Program
- On-Site Sewage Systems Program
- Sewer Gauging and Modelling Program (SGMP)

The **Accelerated Sewerage Program** provides funding assistance to local councils to fast track sewer services and sewage treatment infrastructure upgrades in the Catchment. The SCA has an agreement as part of the State Government's **Country Towns Water Supply and Sewerage Program** to provide $20 million funding through the Accelerated Sewerage Scheme over five years from 2002-2003 to 2007-2008. Some sewage system projects undertaken during the 2007 Audit period include:

- Bowral STP – the upgrade plant became operational during the 2007 Audit period
- Goulburn STP – upgrade in construction and will be completed in late 2007
- Lithgow STP – first stage of upgrade was completed in April 2006 and second stage is continuing
- Bundanoon STP – environmental impact statement has been prepared for the upgrade. As an interim measure, Wingecarribee Council has placed a moratorium on approvals for new dwellings, to help prevent overload of the existing STP
- Wallerawang STP – investigations into an upgrade to improve treatment performance are continuing and will involve water reuse
- Taralga – a development application for the proposed scheme is being assessed by Lachlan Shire Council
- Kangaroo Valley – undertaking of an options analysis for a sewerage system at Kangaroo Valley to serve 2,000 people

- Robertson – Wingecarribee Shire Council has purchased the site for the proposed plant and prepared the environmental impact statement. As an interim measure, Wingecarribee Council requires existing residences to have regularly maintained sewage pump out systems.

The STPs being upgraded or constructed under the **Accelerated Sewerage Program** (ASP) collectively have the capacity to service 58,500 people. When the program is complete, the capacity will increase to 86,100 people. The SCA estimates that if all the upgrades of all STPs in the ASP are completed the annual loads of total nitrogen and phosphorus will be reduced by 30 tonnes and 15 tonnes respectively, as well as microbial pathogens entering the Catchment (SCA, 2003b).

The SCA's Sewage Strategy also includes an **On-site Sewerage Management program**, this program was launched in July 2005. Five councils (Wingecarribee, Wollondilly, Palerang, Shoalhaven and Lithgow) were granted a total of $184,434 in 2005-06. Through the program 2,157 on-site systems were inspected in 2005-06 and 205 were found to be not performing satisfactorily. Approximately 410 of the 4,075 on-site sewerage systems inspected during 2006-07 had a serious failure. Councils have started rectification actions for the unsatisfactory systems.

There are a number of small sewage treatment systems in the Catchment that do not require a licence under the POEO Act. These middle-sized systems serve the needs of schools, resorts, camping grounds and residential camps. In 2005, SCA commenced an audit program of these premises. During the 2007 Audit period, 38 systems were inspected and from these inspections 13 systems were operating satisfactorily and 25 needed rectification.

Through the **Sewer Gauging and Modelling Program** (SGMP), an initiative to reduce the risk of raw sewage contamination from sewer system overflows, the SCA has provided funding for projects in the Goulburn, Moss Vale, Berrima, Bundanoon, Bowral, Mittagong, Lithgow and Wallerawang areas. This program represents the SCA's participation in the delivery of Pollution Reduction Programs for sewer system performance assessments required of council STS operators by DECC (See Section 3.1 in Chapter 3).

- Assessment of the sewer infrastructure, including pipes and pumping stations, was completed at Goulburn, Mittagong, Berrima, Bundanoon and Moss Vale and is in progress at Wallerawang, Lithgow and Bowral.
- Bowral and Mittagong sewerage system gauging model was calibrated and simulated sewer performance.
- Goulburn CBD sewer system was refurbished. SCA provided 50 per cent of the funding. In 2006-07 upgrades to 2,300 metres of sewer mains were completed and this extensive project will be completed in the next year.
- SCA has provided $200,000 to Palerang Shire Council to replace two sewage-pumping stations at Braidwood. This work will reduce the potential overflows from the Braidwood sewer system.

The SCAs **Catchment Protection and Improvements grants** for community groups funded a project to improve on-site sewage management. The Gundillion Recreation Reserve Trust was granted $7,500 to upgrade on-site sewage management and waste water facilities at Gundillion Hall.

Sydney Water's **Priority Sewerage Program** provides improved wastewater services to unsewered urban communities. By connecting to the sewer, residents will be helping to reduce the number of septic systems in their area. This reduces risks to public health and helps improve local waterways. A number of sewerage schemes have been completed or are proposed as part of the **Priority Sewerage Program**:

- Mulgoa, Wallacia and Silverdale Sewerage Scheme (completed). This scheme involved the de-commissioning of the Warragamba STP and diversion of the sewage to a new STP outside the Warragamba sub-catchment.
- Bargo, Yanderra and Buxton
- Nattai
- Upper Blue Mountains Sewerage Scheme (in progress). This scheme will provide an improved sewerage service to the unsewered urban areas of Mount Victoria, Blackheath and Medlow Bath. The scheme involves the installation of new sewer pipes in Mount Victoria, Blackheath and Medlow Bath and the transfer of wastewater from the three villages to the Winmalee STP. The existing STPs at Mount

Victoria and Blackheath will be de-commissioned once the scheme becomes operational, and wet weather sewage overflows will be restricted to very low frequencies (less than 10 in 10 years).

The Blue Mountains City Council introduced an Environment Levy in July 2005. The Environment Levy provides funding to spend specifically on additional environmental protection and natural resource management projects within the Blue Mountains local government area. The **Connect to Sewer Project**, funded from the Environmental Levy aims to identify properties that are utilising unsustainable on-site wastewater technologies, such as septic systems, and have these properties connect to the public sewerage system whenever available. Environmental objectives of this project are a substantial reduction in weeds, a reduction in native vegetation die-off by restoring natural hydraulic and nutrient regimes, an improvement in the water quality of our natural waterways and improve environmental and public health as a result of reducing the amount of discharged wastewater. Eleven failing systems were identified in 2006, and seven have since been connected to Sydney Water sewers (BMCC, 2006).

Programs to reduce pollution from diffuse sources

Urban stormwater runoff

Stormwater management systems are generally owned by local government. Each local council has an **Urban Stormwater Management Plan** which prioritises works to reduce urban stormwater pollution. The NSW Government is assisting councils to implement these plans by preparing guidelines on stormwater management and funding local stormwater projects.

The SCA's **Healthy Catchments Program** includes an **Urban Stormwater Strategy**. Under the strategy, a **Stormwater Improvement Program** provides funding assistance to local government to improve stormwater management in the Catchment.

Some stormwater projects undertaken as part of the Stormwater Improvement Program during the 2007 Audit period include:

- In 2004-05 the stormwater data was digitised and the risk-ranking model was completed. This model was used to priority rank the projects that SCA supports that manage stormwater based on improved water quality outcomes.
- The SCA contributed $89,817 in 2005-06 to assist Lithgow City Council to improve major road and river crossings on the Coxs River, with the aim of reducing sediment runoff to the river.

The following guidelines have been produced during the 2007 Audit period, and assist in reducing pollution from urban runoff:

- In 2006, DECC (formerly DEC) produced the '**Managing Urban Stormwater. Harvesting and Reuse'** guideline to provide guidance on key considerations for future stormwater harvesting and reuse projects, based on experience gained from early stormwater harvesting projects (DEC, 2006).
- **Australian Runoff Quality: A Guide to Water Sensitive Urban Design EM024**, was produced by Engineers Australia in 2006. This guide provides an overview of current best practice urban stormwater management in Australia, within the context of total urban water cycle management and integration into urban design.
- **Water Sensitive Urban Design; WSUD Engineering Procedures: Stormwater**, was produced by Melbourne Water in 2005. This guide provides an engineering design manual and performance specifications for water sensitive urban design (WSUD) elements for Victoria.

The Blue Mountains City Council Environment Levy provides funding to spend specifically on additional environmental protection and natural resource management projects within the Blue Mountains local government area. Two projects to improve stormwater were:

- **Stormwater Control Kubya St, Blackheath** - Environmental objectives of the project were the prevention of sediment, nutrients and weeds from moving downstream to bushland and into the Catchment, prevent further erosion occurring on private land, restore a natural flow path for stormwater and improved stormwater infrastructure to reduce Council's stormwater and road maintenance costs. The installation of a reinforced concrete drainage system and velocity discharge control was completed during the 2007 Audit period.

- **Stormwater Control at Sublime Point -** Environmental objectives of the project were to improve water quality in Gordon Creek, a tributary of the Catchment, prevent dispersal of nutrients, sediment and weed seed across private and public land and improve drainage along Sublime Point road preventing local flooding and road closure. During the 2007 Audit period the stormwater pipeline and energy dissipater to disperse stormwater were installed.

Rural runoff

The following programs or actions have been initiated or undertaken during the 2007 Audit period, and assist in reducing pollution from rural runoff:

- the SCA's **Rural Lands Strategy** under its **Healthy Catchments Program**,
  - SCA and DPI have commenced a grazier education partnership which supports graziers through education and follow-up activities
  - The Dairy Effluent Management Program is continuing with sludge build-up in dams emerging as an issue (being addressed with the development of a routine maintenance program).
- the **Catchment Protection Scheme** which is co-ordinated by the CMAs and which receives funding from a range of sources including SCA. The Scheme provides advice and funding for on-ground works such as erosion management, rehabilitation and protection of riparian zones and effluent runoff.
- various **Best Practice Guidelines** (BPGs) to maintain a strong, profitable agricultural sector at the same time as promoting environmentally sound practices were developed during the 2007 Audit period, including:
  - Best Practice Guidelines for using Poultry Litter on Pastures (DPI, 2007a) - These guidelines aim to ensure that poultry litter is used wisely to optimise pasture production and minimise the risk of problems concerning stock health, stock feeding bans, pollution and the environment.
  - Deep Litter Housing for Pigs (DPI, 2006b) - The Prime Fact reviews deep litter housing for pigs including construction, controlled drainage and storage and treatment of spent litter. It also offers practical design, performance and process guidance.
  - Recycled Organics in Catchment Management (DPI & DEC, 2005b) - The main aims of the project are to determine desirable product specifications for composted recycled organics (RO) products for use in runoff and erosion control in water catchments in NSW, to determine the benefits to water quality and catchment health of the strategic use of RO products for runoff and erosion control by replicated and demonstration field trials, to evaluate the use of RO products for runoff and erosion control in catchment areas as a viable market option for the RO industry.
  - Guide for Agricultural Development (SCA, 2007a) - provides advice on the definition of 'intensive plant growing' and the development assessment requirements for agriculture.
- Implementing Best Practice for Sustainable Grazing Management in the H-N CMA, is a collaboration between DPI and H-N CMA and aims to recognise and improve the capacity of land managers to develop and implement grazing practices that lead to profitable, sustainable and productive enterprises, and which also contribute to drinking water quality and healthy catchments.
- The Shoalhaven Illawarra Dairy Partnership is a collaboration between Southern Rivers Catchment Management Authority (SR CMA), DPI and the South Coast and Highlands Dairy Industry Group. This partnership supports dairy farmers in the Kangaroo Valley to manage nutrients via on-ground works and capacity building. On-ground works include effluent management system upgrades, riparian fencing, alternative watering systems, laneway and creek crossing improvements.

Case Study – Dairy Best Management Practice

Dairy farms have been identified as a point source of nutrient and pathogenic pollution by the SCA under the Pollution Source Risk Management Plan. Some of the major sources of pollution in dairy farms include dairy shed waste, and poorly constructed stock laneways (which often cross watercourses). These result in an inherent threat to water quality in the Catchment.

In 2001-02 the SCA established its Priority Industries Program (PIP) in collaboration with dairy farmers and the Department of Agriculture (now DPI), to provide expert advice and funding to improve dairy waste management practices throughout the Catchment. SCA covers approximately 80 per cent of the costs. The objectives were primarily to stop dairy effluent from entering waterways, to encourage farmers to adopt Best Management Practices (BMPs) by providing education, advice and financial incentives, and to monitor before and after water quality to determine the effectiveness of the implemented actions.

The current BMP involves the use of a two-pond dairy wastewater management system. A sump is placed immediately outside the dairy shed, to separate liquids from solids in the wastewater. Solids can be dried and applied to the land as fertiliser, whilst liquids pass through to the ponds for treatment. The treated effluent can be recycled to irrigate crops and pasture. The 2007 Audit Team inspected a premises utilising these practices in the Kangaroo Valley.

In the 2007 Audit period, the SCA and the University of Wollongong collaboratively developed a research project to monitor the performance of new systems, including water quality before and after implementation of the BMPs. Preliminary findings have confirmed a significant reduction in most nutrients and other pollutants following the implementation of current BMPs, including the dairy shed waste management system.

Figure 3.9: Sump to catch waste from sheds
Source: DECC 2007

Figure 3.10: Calf in holding pen to manage waste
Source: DECC 2007

Programs to investigate exceedences of the Bulk Water Supply Agreement

In April 2007, the SCA completed the preparation of its **Raw Drinking Water Quality Management Framework (2007-2012) (RDWQMF)**. The framework provides an overview of all tools and systems used to implement water quality objectives (SCA, 2007b).

The SCA in collaboration with the Cooperative Research Centre for Water Quality and Treatment, the University of NSW and Sydney Water is investigating the generation, chemistry and transformation of iron and manganese in Lake Burragorang to understand those elements in raw water. The outcome of the research will enable the water treatment process to cope with high levels of dissolved iron and manganese in raw water which lead to discoloured water in the distribution system.

Programs to investigate and reduce the incidence of algae blooms

The SCA has developed a **Cyanobacteria Risk Management Strategy** (SCA, 2005a) which identifies the risks posed by cyanobacteria in SCA storages and the risk management strategies required. The plan includes short, medium and long term management options.

The SCA's **water quality monitoring program** (SCA, 2005c) includes specific assessments for the incidence and severity of cyanobacteria outbreaks. This program sets out the frequency and locations of compliance monitoring and the analytes to be measured at sites within the SCA's area of operation.

A fact sheet entitled **'Blue Green Algae: A guide'** has been prepared by the CRC Water Quality and Treatment. This fact sheet provides information on what blue-green algae are, how blooms form, preventing and controlling algal blooms and treatment of water (CRCWQT, 2007a).

The CRC Water Quality and Treatment has also produced another fact sheet with further technical information about Blue green algae entitled '**Cyanobacteria: Management and Implications for Water Quality'** (CRCWQT, 2007c).

Programs to investigate and reduce the incidence of pathogens

The SCA in collaboration with other research organisations has initiated the following research into pathogens:

- Pathogen Budget – A research project on the development of a pathogen budget model for the Wingecarribee sub-catchment. Completed in 2006
- Molecular methods to trace faecal bacteria and bacteriophages in the catchment, with the University of NSW. Completed in 2006
- Molecular methods to trace faecal viruses in the catchment, with the University of NSW. Completed in 2006
- Native animals as potential sources of human pathogens in SCA catchments, with Macquarie University. Completed in 2006
- Prevalence of *Cryptosporidium* oocysts and anti-*Cryptosporidium* antibodies in animals in SCA catchments, with Macquarie University. Completed in 2006
- *Cryptosporidium* in the Warragamba catchment – genotypes and cell culture infectivity, with Macquarie University. Completed in 2006
- Using molecular tools to understand and control the transmission of *Cryptosporidium,* with Murdoch University. Due for completion in 2008
- Novel molecular markers for the historical source tracing of faecal contamination in urban water catchments, with University of NSW. Due for completion in 2007
- *Cryptosporidium* in feral animals is an assessment of which species of feral animals such as deer, pigs, goats and horses carry human-infective strains of *Cryptosporidium* and the risk of transmission of the pathogen is being undertaken, with Macquarie University. Due for completion in 2009
- Estimating the relative pathogen risk from sewage treatment plant effluent, with the University of NSW. Due for completion in 2009
- Riparian and water quality protection by influencing animal movements, with the University of NSW. Due for completion in 2008
- The SCA is researching the health risks posed by large populations of Eastern Grey kangaroos in the Warragamba catchment's Special Area in collaboration, with Macquarie University. The research has found that Eastern Grey kangaroos do not carry types of *Cryptosporidium* that can cause illness in humans.

Tracking long-term bacterial contamination and therefore faecal contamination of catchment waterways is also under way by SCA. About 100 spore isolates from known host animals in the Catchments are being studied to improve the accuracy of host identification. A summary of the contamination status of sediments in the SCA's storages and a selection of rivers will be produced including a map of contaminant histories.

New ways to exclude stock from riparian zones to minimise faecal contamination of streams are also being examined by SCA. As an alternative to fencing, the study is measuring the effectiveness of locating water, food, shade and dry ground away from water courses.

A fact sheet entitled **'*Cryptosporidium* genotyping and infectivity analysis'** has been prepared by the CRC Water Quality and Treatment. This fact sheet provides information on the tools for *Cryptosporidium* typing and viability analysis to help assess the public health significance of oocysts found in catchments and the effectiveness of water quality protection barriers (CRCWQT, 2007b).

The CRC Water Quality and Treatment has also produced another fact sheet with further information about Pathogens entitled **'Pathogen movement and survival in catchments, groundwater and raw water storages'**. The fact sheet presents the findings of a major international research program into the fate of pathogens in catchments, source waters and reservoirs (CRCWQT 2007d).

Gaps in the response

A large number of programs to investigate and understand nutrient sources (point and diffuse), algal blooms and pathogens have been underway in the Catchment during the 2007 Audit period. There are also a number of programs to reduce point and diffuse sources of nutrients to the Catchment, which will reduce the risk of algal blooms. However, the increased knowledge of nutrients and algal blooms in the Catchment now needs to be matched to on-ground programs that target areas which continue to be at risk.

This is also the case for pathogens, where a number of investigations have provided background information on the fate of pathogens in the Catchment. The development of a pathogen budget to prioritise land uses and rectification actions to reduce public health risks from pathogens is now needed in the Catchment.

Chapter 4
Managing Water Resources

Key Points

	Indicator	Status of Indicator
4.1	Surface water extraction	The priority sub-catchments of the Upper Coxs River, Upper Wollondilly River, Wollondilly River, Wingecarribee River and Kangaroo River had the highest volumes of licensed surface water extractions.
4.2	Groundwater extraction	There were 640 new licensed groundwater bores in the Catchment during the 2007 Audit period. The greatest number of groundwater bores are located in the Wingecarribee River (priority), Wollondilly River (priority), Kangaroo River (priority), Mulwaree River (priority) and Upper Wollondilly River (priority) sub-catchments.
4.3	Water for the environment	Environmental releases were reduced from all storages except Fitzroy Falls. The transfer of bulk water may be affecting the health of waterways in the Catchment.

Surface water and groundwater resources need to be sustainably shared between water dependent ecosystems and human uses such as drinking water and agriculture to ensure the continued availability of good quality water for all. This audit examines surface and groundwater extraction within the Catchment, environmental flow releases and bulk water transfers.

Pressures in the Catchment

Extraction of surface water and groundwater for human uses such as drinking water, agriculture and industry can place significant stress on the environment, as reduced volume and less variability of flow affect in-stream ecological processes.

The major impacts of surface water extraction, and associated weirs and dams, include:

- reduced volumes of water for the downstream environment
- reduced ability of the environment to cope with natural drought periods
- reduced variability of flow regimes
- changes in the duration and timing of flow events
- creation of large, standing water bodies which are ideal for algal blooms
- degraded water quality (Chapters 3 and 6)
- loss of habitat connectivity, including physically blocking fish passage (Chapter 6)
- change in water temperatures (Chapter 6).

Groundwater is extracted for irrigation, industry and commercial purposes, but the majority of extraction is for stock and domestic purposes. Groundwater use can also increase in drought periods in response to reduced availability of surface waters. Groundwater extraction can modify the catchment hydrology by reducing water available for groundwater-dependent ecosystems such as wetlands, and reducing base flow in surface streams.

Environmental flows are those aspects of a stream flow regime that are important in maintaining the health and values of river-dependent ecosystems, including aquatic and riparian systems (Land and Water, 2002). The volume, seasonality, velocity and rate of rise and fall of a flow can affect waterway health (Land and Water, 2002). Climatic variability, including rainfall and drought periods, should be reflected in the management of flow regimes and water extraction to provide sufficient environmental flows.

Bulk raw water is also often transferred in large amounts between areas and storages via rivers and streams in the Catchment as part of the SCA's management of supplies to water filtration plants. These bulk water transfers can place significant stress on the geomorphology of rivers and streams and on aquatic ecosystems and habitats. The physical process of erosion and the rapid and extreme change in flow rate and height are the impacting forces. SCA's Water Management Licence restricts the changes in flow rate to limit impacts downstream.

4.1 Surface water extraction

Background

The allocation of water is very important in Australia to deal with rainfall and stream flow variability. The harvesting of surface water through farm dams or from direct extraction from waterways must be managed so there is adequate water at all times to supply human uses and to maintain healthy ecosystems. The sustainable management of surface water resources therefore requires knowledge of the rate of replenishment and flow, the amount of surface water that is extracted from streams or collected in dams, and the ecological impacts of different levels of extraction within the Catchment.

Approximately 570 gigalitres per year (or about 72 per cent of total surface water use) are extracted from the Catchment for urban water supply. A total of approximately 105 gigalitres per year is used for irrigation purposes both in the Catchment and below the storages in the Hawkesbury-Nepean catchment, which accounts for about 16 percent of total surface water use from the Catchment. Between about 80 and 90 gigalitres per year (or about 12 percent of total surface water use in the Catchment) are released from the Catchment storages specifically for environmental purposes.

Although the extraction of surface water for uses other than urban water supply are relatively modest in the overall catchment water balance, all surface water extraction is important to local stream flow and ecosystem health because of the location and timing of extraction. Water retained and extracted from the SCA's

storages primarily impacts on the natural flows of the river systems below the dams. These concepts are addressed through Water Sharing Plans outlined in the Actions and Response section of this Chapter.

To extract water from rivers and streams beyond 'basic' land holder rights, a water licence must be obtained from the DWE (formerly DNR) under the *Water Act 1912* (or the *Water Management Act 2000* for the Kangaroo River (priority) sub-catchment where a Water Sharing Plan has been gazetted). These licences detail the purpose of extraction and the maximum annual extraction volume that is permitted under the water licence.

From 1998 a landholder's right to harvest the runoff in a dam without needing a licence, registration, fees or metering was limited to 10 per cent of the average regional rainfall runoff from the property. This is referred to as the 'harvestable right'. The harvestable right enables the retention of runoff in farm dams. Farm dams capable of taking more than the designated harvestable right need to be licensed by DWE under the *Water Act 1912*. The Act provides exemptions from licensing for dams constructed for the control or prevention of soil erosion, runoff detention or flood mitigation, dams that capture contaminated waters and dams on very small properties.

For surface water extraction, this audit examines:

- the maximum permissible annual volume of surface water that can be extracted under water access licences in the Catchment
- the number and location of farm dams.

Findings

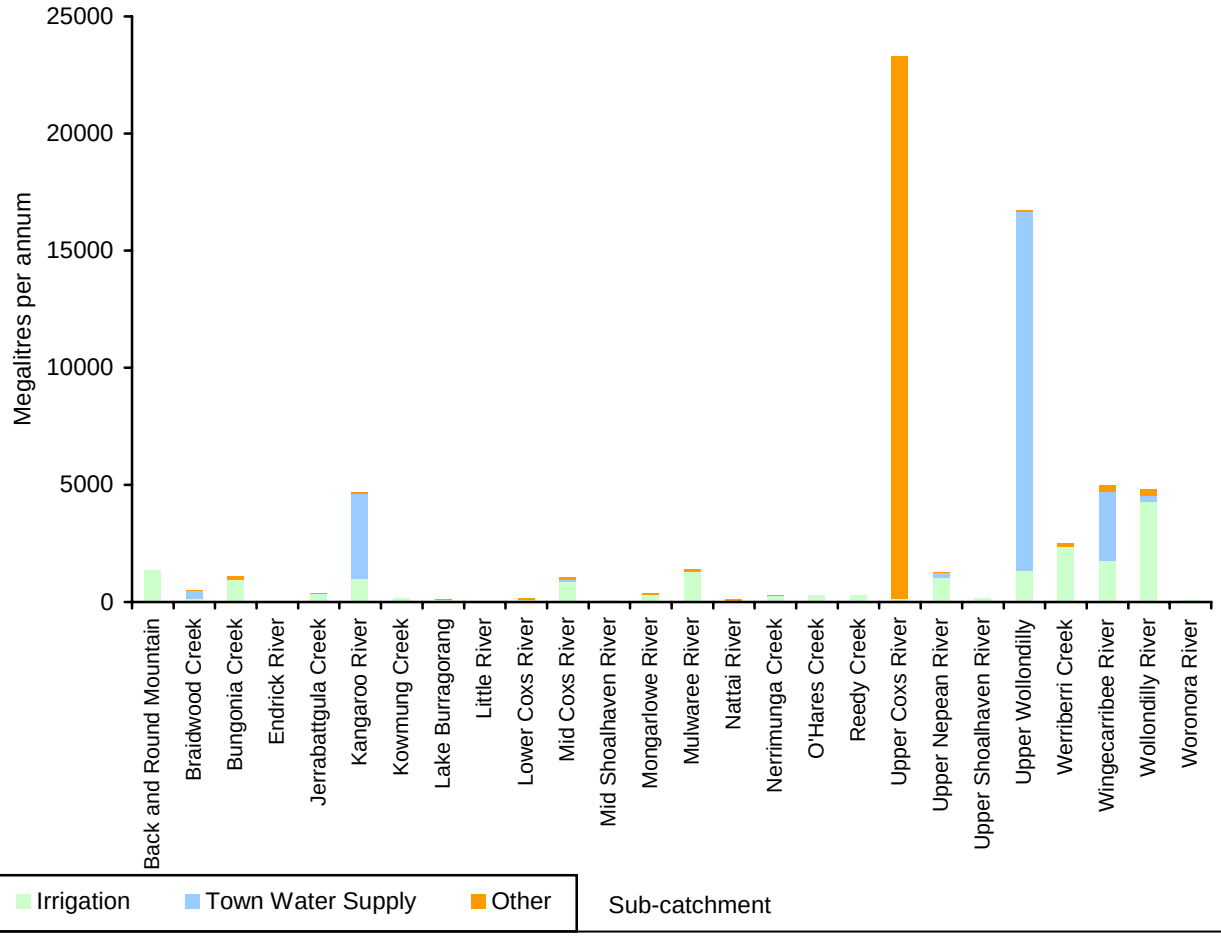
Surface water extraction

The aggregate annual maximum volumes that are permitted by these licences to be extracted from each sub-catchment is summarised in Figure 4.1. Large water volumes are permitted to be extracted in the Catchment for irrigation (18,545 ML/annum) and town water supply (22,819 ML/annum) under water access licence arrangements. Other purposes for surface water access licences include stock, railway, pisciculture, domestic, industry, mining, power stations, farming, and high and low security recreation (Table 5 in Appendix C). Delta Electricity is also a major water user, with a maximum annual extraction volume of 23,000 ML from Lake Lyell in the Upper Coxs River (priority) sub-catchment for the operation of Mount Piper and Wallerawang power stations.

After the Upper Coxs River (priority) sub-catchment, the Upper Wollondilly River (priority) sub-catchment has the highest aggregate water volume permitted to be extracted under water access licences. This large permissible volume is due to extractions for town water supply (Figure 4.1). The Wollondilly River (priority) sub-catchment has the highest volume of water permitted to be extracted for irrigation purposes.

DWE has determined draft daily access rules based upon a risk and value assessment of the sub-catchments. Risk refers to the likely loss to in-stream ecological values due to water extraction and the likely loss to extraction due to protection of in-stream values. Value refers to the importance of in-stream ecology and the importance of water extraction. As part of this assessment, the Wollondilly River, Wingecarribee River, Coxs River and tributaries, Nepean River, Nattai River, Little River and Werriberri Creek were identified as locations with the highest rating for risk and value assessment.

Figure 4.1: Maximum annual volumes (megalitres) permitted to be extracted by water access licences



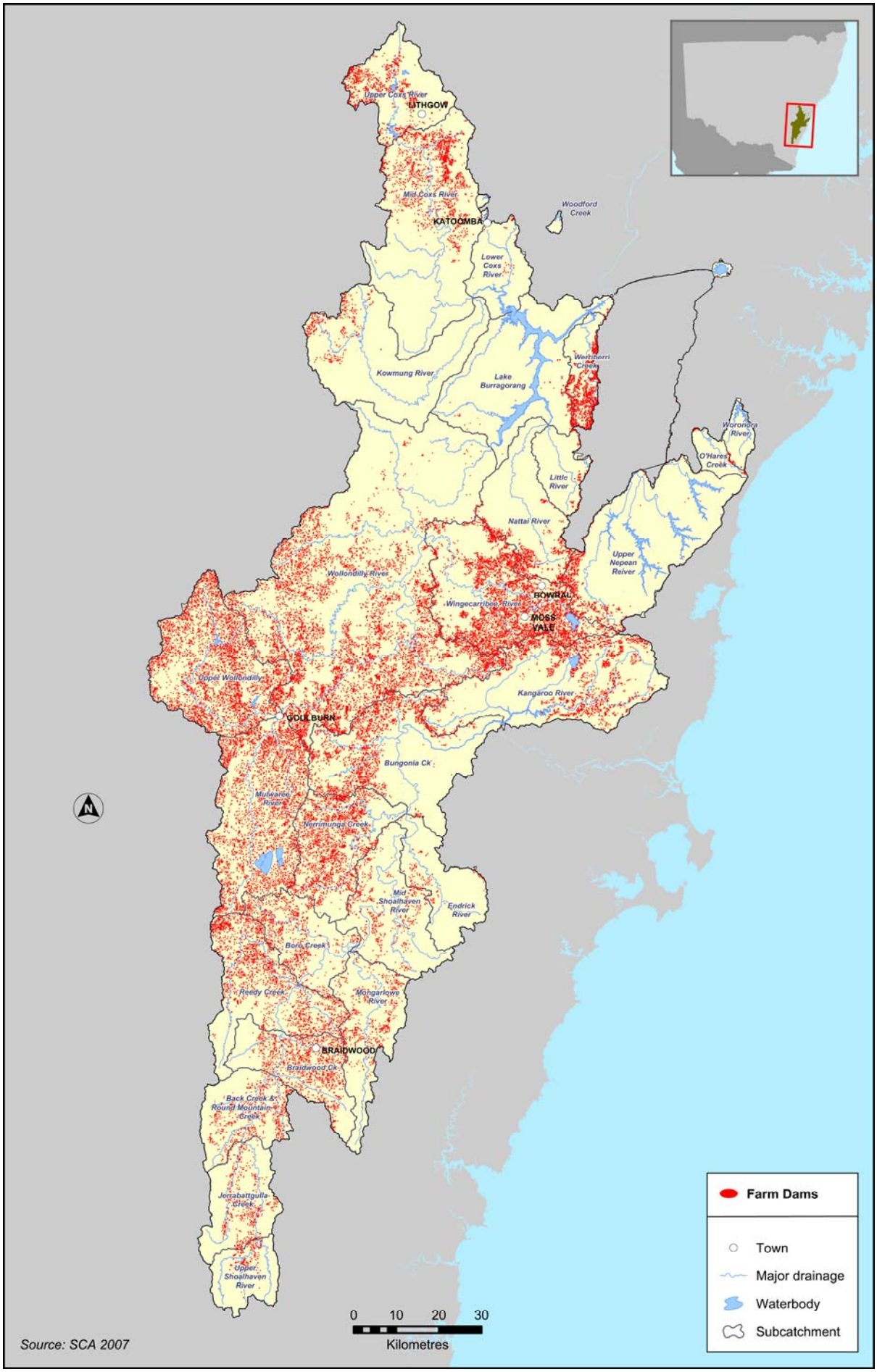
Source: DWE 2007

Farm dams

Farm dams may indicate pressure on water quantity for local ecosystem health in the Catchment as they intercept a significant proportion of surface flow from low and medium intensity rainfall events. In 1999, the thenDepartment of Land and Water Conservation (DLWC) conducted an assessment of the impact of farm dams on stream flow yield in the Hawkesury-Nepean basin. The assessment indicated that farm development reduced low flows by up to 13 percent, median flows by up to 13 percent and high flows by up to 10 per cent (DLWC, 1999). During the 2007 Audit period, DWE determined that in the face of significant over-allocation of water, applications for new farm dam licences throughout the majority of catchments of the Shoalhaven and Hawkesbury-Nepean rivers would not be granted.

The SCA has mapped the distribution, surface area and estimated volume (at full storage) of farm dams in the Catchment (Map 4.1). Aerial photography and high resolution satellite imagery were used and a report compiled of baseline data to enable trend analyses in the future. From the SCA mapping a total of 36,580 farm dams were recorded in the Catchment with a full holding volume of water retained of just under 72,000 ML, covering a surface area of 5,329 ha.

There are over 7,000 of these farm dams located in the Wollondilly River (priority) sub-catchment, and over 2,000 farm dams in each of the Upper Wollondilly River (priority), Mulwaree River (priority), Wingecarribee River (priority), Nerrimunga River and Kangaroo River (priority) sub-catchments (Map 4.1). There are over 1,000 farm dams located in the Bungonia Creek, Braidwood Creek, Mid Coxs River (priority) and Reedy Creek sub-catchments. The sub-catchments that drain to Lake Burragorang have higher numbers of farm dams than the sub-catchments flowing into other storages (Map 4.1).



Map 4.1: Farm dam locations in the Sydney drinking water catchment

Implication

Current data do not allow an assessment to be made about the extent to which surface water extraction or water harvesting in farm dams affects local ecosystem health in the Catchment.

Future directions

As identified in the 2003 and 2005 audit reports, better quantification of actual extraction volumes and the impact of different extraction levels on ecosystem health are required to guide sustainable water resource allocation decisions in the Catchment. This is particularly important in drought conditions where water supplies and ecosystem health are likely to be under pressure and knowledge about trade offs is required in water resource management decisions. Coordinated research into the impact of different extraction levels and flow regimes on riparian and aquatic ecosystems in the Catchment is needed. This research should seek to improve the understanding of water resources and provide a basis for Water Sharing Plans and other water resource initiatives in the Catchment. Systems for measuring and reporting of flow and flow variability for all sub-catchments are required. This will support the implementation of extraction rules and allow a periodic review of the Water Sharing Plan for the Catchment in the future. Recommendation 9 from the 2005 Audit report should therefore be continued to further understand the impacts of water extraction.

A Water Sharing Plan for the Greater Metropolitan Region is presently being developed by the DWE. This plan will include rules on surface water extraction by irrigators and other water users. The DWE has also developed a NSW Water Monitoring Policy that requires monitoring of actual extraction volumes in the Catchment. When available, these data should be used in conjunction with flow gauging and in-stream ecosystem monitoring such as AusRivAS (see Chapter 6) to provide improved knowledge of the impacts of extraction and farm dams on ecosystem health. This improved knowledge should be used in periodic reviews of Water Sharing Plans in the Catchment.

A number of current Catchment stakeholders (in particular the H-N CMA) advised the Auditor of the importance of having a Water Sharing Plan in place for the Catchment, and the Auditor shares this view.

Recommendation 5: DWE should work with stakeholders to complete the Water Sharing Plan that covers the Catchment as soon as practicable.

4.2 Groundwater extraction

Background

Groundwater is derived from rain which percolates down through the soil or through fractures in rock, filling up the pores between sand grains or the fissures in rocks. Up to half of all rainfall may reach the water table and recharge groundwater systems. About 97 per cent of the world's available freshwater lies underground (Boulton *et al.* 2003).

Geological formations such as those composed of sand, sandstone and limestone which contain usable quantities of groundwater are called aquifers. The aquifer closest to the ground surface is called the shallow, or unconfined, aquifer (its upper surface is the water table) but there are also deeper, confined (sometimes called artesian) aquifers where the water is confined under pressure between relatively impervious layers (WRC, 2003).

Many surface water ecosystems in Australia are reliant on groundwater for baseflows, and exchanges between stream and groundwater along the course of channels (Boulton *et al.* 2003). In periods of low flow and drought, groundwater can assume greater importance to maintaining base flows in streams and wetlands. This also means that groundwater can have greater influence on water quality during drought conditions. The extraction of groundwater must also be managed as it can result in more saline water entering the aquifer, as well as reduce base flows to waterways.

The extraction of groundwater requires a licence under the *Water Act 1912*. Extraction for irrigation, industry, recreation (e.g. golf courses) and commercial purposes is managed through renewable licences. Extraction for stock and domestic supply as a 'basic landholder right' is administered through a non-renewable (perpetual) licence. Applications for extractions of significant quantities of groundwater are required to be supported by an impact assessment.

The DWE is currently implementing a NSW Water Extraction Monitoring Policy. As a result of this policy all groundwater licensees, other than those for stock or domestic purposes, are required to install volume meters. However, there are no current data on groundwater extraction volumes for all licences in the Catchment. This audit therefore examines the number of groundwater bores in the Catchment. It is expected that future audits will be able to report on actual groundwater extraction volumes.

Findings

There is currently an embargo in place on all new groundwater bores in parts of the Wingecarribee River (priority), Wollondilly River (priority), Kangaroo River (priority), Nattai River, Upper Nepean River, Werriberri Creek (priority), Lake Burragorang and Lower Coxs River (priority) sub-catchments.

Only one of these embargoes was in existence at the time of the 2005 Audit period (Southern Highlands parishes of Berrima, Bong Bong, Mittagong, Sutton Forest and Yarrunga). Subsequent to the 2005 Audit period, an additional seven parishes in the Southern Highlands were embargoed in December 2005 (Southern Highlands parishes of Belanglo, Bundanoon, Burke, Kangaloon, Murrimba, Wingello and Wongawilli), and a further seven in June 2007 (Southern Highlands parishes of Bangadilly, Bullio, Burrawang, Nundialla, Uringalla, Weromba and Yarrawa). A further embargo was gazetted in February 2007 for the Blue Mountains Sandstone Water Source, and a restriction on domestic groundwater use was gazetted in June 2007 for the Blue Mountains City Council local government area.

Under the embargoes, the processing of applications of all groundwater licences for the defined areas are prevented, with exemptions for:

- domestic, stock, farming, cultural, town water supply and monitoring purposes
- those circumstances where a bore is already existing and trading of entitlement is proposed, replacement of the bore is required, or conversion from a test to production licence application has been lodged within a specified timeframe.

Under such embargoes, the further development of groundwater resources for commercial (irrigation, industrial etc.) purposes has effectively ceased. The taking of groundwater under existing domestic licences is restricted under the *Water Management Act 2000* in order to prevent unreasonable use or wastage of water.

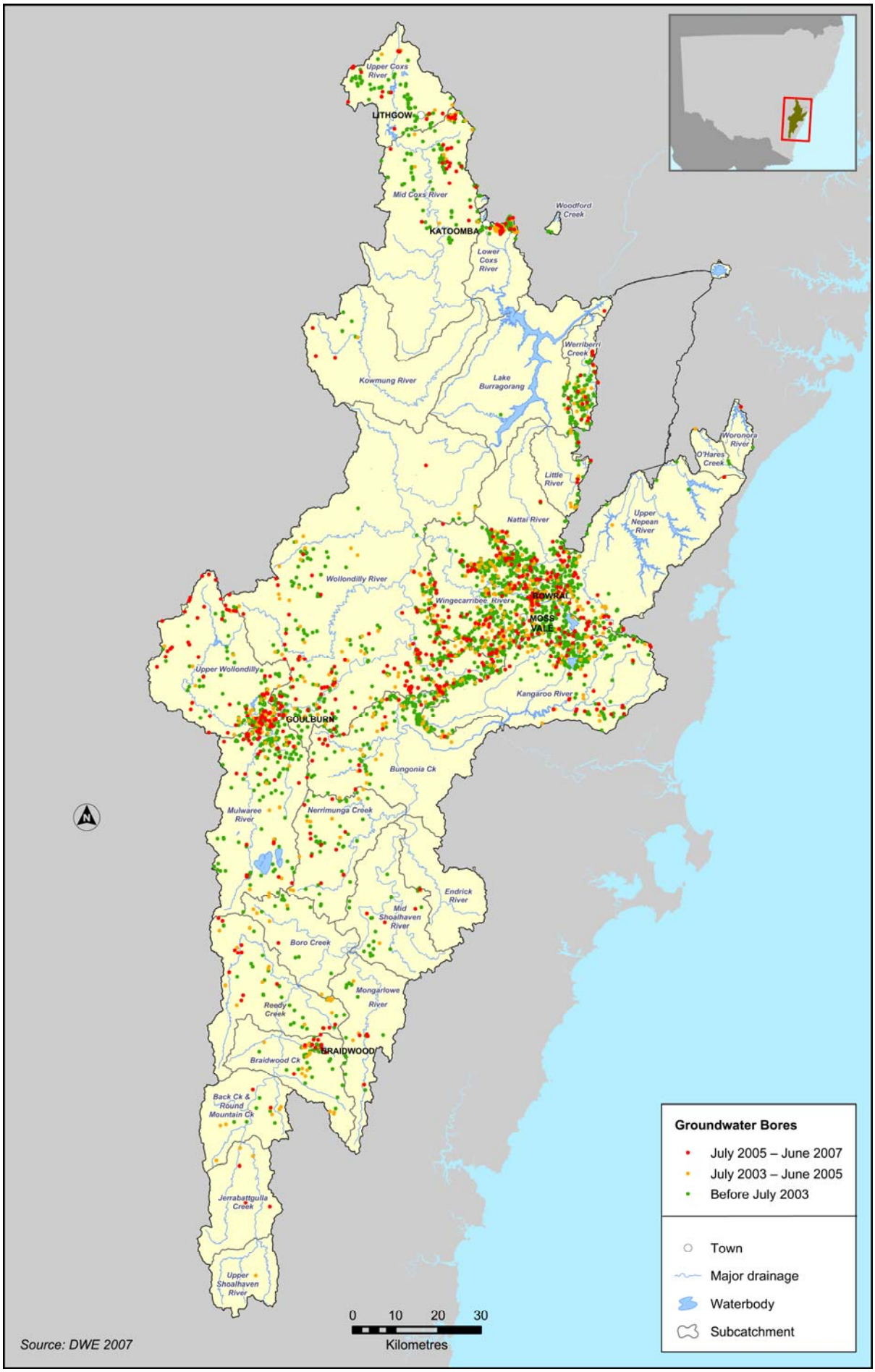
There were 640 new licensed groundwater bores sunk in the Catchment during the 2007 Audit period. DWE advised the Auditor that 479 of these licences were for basic rights bores, 77 were general water licences (including 6 recreational, 4 industrial, 3 mineral water and 64 irrigation), and 84 licences were test and monitoring bores. The new licensed groundwater bores were primarily in the Wingecarribee River (priority) and Wollondilly River (priority) sub-catchments. The highest number of groundwater bores is located in the Wingecarribee River (priority) sub-catchment. The Wollondilly River (priority), Kangaroo River (priority), Mulwaree River (priority) and Upper Wollondilly River (priority) sub-catchments also have high numbers of groundwater bores (Map 4.2).

Map 4.2 shows past audit borehole location data and 615 new locations. The Auditor and DWE were unable to resolve minor discrepancies in the groundwater bore information prior to publication of this report and DWE need to ensure that the groundwater database is current. Nonetheless, the Auditor believes that the 615 new locations added to the map largely represent the geographic spread and concentrations of licensed groundwater extractions across the Catchment in the audit period.

Implication

A combination of increased groundwater extraction licensing, declining water levels, un-monitored extraction and continuing drought conditions, are likely to result in increased pressure on groundwater dependent ecosystems in the Catchment. Groundwater dependent ecosystems in the Southern Highlands, Wingecarribee River (priority), Kangaroo River (priority) and Werriberri Creek (priority) sub-catchments are likely to be under pressure.

Under the embargos, areas in the Catchment that have been identified as being at risk of over-extraction of groundwater (i.e. groundwater extraction pressures) are effectively capped at the existing entitlements and further growth in allocations is prevented. The domestic restriction order also brings licensed groundwater users at least in part into line with residents relying on mains water. This approach identifies groundwater as



Map 4.2: Groundwater bores in the Sydney drinking water catchment

a valuable resource that should not be improperly used under a domestic licence for extensive garden enterprises, or wasted in the cleaning of hard surfaces.

As identified in the 2003 and 2005 Audit reports, the extent of demand for groundwater is not well quantified. There is also limited knowledge about the impact of groundwater extraction on groundwater dependent ecosystems.

Future directions

More information is needed about actual groundwater extracted in the Catchment, and the cumulative impact of groundwater extraction on each aquifer, to enable decisions about sustainable use of groundwater. The implementation of the NSW Water Extraction Monitoring policy will provide data about the actual groundwater extraction volumes. While it may be desirable for all water extracted under licences to be metered, DWE has stated that it is impractical to do this. Therefore a risk-based approach to water-use monitoring is to be utilised, whereby risks to the natural resource system can be reduced. The larger users will be fully metered, the mid range users will have less costly but still effective monitoring strategies and the very small users will be required to report usage on a regular basis. In general the licensee will install, own, maintain, calibrate and observe the water meter or alternative monitoring equipment.

The Southern Highlands, Kangaroo River (priority), Werriberri Creek (priority) and Wingecarribee River (priority) sub-catchments will be considered as priority areas for implementation of metering. Given the limited resources that are available to undertake the task, in the first stage it is unlikely that all groundwater extraction will be metered. In addition, water taken for stock and domestic purposes will not normally be subject to a requirement for installation of a water meter.

Surface and groundwater interaction

The specific dynamics of the interaction between surface and groundwater systems in the Catchment is not well documented or understood. This interaction is particularly important to groundwater dependent ecosystems, to base flow and possibly to surface water quality during low flow and drought conditions.

The DWE in cooperation with State Water is presently developing the Water Information Exchange (WIX). WIX is the state-wide system of gathering, storing, retrieving, and disseminating information on surface and groundwater. The WIX system will receive and store water meter readings, water allocation orders, river flow gauge readings, irrigated crop statistics and on-farm storage data. It will disseminate water allocation account balances and statements, pumping permissions/rules, river flow gauging and storage data, water allocations and daily river and storage reports.

The development of a hydrological model of the interactions between surface and groundwater was Recommendation 13 in the 2005 Audit report. This recommendation has not been adopted to date but DWE and SCA are both working on projects to address this issue.

The current modelling being undertaken by both SCA and DWE will gather additional information about the surface water and groundwater processes and behaviour of the systems and their interaction. DWE has informed the 2007 Audit that the development of a single model (or a series of models) that simulate surface water hydrology and groundwater hydrogeology. The interaction between the two water sources, would be very complex and need to cover a wide area spatially as well as a range of hydrogeological conditions. This modeling capacity is not foreseen to be available for some years. The Audit considers that this work needs to be progressed because it is important for the sustainable management of groundwater resources.

SCA in collaboration with Parsons Brinckerhoff is undertaking research into the conceptualisation and modelling of surface water – groundwater interaction in the Upper Nepean fractured aquifer system, due for completion in 2008.

Since 2005, more than 30 bores have been sampled for environmental and radio-isotopes to assist SCA in assessing recharge/discharge areas, and determining the sustainability of resource development in this area. This sampling program has shown that groundwater in the Catchment is sourced entirely from rainfall, and, using various techniques, that the age of groundwater in the Catchment ranges from modern (less than 50 years old) to 11,000 years old. Much of this work has been part of the SCA's groundwater investigations into deep aquifers in the Southern Highlands area of the Catchment, under the Government's Metropolitan Water Plan.

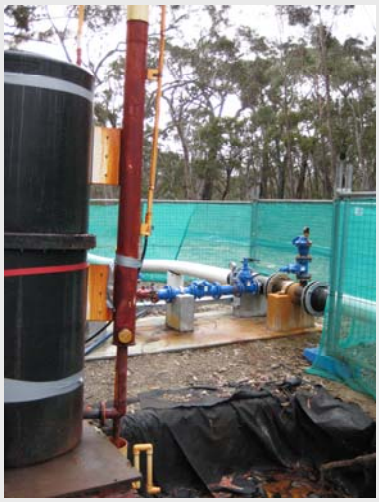
Case Study – Groundwater extraction at Kangaloon

The Catchment has been experiencing periods of extended drought. In response to the current drought, and to secure Greater Sydney's water supply to 2015 and beyond, the NSW Government has outlined a series of projects and initiatives for water supply and demand management under the 2006 Metropolitan Water Plan (MWP) (NSW Government, 2006b).

As part of the MWP, the Government committed funding for groundwater investigations in seven priority areas. The investigation program, which began in December 2004, was designed to obtain scientific data on a scale not before undertaken for groundwater development in NSW.

Kangaloon in the Upper Nepean River sub-catchment is one of the seven priority sites, and it was identified as a potentially major groundwater resource. Extensive testing and scientific studies by hydrological and environmental specialists are in progress to fully assess the viability of a borefield at Kangaloon as a short term back-up supply of water for Sydney in the case of extended severe drought.

If a borefield was to be constructed in the Southern Highlands, it is expected that an extraction rate of up to 15 billion litres of groundwater per year for up to 3 years is achievable from the Kangaloon aquifer. The extracted water would be released down the Nepean River and into either the Nepean or Avon Dam, where it would be stored for later use in either Sydney or the Illawarra.



The borefield would be used for periods of 2-3 years, after which time pumping would be stopped to allow the aquifer to recover and recharge to previous levels. This would take an estimated 5-7 years (under average to above-average rainfall conditions).

There is strong community interest in the project, and the SCA has been actively engaged in community consultation.

The 2007 Audit Team inspected a trial groundwater treatment system at the Kangaloon investigation site, which has been installed to remove natural iron from the extracted water before the water is discharged to the Nepean River.

Figure 4.2: Trial groundwater treatment system at Kangaloon
Source: DECC 2007

State of the Catchment

4.3 Water for the environment

Background

'Environmental flows' is the term used to describe water released from dams as well as water that is protected from extraction by rules and extraction limits. Environmental flows supply the needs of the environment to maintain ecosystem function by mimicking the elements of natural variability between high and low flows (NCC, 2003). Flow regime is a key driver of aquatic ecosystem health. Changes in the flow regime can cause changes to river geomorphology, habitat and water quality and greatly influence the riverine biota. Environmental water is the term used in the audit to describe water that is protected from extraction by rules and extraction limits.

The magnitude and timing of flows in many NSW rivers has been modified as a result of the demand from both urban and agricultural development. The harvesting of water through farm dams and river extractions (see Section 4.1 Surface Water Extraction) and the construction of dams and weirs on NSW rivers has changed the frequency and timing of natural flow. This has contributed to an increase in periods of no flow

and extremely low flow, degraded water quality, reduced riverine habitat, reduced flooding of riparian zones and wetlands, increased algal blooms and erosion of river channels.

To ensure sufficient volumes of flow for the riverine environment, the amount of water extracted and the amount of water captured by dams must be managed. The SCA is required to release water from its storages for the downstream environment, in accordance with requirements of its Water Management Licence. The current requirements under the Water Management Licence for releases from dams for environmental flows are a result of the Healthy Rivers Inquiry into the Hawkesbury–Nepean River system (HNRMF, 2004). Water released from the Woronora, Warragamba and Tallowa Dams, and the Pheasants Nest and Broughtons Pass weirs, flows to rivers and streams outside the Catchment, while releases from Nepean, Avon, Cataract and Cordeaux Dams flow within the Catchment examined by this audit.

The bulk transfer of water through natural watercourses can also significantly affect ecosystems through high flow, rapid change in flow, prolonged flooding, and streambank erosion. In accordance with SCA's Water Management Licence, bulk water transfers occur within the Catchment from Wingecarribee Reservoir through the Glenquarry Cut to the Nepean River in the Upper Nepean River sub-catchment, and into the Wingecaribee and Wollondilly Rivers (priority) sub-catchments to Lake Burragorang.

This audit examines:

- dams, weirs and other barriers to flow in the Catchment
- total volume of water released from SCA storages in the audit period
- total volume of water released for environmental purposes in the Catchment
- the management of bulk water transfers in the Catchment.

Findings

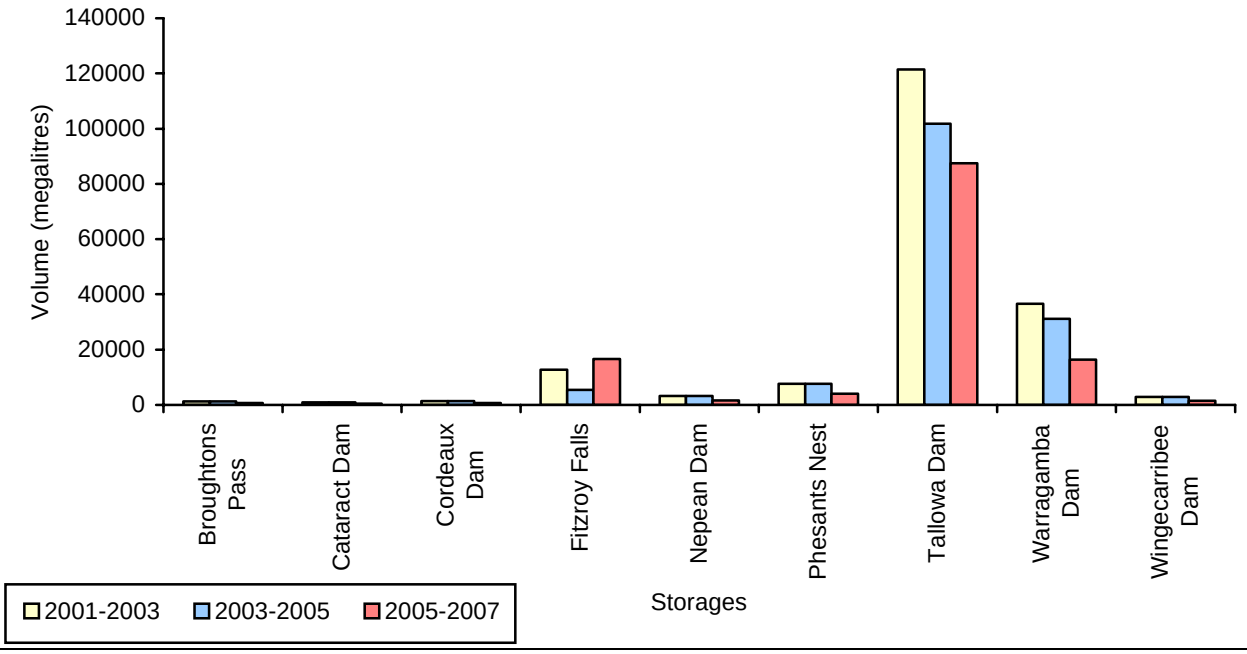
Dams, weirs and barriers permanently alter the flow of rivers and streams, create a barrier to fish passage and affect water quality, particularly temperature and the movement of nutrients out of the sediment when the weir pool stratifies or destratifies, which can cause conditions suitable for algal blooms. The majority of weirs and barriers in the Catchment are located in the Upper Wollondilly River (priority), Kangaroo River (priority), Wingecarribee River (priority), Werriberri Creek (priority), Upper Coxs River (priority) sub-catchments and the upper section of the Bungonia Creek sub-catchment around Barbers Creek. See Chapter 6 for information on weir review and weir removal programs.

Water for the environment

The SCA is required by its Water Management Licence to release specified volumes of water for environmental flow purposes from Broughtons Pass Weir, Cataract Dam, Cordeaux Dam, Nepean Dam, Pheasants Nest Weir, Warragamba Dam and Wingecarribee Dam. The SCA has met its environmental release requirements 99.8–100 per cent of the time since the commencement of the Water Management Licence in April 2001. Delta Electricity is also required to make environmental flow releases under its water licence.

Tallowa Dam has the highest volume of water released for environmental and riparian purposes, although this has decreased since the 2003 Audit period. There has also been a decrease in the volume of water released during the 2007 Audit period from Broughtons Pass, Cataract Dam, Cordeaux Dam, Nepean Dam, Pheasants Nest, Warragamba Dam and Wingecarribee Dam; and an increase in environmental releases at Fitzroy Falls during the 2007 Audit period (Figure 4.3).

Figure 4.3: Volume (megalitres) of environmental and riparian water released from water storages, for the 2003, 2005 and 2007 Audit periods



Source: SCA 2007

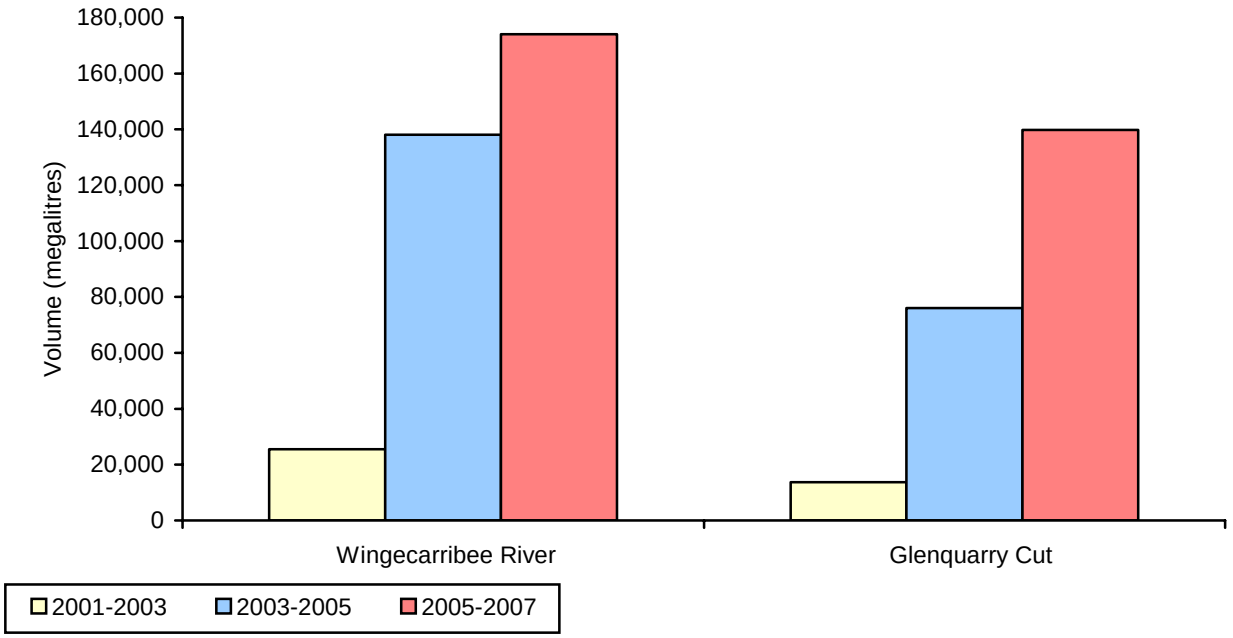
Note: Wingecarribee Dam values are for environmental and riparian water releases and do not include bulk water transfers.

During the 2007 Audit period, the NSW Government decided to adjust requirements for environmental flow releases to the Hawkesbury-Nepean catchment in response to the severity of the drought. These are temporary measures and the full environmental releases will be reinstated when the drought breaks. Environmental releases were reduced from 33 ML/day to 17 ML/day from Warragamba Dam, 4.4 ML/day to 2.2 ML/day from the Nepean Dam, 1.9 ML/day to 1 ML/day from Cordeaux Dam and 1.3 ML/day to 0.65 ML/day from Cataract Dam. Environmental flow release requirements for the Shoalhaven and Woronora rivers have not been changed. The current environmental flow rule for the Shoalhaven River requires that all inflows to the dam of up to 90 ML/day must effectively pass straight through the dam. Woronora River downstream of the dam receives up to 50 per cent of the inflows below 30 ML/day and an annual high flow release of 800 ML/day for a minimum of three days. The licence condition requiring high flow contingency release from Woronora Dam was suspended during the 2007 Audit period due to the drought.

Bulk water transfer

The volume of water released to the Wingecarribee River from the Wingecarribee Reservoir greatly increased between the 2003 Audit period and the 2005 Audit period. During the 2007 Audit period the volume of water released to the Wingecarribee River again increased although the increase was not as great as in previous Audit periods (Figure 4.4). The volume of water released from Wingecarribee Reservoir to Glenquarry Cut followed a similar pattern to that of water released to the Wingecarribee River, with large increases in water released between Audit periods (Figure 4.4). The increase in water released from Wingecarribee Reservoir is due to the need to transfer large volumes of water to Sydney's water storages during the current drought.

Figure 4.4: Total volume of water (ML) released from Wingecarribee Reservoir to rivers which flow inside the Catchment, for the 2003, 2005 and 2007 Audit periods.



Source: SCA 2007

Note: The volume includes environmental flow releases and customer extractions releases via rivers

Implication

Water for the environment

The decision to reduce environmental flows as a drought response highlights that the water resource is limited and that environmental flows need to be well managed to protect Catchment health.

Under the Metropolitan Water Plan improved regimes of environmental releases will be gradually implemented at SCA storages, and will be reflected in Water Sharing Plans. The river reaches below SCA's four upper Nepean Dams in the Catchment are expected to show environmental benefits from new flow release arrangements. The Water Sharing Plans will be critical to securing water for the environment and in maintaining aquatic and riparian ecosystem health in the Catchment. Continued assessment of flow regimes, water quality and riparian and aquatic ecosystem health should inform periodic reviews of the Water Sharing Plans. Some of the recycled water from the **Western Sydney Recycled Water Initiative (WSRWI)** will be used to replace environmental releases from Warragamba Dam. The completion of the flow substitution component of the WSRWI is scheduled for 2009, which will coincide with the commencement of Upper Nepean environmental flow releases. These initiatives should ensure environmental benefits.

Management of bulk water transfers

The current bulk water transfers through natural watercourses in the Catchment have the potential to affect ecosystem health. Increasing flow releases can improve downstream water quality in the river, but can adversely impact on landholders, on aquatic life and on riverbanks. Decreasing the magnitude of the Minimum Operating Levels in the storages reduces the negative impact on landholders due to fluctuations in dam levels. These trade-offs need to be managed, and some of the impacts can be mitigated, through channelisation, bank protection and pipework.

The pipes or tunnels proposed in the Metropolitan Water Plan to transfer further bulk water from the Shoalhaven system by 2009 are likely to address the pressures on ecosystem health caused by run-of-river bulk water transfers through Glenquarry Cut and Doudles Folly Creek to the Upper Nepean dams (See Case Study – Bulk Water Transfers).

The SCA commissioned an assessment of the impact of bulk water transfers from the Shoalhaven system into Glenquarry Cut and Doudles Folly Creek (Upper Nepean River sub-catchment) in 2003. The assessment was undertaken by Woodlots and Wetlands Consultants. The Woodlots and Wetlands assessment identified that there is streambank erosion in Glenquarry Creek, although there were likely to be a number of contributing factors including the bulk water transfers, livestock access and lack of riparian vegetation.

It was recommended in the 2005 Audit report that SCA should proceed with the works and other concurrent measures recommended by the Woodlots and Wetlands report (SCA, 2004) for rock armoury and vegetative stabilisation, as an interim measure to reduce streambank erosion caused by bulk water transfers (2005 Recommendation 6). However, in 2006, SCA commissioned a report on the potential hydrological and geomorphological impacts that may occur from the transfer of additional water and to assess subsequent changes in and the management of erosion and sediment processes. The report by Patterson, Britton and Partners (SCA, 2006e) found that the resistant nature of the sediments would limit erosion and the additional flows are not expected to create any significant systemic or episodic change to the Wingecarribee River. It was also expected that Doudles Folly and Glenquarry Creeks would maintain their current state of equilibrium due to the extensive armouring of the bed combined with the steep valley sides. They also considered that hard structural mitigation measures to stabilise the channel were not necessary or appropriate. It was recommended that monitoring the channel geometry during and after release periods at selected locations be done. The Auditor expects that the next audit will be able to report on the results of that monitoring.

Case Study – Bulk water transfers

The current Shoalhaven transfer scheme is a back-up water supply system to support Sydney's water storages in times of extended drought, and is one of a suite of such contingency and insurance plans. The Shoalhaven catchment receives much more regular rainfall than the catchment surrounding Warragamba Dam. For this reason, Tallowa Dam was constructed at the junction of the Shoalhaven and Kangaroo Rivers in the 1970s as a support measure for the Lake Burragorang (Warragamba) and Upper Nepean storages.

Pumping from the Shoalhaven scheme occurs when storage levels fall below a certain trigger point. This has happened three times since it began operating in 1977: from 1981 to 1983, 1993 to 1994, and from 2003 to the present. Since 2003, in the current drought, around 48 per cent of total inflows to Tallowa Dam have been transferred. Over 400 billion litres of bulk water have been supplied, which is approximately 25 percent of the greater Sydney's system demand under current water restrictions (SCA, 2006b). The 2007 Audit Team inspected locations along the Wingecarribee, Wollondilly and Upper Nepean rivers where transfers have greatly increased the base flows in these rivers.

The NSW Government's Metropolitan Water Plan (MWP) 2006 aims to insure that Sydney's water supply in the face of drought and unpredictable rainfall patterns is uninterrupted to 2015 and beyond. The Government directed the SCA to investigate options for altering its existing Shoalhaven Water Transfer Scheme, to increase the long term availability of water to greater Sydney by approximately another 30 billion litres per year (NSW Government, 2006b).

To increase the long term availability of water to within this target, the SCA developed a range of six options for community comment in late 2006. These included increasing the flow rate of water or the length of time of transfers under current run-of-river courses, and building various lengths of tunnels or pipes to reduce environmental impacts on the Wingecarribee, Wollondilly and Nepean Rivers.

Increased flow volumes in rivers due to transfers can affect river health and functioning, increase erosion and negatively impact upon the habitat of the fauna that utilise both the water and the river banks (e.g. platypus). Additionally, localised flooding may caused access problems for farmers and others. There is also the increased potential for the spread of plant and animal species across areas where they may previously not have existed (e.g. noxious weeds and pest species) (SCA, 2006b).

The construction of pipes or tunnels to bypass the rivers would remove these concerns and alleviate the impacts caused by the current transfers. Such options are more expensive, and may impact on terrestrial ecosystems during the construction phase. In response to community comment, the range of options has been reduced to three, and the SCA is focusing on options that reduce or remove the use of rivers for bulk water transfers. The SCA is conducting further technical investigations and studies on the three remaining options and will report back to the Government.

Actions and Response

Response to issue

Sustainable water resource management needs to focus on water availability for human uses, as well as for the needs of the environment. Water resource management requires an understanding of the complex interaction between water availability, extent and timing of human needs, and the natural variability which supports ecosystem function and health. This section covers the major actions aimed at managing water resources within the Catchment. These include programs to:

- ***understand and manage water resources***
- ***address drought conditions***
- ***encourage more efficient water use***
- ***implement and understand environmental flows.***

In 2006, the NSW Government released the **NSW State Plan**. The Plan sets priorities for the State Government to action. There are five areas of activity including the Environment for Living. Within the Environment for Living there is the *Securing our supply of water and energy* result area. Below are listed the targets in this result area of the NSW State Plan that are relevant to managing water resources in the Catchment (NSW Government, 2006a).

Increase water recycling:

- in Sydney, increase the volume of water recycled from 15 billion litres per year to 70 billion litres of water per year by 2015;
- in regional centres, increase the volume of recycled water.

Improve efficiency of water use:

- in Sydney, save 145 billion litres of water per year by 2015, representing almost 25 per cent reduction from Sydney's projected water demand in that year.

Programs to understand and manage water resources

The **National Water Initiative** is a strategy to improve water management across Australia, involving a Commonwealth of Australian Governments (COAG) agreement that sets out objectives, outcomes and actions for the ongoing process of national water reform in Australia.

Key elements of the National Water Initiative include:

- water access entitlements and planning framework
- water markets and trading
- best practice water pricing
- integrated management of water for the environment and other public benefit outcomes
- water resource accounting
- urban water reform
- knowledge and capacity building
- community partnerships and adjustment.

Central to the National Water Initiative is the formation of the **National Water Commission**, which is responsible for driving the national water reform agenda. The National Water Commission also administers parts of the **Australian Government Water Fund**.

The **Metropolitan Water Plan 2006** was prepared by the NSW Government using the principles of the original **2004 Metropolitan Water Plan**. The plan focuses on ensuring Sydney's water needs are met over the next 25 years, taking into account anticipated population growth, climate change and water needed for the environment (NSW Government, 2006b). The 2006 Plan looks at issues related to:

- managing the drought
- understanding Climate Change
- increasing Recycling
- reducing Sydney's demand for Water
- increasing Supply
- protecting Catchment and River Health
- creating a dynamic and competitive water industry.

Many of these issues directly affect the management of the Catchment.

For our river and groundwater systems to be healthy, it is critical to balance the competing needs of the environment and water users. A **Water Sharing Plan** is a legal document prepared under the *Water Management Act 2000*. It establishes rules for sharing water between the environmental needs of the river or aquifer and water users, and also between different types of water users such as town supply, rural domestic supply, stock watering, industry and irrigation. Water sharing plans have been developed for a range of rivers and groundwater systems across NSW, covering 80 per cent of the State's water resources. The Kangaroo River Water Sharing Plan was gazetted in February 2003, providing Shoalhaven City Council with a water entitlement of 85 ML per year from the Kangaroo River.

Macro Water Sharing Plans are being developed to cover most of the areas of NSW that were not addressed in the first round of **Water Sharing Plans**. These will generally apply to catchments where there is less intensive water use, accounting for most of the remaining 20 per cent of water use not already managed by existing water sharing plans. A separate process is being undertaken for specific high use or complex systems such as Greater Metropolitan Region that covers a large part of the Catchment.

The DWE is preparing a water sharing plan for the Greater Metropolitan Region. The plan will provide for a long term (annual) average usage limit on the extraction of water by the SCA and a limit on average usage by unregulated river access licences. The plan will also provide for daily access rules for unregulated river access licences to protect low flows, and in a number of catchments to protect medium and high flows. The daily access rules will include pumping requirements and daily limits on water extraction. The rules will serve to protect identified instream values whilst recognising the dependence on the river of licensed extraction. The rules will also serve to protect the passage of environmental flows from SCA dams on the upper Nepean rivers. The daily access rules will be based upon a risk and value assessment of the Catchments that was undertaken by the DWE, see Recommendation 5.

The DNR prepared the **NSW Water Extraction Monitoring** policy in 2005 which outlines principles for monitoring of surface and groundwater throughout NSW. The objective of this policy is to increase the extent of active monitoring of water extraction. In the regulated rivers, extraction monitoring is generally at an acceptable level, with the vast majority of licences being measured using flow meters. For unregulated and groundwater sources, the current level of extraction monitoring is to be progressively expanded, with the aim of having 90 per cent of the total volume of water extracted in each Water Sharing Plan area being subject to active monitoring (by flow meter or alternative) (DNR, 2005).

Programs to address drought conditions

The NSW Government's response to the drought is outlined in the **2006 Metropolitan Water Plan** (NSW Government, 2006b) and includes:

- access to deep water at the bottom of Avon, Nepean and Warragamba dams
- increased bulk water transfers from the Shoalhaven to provide an additional 30 billion litres of water to Sydney's water supplies, although this is subject to a current community consultation process
- investigating sources and using groundwater to augment supply in droughts. These investigations will also increase knowledge about the extent of groundwater in the Catchment and its interaction with surface water systems
- increasing recycling and water savings measures to slow demand (see also the following section, Programs to encourage more efficient water use)
- constructing a desalination plant.

Accessing Deep Storages – The Warragamba and Nepean dams have been modified so that water at the bottom of the dams can be accessed for the first time. The Nepean Dam works were completed in the Audit period (Figure 4.5). This will provide an extra 40 billion litres of water per year, which is 10 billion litres or 33 per cent more than the original estimate of 30 billion litres of water. The works will increase the amount of water that can be accessed from the storage system by 8 per cent.

Figure 4.5: Nepean Dam deep water pumping station
Source: DECC 2007

Shoalhaven Transfers Scheme – Under the scheme, water is pumped from Tallowa Dam through a series of pipelines and reservoirs to either the Nepean or Warragamba Dams via Wingecarribee Reservoir and two 'run-of-river' routes using natural river channels (see Section 4.3 in this chapter).

New Groundwater Resources - Large volumes of good quality underground water around Sydney are being investigated, with a focus on the Upper Nepean catchment near Kangaloon and in Western Sydney near Leonay. See Section 4.2 in this chapter for details.

By June 2011, water savings from the State Government's **Water Recycling programs** are expected to exceed 28,000 ML/year. Water recycling programs will involve significant capital works as part of their implementation, including several local projects and the **Western Sydney Recycled Water Initiative (WSRWI)**. The **Replacement Flows Project** is a component of the **Western Sydney Recycled Water Initiative**. It will provide recycled water to replace the current releases from Warragamba Dam into the Hawkesbury-Nepean River for environmental base flows and extraction by water uses. This will save up to 18 billion litres of water each year and will provide base flows in the river even in drought conditions. The completion of this dam-releases substitution component of the WSRWI is scheduled for 2009, which will coincide with the planned commencement of Upper Nepean environmental flow releases.

The construction of Sydney's **desalination** plant has commenced. The plant has been designed to produce at least 250 ML/day when it is commissioned in 2009.

Programs to encourage more efficient water use

The **Australian Government Water Fund** is a $2 billion Australian Government program developed to support practical on-ground water projects that will improve Australia's water efficiency and environmental outcomes. Projects that align with the National Water Initiative will be eligible to receive assistance from the fund. The fund comprises three programs:

- **Water Smart Australia program** aims to accelerate the development and uptake of smart technologies and practices in water use across Australia. The $1.6 billion program has funding over five years until 2010, and is targeted at large-scale projects. As a general guide, the minimum level of funding available through the program for a project is $1 million, and the maximum funding duration is four years. The program is administered by the National Water Commission.
- The **Raising National Water Standards program (RNWS)** aims to assist the development of the necessary tools for good water management in Australia. It will target investment to improve Australia's national capacity to measure, monitor and manage its water resources. RNWS will focus on activities that will achieve better outcomes when undertaken on a national basis and where compatibility is

required across jurisdictions. Funding for the program is $200 million over five years and it is administered by the National Water Commission.

- The **Community Water Grants program** has been developed to make a real difference in the way communities use water resources. Funding of $200 million (over five years) has been made available for local communities to apply for grants of up to $50,000 for practical on-ground projects that will result in the wise use of water. The program is administered by the Australian Government Department of the Environment and Water Resources, and Department of Agriculture, Fisheries and Forestry.

More efficient use of water drawn from the Catchment can reduce the pressures on the Catchment, particularly during drought periods. As a result of the current water restrictions and water savings initiatives, Sydney's annual water demand has fallen from 630 billion litres per year before restrictions to 507 billion litres per year (for 2006-07), a reduction of 19.5 per cent (NSW Government, 2006). There are many programs operating within and outside the Catchment to improve water use efficiency.

Residential water efficiency

The residential water efficiency programs are those that target demand in the residential sector. These programs include:

- **WaterFix (formerly 'Retrofit')** - offers householders the opportunity to have a qualified plumber visit their home to provide a water efficiency 'tune-up'. The program includes the installation of a new water efficient (3 star rating) showerhead and tap flow regulators, a toilet cistern flush arrestor and the repair of minor leaks for those participating.
- A second component to the program involves a WaterFix service of Department of Housing properties. The service is offered to Department of Housing tenants for free, and is funded jointly by Sydney Water and the Department of Housing.
- **Do It Yourself water saving kits** - Developed as an alternative to the full service WaterFix, the free kits contain two flow regulators for showers, two flow regulating aerators for bathroom basin taps and one flow regulating aerator for kitchen taps. The program also provides easy access to water efficiency for those households who would prefer to organise their own installation.
- **Washing Machine Rebate** - A rebate of $150 is available to residential customers and tenants for the purchase of new washing machines with either a 4 star or 5A water efficiency rating. The rebate commenced on 1 March 2006, and runs to 31 July 2008. It is expected to save 1 million litres of water per day across Sydney once the program is fully implemented.
- **Rainwater Tank Rebate** - The Rainwater Tank Rebate Program offers Sydney Water customers the opportunity to receive a rebate on the installation of a new rainwater tank, excluding properties that have to install a tank to comply with BASIX. To encourage the maximum water saving yield from a tank, the program offers rebates ranging from $150 for a 2,000 litre capacity tank to $500 for tanks with a capacity equal to or greater than 7,000 litres. An additional $150 rebate is available if a licensed plumber connects the tank for indoor use to supply washing machines or toilets.
- **Residential Landscape Assessment** - An on-site assessment of residential landscapes to determine its irrigation demand, based on a number of measured variables including soil types and depth, vegetation, shading and aspect. The program aims to determine irrigation demands of individual landscapes and identify the gap between how much water is typically applied for irrigation and how much is actually required.
- **Outdoor Water Conservation** - This program involves an ongoing campaign of community education combined with regulatory measures such as pricing reform and water saving measures. Sydney Water offers a range of water efficient outdoor products for sale on the website and at community events to encourage behavioural changes in customers. Water efficient outdoor products are covered by the Smart Approved Watermark (SAWM) scheme established in 2003. The objective of the SAWM scheme is to reduce water consumption by recognising products, services and organisations that will contribute to reductions in outdoor water use and to promote the adoption of proven water smart technology. Endorsed products, services and organisations can then use the scheme logo for water saving recognition and marketing purposes.

Business water efficiency

The business sector (non-residential) accounts for around 30 per cent of customer water use in a typical year. Sydney Water has worked in partnership with business customers to develop a successful program to address business water use. This program is known as the **Every Drop Counts (EDC) Business Program**, and targets high water using customers and sectors including the manufacturing, commercial, hospitality, education, health and government sectors. Sydney Water's **EDC Business Program** has found that water savings of 10 to 30 per cent can be achieved by businesses. This program will continue to support businesses to become more water efficient.

In the course of implementing the **EDC Business Program**, a number of other programs have been developed to further enhance water savings in the business sector. These include:

- **Water Saving Action Plan** – The plans are part of the NSW government's water and energy savings initiatives. Water Saving Action Plans are required by all local councils within Sydney Water's area of operations and businesses and government agencies within Sydney Water's area of operations with sites which use more than 50ML of water a year. Water Saving Action Plans involve identifying measures to reduce water use and achieve savings (DEUS, 2006b).
- The NSW Government's **Water Savings Fund,** established in September 2005, provides funds for projects which help save potable water and reduce demand in the residential, industrial, commercial and government sectors. The Water Savings Fund was increased by $10 million in 2006. This money will be used to assist high water-using councils and businesses to implement actions identified in their **Water Savings Action Plans**. This is expected to deliver savings of over 9 million litres per day, and is a highly cost effective way of reducing pressure on water supplies.

Schools programs

Three programs have been developed that specifically target schools:

- **Every Drop Counts in Schools** - Developed in conjunction with the NSW Department of Education and Training, the program targets reducing water use in primary schools by increasing the awareness of water conservation. This occurs through a series of curriculum-based lessons involving students in a water audit and development of a water saving plan for the school.
- **Rainwater Tanks in Schools Rebate** – The program was introduced as an extension of the successful Rainwater Tanks Rebate Program for residential properties. This program offers schools a rebate of up to $2,500 towards the cost of purchasing and installing a rainwater tank. To receive a rebate each school must complete a water conservation education program.
- **Schools Leak Detection Pilot –** A trial project of permanent smart monitoring and alarm systems in 20 schools to reduce the frequency and volume of water leaks. If the trial is effective, the program will be rolled out to the other 920 government schools within greater Sydney by 2008.

NSW Government water efficiency

In addition to the savings that will be achieved in the Government sector through the EDC Business Program, Water Savings Fund, Water Savings Action Plans and the schools programs, the NSW Government has developed a new policy on Sustainable Water Use by Government. The target is to reduce overall drinking water consumption by Government agencies by 15 per cent by 2010.

Other programs

International Council for Local Environmental Initiatives (ICLEI) Water Campaign is a voluntary program for local government. Councils sign-up to a five milestone process to conserve water in the corporate and community sectors and improve local water quality. The Water Campaign involves participants setting targets for reducing consumption, and improving water quality, and preparing a Local Action Plan to identify ways to meet the targets (DEUS, 2006a).

The **Water for Life Education Program** is an integrated component of the Metropolitan Water Plan. The focus of Water for Life is to support and increase understanding in the greater Sydney community to use water more efficiently. The program includes innovative on-the-ground water education projects and training.

In July 2004, the Government implemented the **BASIX (Building Sustainability Index) scheme** which requires new and renovated houses and apartments built in Sydney to reduce mains-supplied water consumption by 40 per cent compared to the current average for similar sized homes.

Water Efficiency Labelling and Standards (WELS) Scheme involves the introduction of mandatory labelling to inform consumers about the water efficiency of certain water-using appliances. This is now being implemented with all appliances to be labelled after 1 July 2006. Products covered by the scheme include clothes washing machines, dishwashers, taps and flow controllers, toilet equipment, showers, and urinals. In the case of toilets, the scheme requires minimum standards of efficiency.

The **WELS Scheme** will upgrade and completely replace the existing voluntary water efficiency scheme managed by Water Services Association Australia which rates and labels products using 'A's on a scale of one to five 'A's with increasing levels of water efficiency having more 'A's. The performance levels and testing requirements for the products covered in the WELS scheme are detailed in *Australian Standard AS/NZS6400:2005 Water efficient products-rating and labelling*.

The **Springvale Coal – Delta Electricity Water Transfer Scheme** has the potential to save over 3 billion litres of water for the Sydney drinking water catchment. Under the scheme water from the mine's dewatering bores is pumped into a storage tank and then transferred by gravity through a 10km pipeline to Wallerawang Power Station. The scheme was awarded the 2006 Water Recycling and Conservation Leadership Award at the DEUS 2006 Energy and Water Green Globe Awards (NSW Minerals Council, 2007).

During the 2007 Audit period DEUS prepared a **Guideline for Greywater Reuse in Sewered, Single Household Residential Premises** (DEUS, 2007), which provides direction on:

- use of greywater diversion devices in single household
- information to owners of sewered residential premises on greywater treatment systems
- manual bucketing of greywater
- guidance on the use of greywater treatment systems.

An extensive water education campaign is already in place in NSW, featuring the following:

- Sydney Water's outdoor water conservation education programs **Go Slow on the H2O**, encourage customers to adopt low-level restriction practices such as restricting watering times and using trigger nozzles on garden hoses.
- The **Greenhome Project** is part of the *It's a Living Thing* sustainability education partnership program, it involves a series of community workshops and events focusing on what people can do in their own lives to help the environment. Plans to expand the project to include workshops for households to specially focus on water conservation.
- DPI's **WaterWise on the Farm** aims to improve the capacity of irrigation for farm managers to adjust to water reforms primarily through the adoption of best irrigation management practices and technologies

To build on this work, the **Metropolitan Water Education Plan** is being implemented to provide further information to the community about what is being done. It includes the following objectives:

- increase the perceived value of water;
- change water use practices among individuals, households, farmers, industry and business throughout greater Sydney to reduce demand for water;
- respond to needs for communication and education that emerge through implementation of the 2006 Metropolitan Water Plan;
- demonstrate the government's leadership to secure long term water supply for the community.

Programs to implement and understand environmental flows

New rules for environmental flows for Shoalhaven River and four Upper Nepean dams were recommended as part of the 2004 and 2006 **Metropolitan Water Plans**.

New environmental flow rules for the lower **Shoalhaven River** were announced in March 2007. The new environmental flows will ensure more water is protected for the health of the Shoalhaven River and will also better mimic the natural river flows. Currently up to 90 million litres of water is released daily from Tallowa

Dam for the health of the Shoalhaven River, but the new rules will see far greater range of flows. This will protect the critical low river flows. Medium flows will be partially protected, while a large proportion of high flows, which flush the river will continue to flow over the dam wall. The new environmental flows will be implemented when the current drought is over.

The new Shoalhaven River environmental flow rules include 100 per cent of low dam inflows less than or equal to the 80th monthly inflow percentile, that will be released for river health. Twenty per cent of medium flows above the 80th monthly inflow percentile will also be released and special purpose environmental flow releases could be made to address specific downstream river health issues. Water will also continue to spill over the dam wall when Tallowa Dam is full (DNR, 2007).

The Metropolitan Water Plan requires the SCA to modify the environmental flow releases from the four Upper Nepean dams by 2010. The first phase of the new regime in the Upper Nepean system will see six billion litres of water per year released from Avon Dam specifically for environmental purposes. Works to allow these releases from Avon Dam were completed during the audit period. Environmental flow regimes of approximately 26 billion litres per year at Cataract, Cordeaux and Nepean dams from 2010 will also be progressively implemented.

While the impact of environmental flows is outside of the Catchment, DECC is currently developing a monitoring program that will provide data on the effects of reduced environmental flows in the Hawkesbury-Nepean River.

Gaps in response

There are a large number of programs to address the drought, encourage more efficient water use and manage water resource in the Catchment. The completion of water sharing plans, implementation of NSW Water Extraction Monitoring Policy and measures to minimise the impact of the bulk water transfers need to be finalised.

Chapter 5
Land Condition

Key Points

	Indicator	Status of Indicator
5.1	Changes in land use	The number of development applications submitted to the SCA for review and concurrence decreased during the 2007 Audit period. Large areas of agriculture and increased urbanisation and rural residential development may put pressure on water quality in the Catchment, unless best management practices are adopted.
5.2	Sites of pollution and potential contamination	Overall the total number of assessed sites in the very high, high, and medium risk categories has decreased by 17 per cent.
5.3	Soil erosion	Active gully erosion has been observed in only 776 ha of the Catchment, but local impacts can occur and remediation is required. Eleven percent of the Catchment has very high or high estimated rill or sheet soil erosion.
5.4	Dryland salinity	A small area of the Catchment (three per cent) is susceptible to salinity. Localised salinity has been identified in 0.14 per cent of the Catchment.

Land condition can directly affect water quality and ecosystem health. Land condition is a function of the inherent characteristics of land, natural processes such as drought and flood, and human land use and land management practices. This audit focuses on:

- human induced pressures on land condition; namely land-use change and sites of potential pollution and contamination
- the state of soil erosion and dryland salinity risks in the Catchment.

Pressures in the Catchment

The primary human induced pressure on land condition in the Catchment is land use and land-use change. The land uses in the Catchment include varying densities of urban development, variable types and intensity of agricultural activities, extractive industry, electricity generation and restricted areas around drinking water storages. Poorly managed land use can cause erosion, degradation and contamination of soil, dryland salinity, and the loss of riparian zones and habitat which can ultimately impact upon Catchment ecosystems and water quality. Examples of human land use and activities that can cause risk of impacts are:

- urbanisation and rural residential development, especially during the site preparation and construction phase when vegetation is cleared and soil is disturbed, increasing the risk of soil erosion
- industrial activities, which if inappropriately managed can have significant impacts on land condition. Activities including extractive industries, waste disposal, and intensive livestock industries can cause land pollution or contamination, which may spread to other areas including water bodies
- underground mining, particularly long-wall coal mining can cause subsidence, with impacts on the environment, including soil erosion, diversion of water flow, reduction in water quality, and physical disturbance of the geological and built environments.

Land use and land-use change at a sub-catchment and catchment scale has a potentially cumulative impact on land condition, water quality and ecosystem health. The extent to which each activity actually alters the natural landscape in the Catchment depends on the inherent risks of that land-use type, the intensity of the land use and the level and appropriateness of management practices adopted at each site. This audit assesses the pressures to land condition that are caused by land use on a Catchment wide scale, as well as sites of potential pollution or contamination in the Catchment.

5.1 Changes in land use

Background

A clear understanding of land use in the Catchment is critical in identifying likely impacts on water quality in drinking water storages. Changes in land use include transferring from one type of land use to another or changing the intensity of land use. Examples include moving from native pasture to improved pasture, pasture to cropping or intensive agriculture and agriculture to urban or rural residential. Land-use change has the potential to increase pressure on ecosystem health and water quality in the Catchment, and yet also offers the opportunity in some cases to reduce impacts from past land uses and poor land management practices.

Land use mapping of the entire Catchment is not undertaken at a frequency which enables an assessment of land-use change at two-year audit intervals. Further, land-use changes over a two year audit period are likely to be relatively minor on a Catchment wide scale. The assessment of land use change at a Catchment scale is therefore a more useful longer term measure of the pressures on land condition. In 2000, the former Department of Infrastructure Planning and Natural Resources (DIPNR) carried out land-use mapping in the Catchment at a more descriptive scale than was presented in the 2003 Audit report. The 2007 Audit report presents this land-use information in Map 5.1. In 2007, DECC undertook mapping of land-use change. The change in land use was determined by comparing 2004 land-use information and recent changes in land use. The areas were identified using aerial photographs dated 2006.

The audit also examines the number and type of development applications submitted to the SCA during the 2007 Audit period as a surrogate measure of short term land use change. The Regional planning instruments that apply or have applied to the Catchment (REP 1/SEPP58) require certain development applications to be referred to the SCA for concurrence (see Actions and Response section in this chapter).

Findings

Land use

Land use across the Catchment is shown in Map 5.1. The Wollondilly River (priority), Upper Wollondilly River (priority), Mulwaree River (priority), Wingecarribee River (priority) and Reedy Creek sub-catchments have large areas of pastureland.

Large urban areas are located at Goulburn (Mulwaree River (priority) sub-catchment), Bowral and Moss Vale (Wingecarribee River (priority) sub-catchment), Lithgow (Upper Coxs River (priority) sub-catchment) and Katoomba (Lower Coxs River (priority) sub-catchment). There is also a large rural residential area in the Wollondilly River (priority) and Nerrimunga River sub-catchment.

The land use change data show that the majority of new urban/rural residential developments between 2004 and 2006 occurred in the Wollondilly River (priority) sub-catchment. There were also small areas in the Wingecarribe River (priority), Upper Wollondilly River (priority), Mulwaree River (priority) and Nattai River sub-catchments.

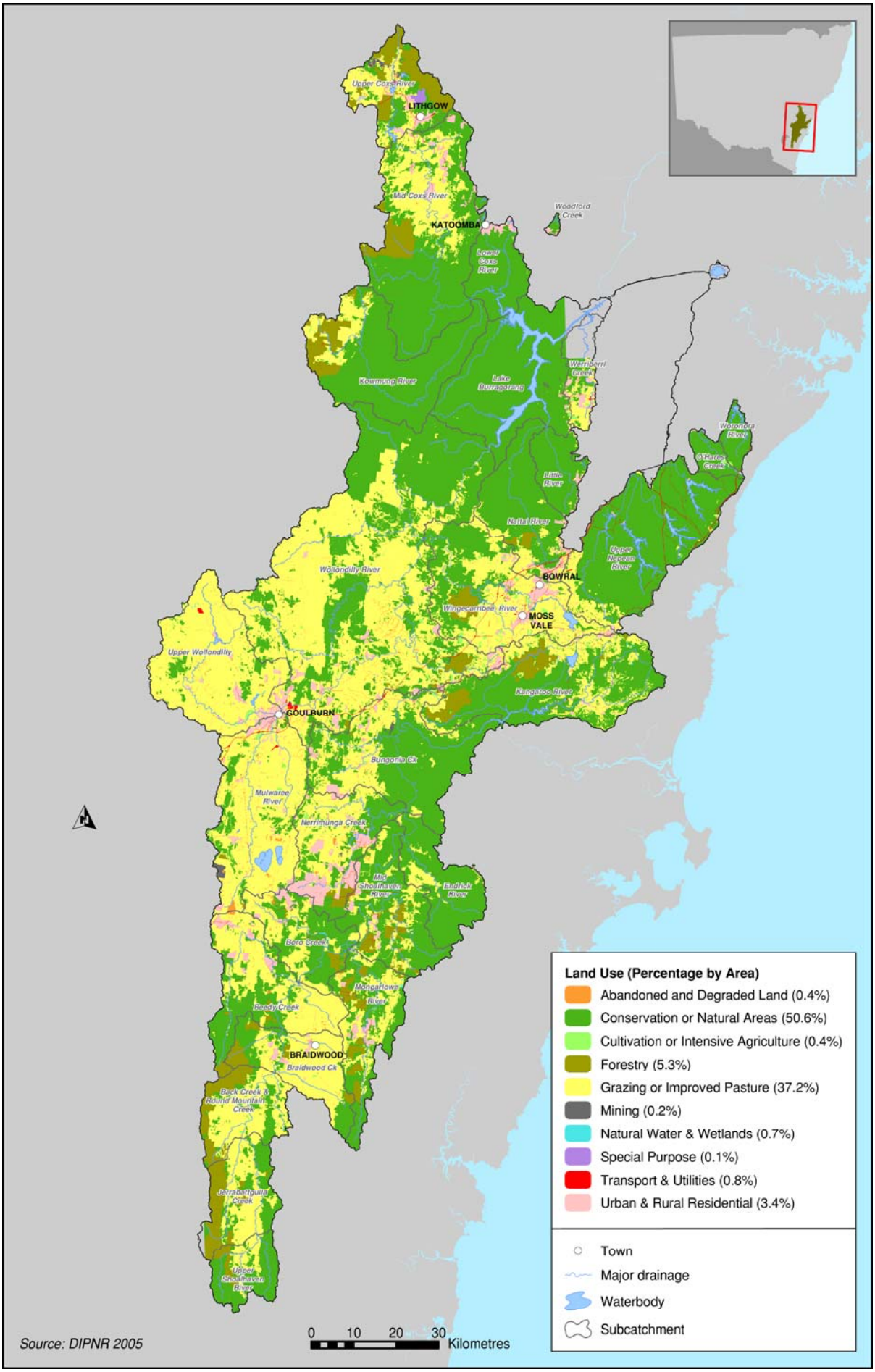
Development applications

There was a seven per cent decrease in the total number of development applications (DAs) submitted to the SCA under the REP/SEPP during the 2007 Audit period compared to the 2005 Audit period.

The greatest number of DAs for dwellings and subdivisions submitted to the SCA during the 2007 Audit period were in the Kangaroo River (priority), Wingecarribee River (priority) and Wollondilly River (priority) sub-catchments (Figure 5.1).

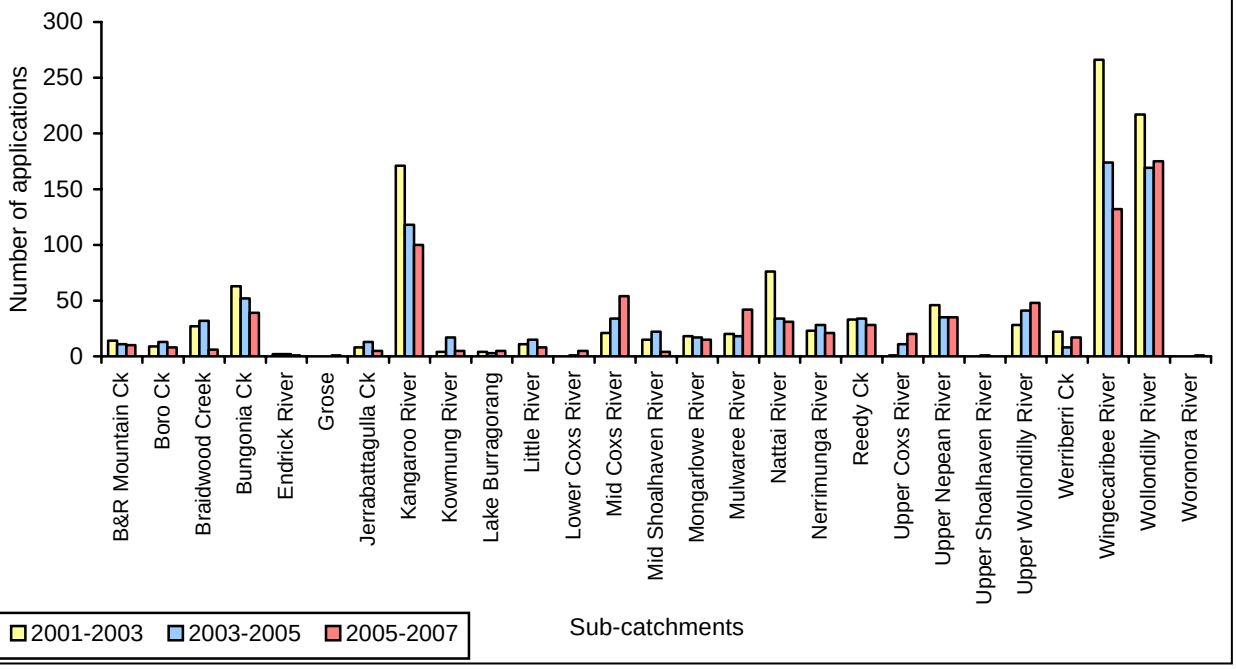
Areas that had increases in the number of applications submitted for dwellings and subdivisions during the 2007 Audit period were the Grose River, Lake Burragorang, Lower Cox River (priority), Mulwaree River (priority), Upper Cox River (priority), Upper Wollondilly River (priority), Werriberri Creek (priority) and Woronora River sub-catchments (Figure 5.1).

During the 2007 Audit period, areas having the greatest number of development applications submitted to SCA that did not include dwellings or subdivisions were the Nattai River, Kangaroo River (priority), Upper Nepean River, Wollondilly River (priority) and Wingecarribee River (priority) sub-catchments (Figure 5.2). These developments include agriculture, effluent/biosolid disposal, forestry, mining, poultry farm, tourism and vineyards.



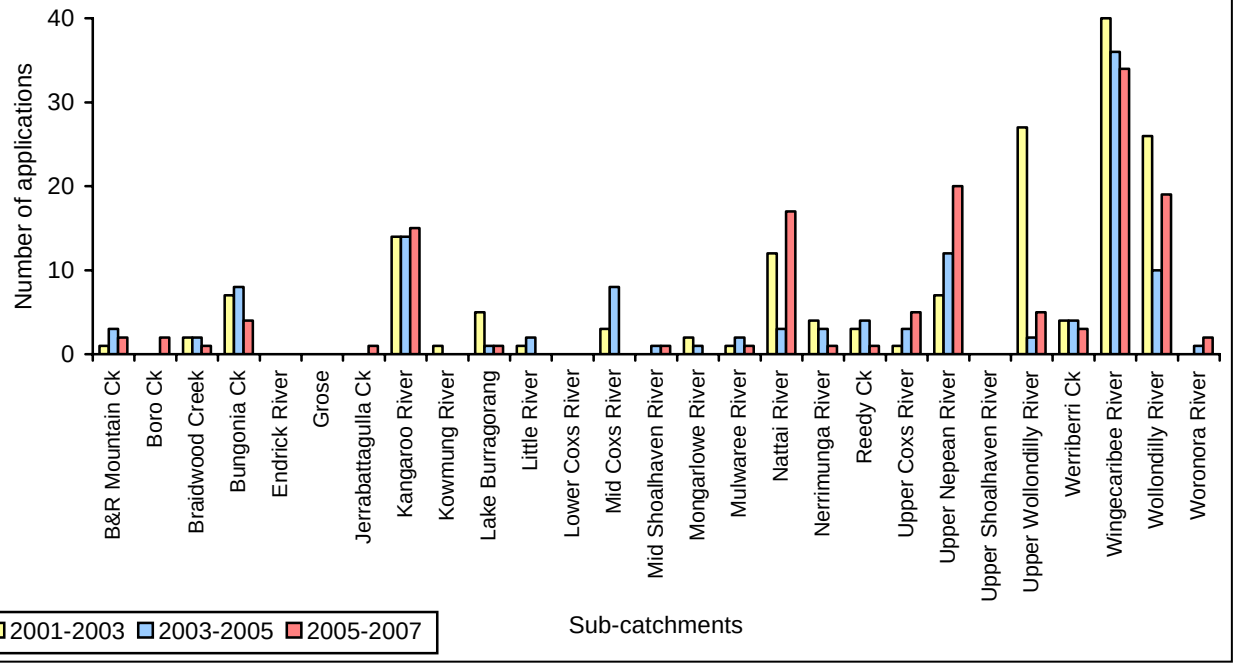
Map 5.1: Land use and percentage of area in the Sydney drinking water catchment

Figure 5.1: Number of development applications for dwellings and subdivisions per sub-catchment for the 2003, 2005 and 2007 Audit periods



Source: SCA 2007

Figure 5.2: Number of development applications excluding dwellings and subdivisions per sub-catchment for the 2003, 2005 and 2007 Audit periods



Source: SCA 2007

Implication

New urban/rural residential developments between 2004 and 2006 occurred in the Wollondilly River (priority) sub-catchment. There were also small areas in Wingecarribe River (priority), Upper Wollondilly River (priority), Mulwaree River (priority) and Nattai River sub-catchments.

The overall number of development applications submitted to the SCA decreased during the 2007 Audit period. However, a large number of urban, rural residential and commercial developments are still occurring in the Wingecarribee River (priority), Wollondilly River (priority), Kangaroo River (priority), Mid Coxs River (priority), Mulwaree River (priority), and Nattai River and Upper Nepean River sub-catchments. This may put pressure on water quality, ecosystem health and land condition in these sub-catchments unless specific management practices are adopted or incorporated to mitigate the potential impacts of vegetation clearing, soil erosion, stormwater and sewage management associated with these developments. The adoption of recommended practices endorsed by the SCA is an appropriate response to these pressures (see Actions and Response section in this chapter).

The Auditor understands that the SCA referral requirements focus on development proposals with potential sewage management issues that may impact on the water quality in the Catchment. Other development proposals that could affect local stormwater quality, for example, and which may also have an impact in the Catchment, are not referred to SCA. Data on this broader dimension of development pressure in the Catchment were not provided to the Auditor.

Other changes in land use such as improvement to pasture through cultivation and application of fertiliser are more difficult to quantify as they are not subject to planning approval processes. Similarly, changes in management practices can significantly change the impact of activities for better or worse but again these are difficult to quantify.

A number of councils in the Catchment predict further residential developments over the next 10 years:

- Goulburn Mulwaree City Council
  - Marys Mount on the North West side of Goulburn. The area of land available for urban development is approximately 234 ha, with a predicted 2,025 residential lots.
  - The Ducks Lane precinct located in the south east of Goulburn contains a total area of approximately 916.5 ha with a predicted 680 residential lots.
  - Clyde Road. The area of land available for development is approximately 169 ha with a predicted 505 residential lots.
  - Marulan village with a predicted 621 new residential lots.
  - Tallong Park Estate
- Lithgow City Council
  - Lithgow potentially 1,424 lots.
  - Wallerawang potentially 1,201 lots
  - Marrangaroo potentially 1,530 lots
  - Lidsdale, 19.6 ha potentially 157 lots
- Wingecarribee Shire Council
  - Wensleydale, 7.5 km north of Mittagong and east of Colo Vale. 248.33 ha with a predicted 910 dwellings
  - Chelsea Gardens, 2km south of Moss Vale. 123.7 ha with a predicted 1000 dwellings
  - Gibbergunyah, south west of Mittagong. 33.23 ha with a predicted 150 residential lots.
- Wollondilly Shire Council
  - Warragamba/Silverdale, up to 150 lots
  - The Oaks, up to 150 lots

Future directions

Given the anticipated rate of land-use change across the Catchment it is envisaged that land use maps could be updated at five-year intervals depending on advances in remote sensing technology and analysis. Such maps provide useful information for catchment managers and land-use planners in identifying where there are changing pressures on land condition, water quality and ecosystem health, and concurrently provide a

useful layer of information for modeling other catchment indicators. Given these potential uses of detailed land maps, the Auditor considers that the SCA should have an interest in ensuring such land use maps remain up to date, and reinforces the recommendation made in 2005 that detailed land-use maps be updated every five years.

Changes in land use, particularly those changes leading to the removal of native vegetation and disruption of soil almost inevitably lead to increased impact on land condition and water quality. However, with appropriate design and management, such impacts can be minimised and potentially lead to overall improved outcomes especially where degraded landscapes are rehabilitated and best practice water-sensitive design principles are implemented.

The SCA's Water Quality Risk Management Framework and rectification action planning process should enable high risk locations and land uses to be identified. The next step would be to identify the areas in which there is potential for improved management practice. Various agencies have already published best management practice guidelines and the SCA has Current Recommended Management Practices. Further guidelines should be developed for remaining high-risk activities and management practices.

5.2 Sites of pollution and potential contamination

Background

Many industrial or agricultural processes can pollute the land during operation and/or by leaving a legacy of contaminated materials. Land pollution and contamination can occur where appropriate management practices are not implemented. Land contamination can potentially be mobilised by surface and groundwater movement and erosion, resulting in migration of contaminants into the broader Catchment. Therefore, it is important to identify operational and historical sites in the Catchment that have a potential to contaminate land and pollute water.

This audit examines:

- sites of potential pollution and contamination identified during the audit period
- risk assessment of the potential sites of pollution and contamination during the audit period
- level of compliance during the audit period of sites licensed to discharge to waters under the POEO Act
- new remediation and rehabilitation works at sites of pollution or contamination during the audit period.

Findings

Risk assessment

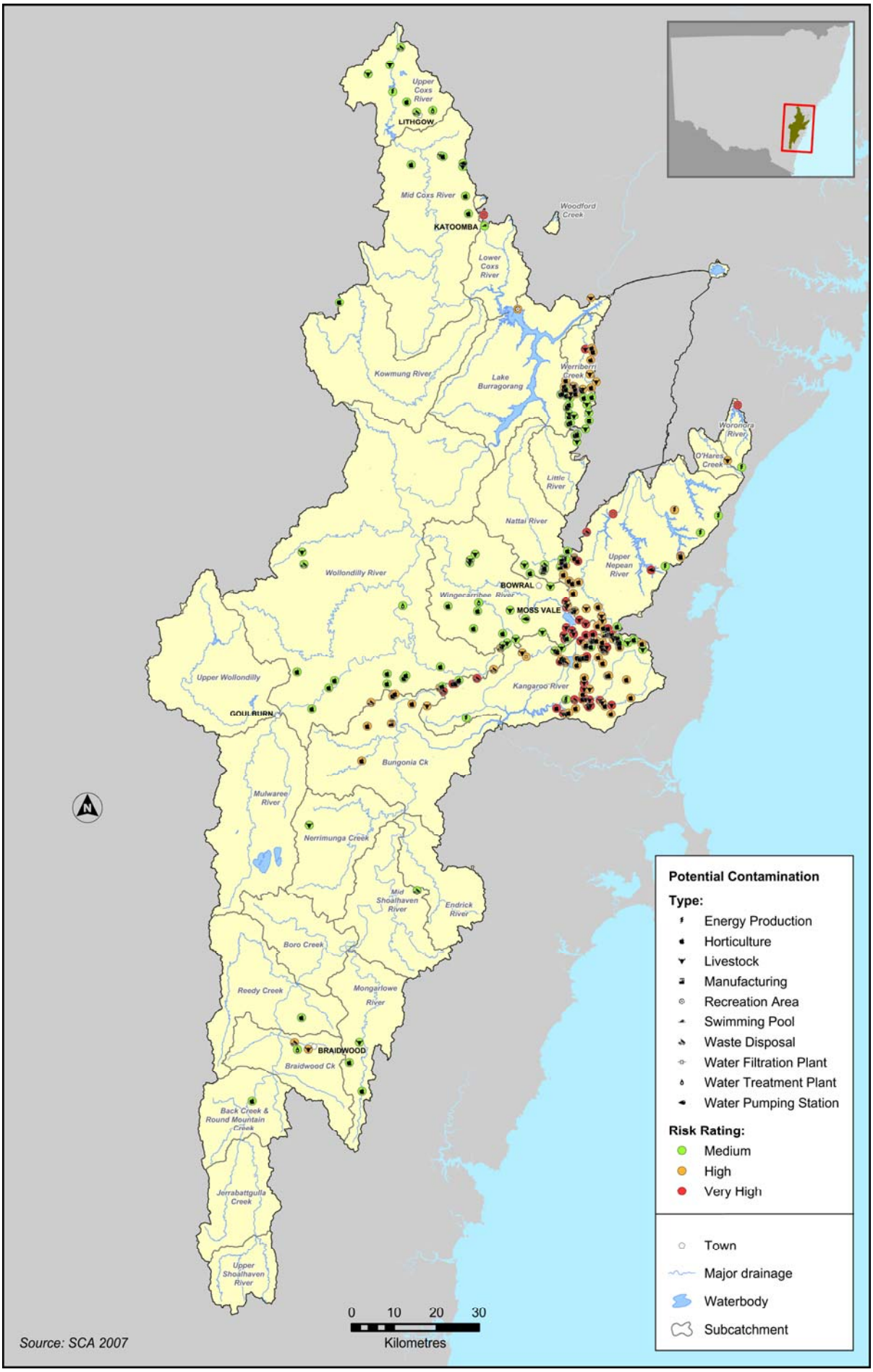
The SCA prepared the Pollution Source Risk Management Plan in December 2000 which identified activities that were expected to occur in the Catchment and that have the potential to pollute land. The SCA then commissioned assessments of nine potentially high risk industry types in the Catchment to identify specific sites of potential pollution in the Catchment. These assessments are known as the Environmental Assessment of Sites and Infrastructure (EASI) assessments. EASI assessments were undertaken for Commercial and Manufacturing Facilities, Commonwealth Facilities, Intensive Horticulture/Forestry, Intensive Livestock Industries, Sewage and Water Treatment, Telecommunications and Energy Production, Waste Disposal, Mines and Quarries. The EASI process identified 1,776 sites of pollution or potential contamination in the Catchment.

During the 2007 Audit period the SCA updated its assessments of potentially polluting sites. The total number of sites currently in the SCA's Compliance Support System has increased from the original 1,776 EASI sites to 2,391 sites. Of these, 1,381 prioirty sites were reassessed, with 65 sites are rated as very high risk to water quality, 195 sites as high risk, 246 sites as medium risk, 500 sites as low risk and 315 sites as negligible risk. The type of assessed sites in the very high, high and medium risk categories are presented in Table 5.1. The locations of very high, high or medium risk assessed sites are shown in Maps 5.2 and 5.3.

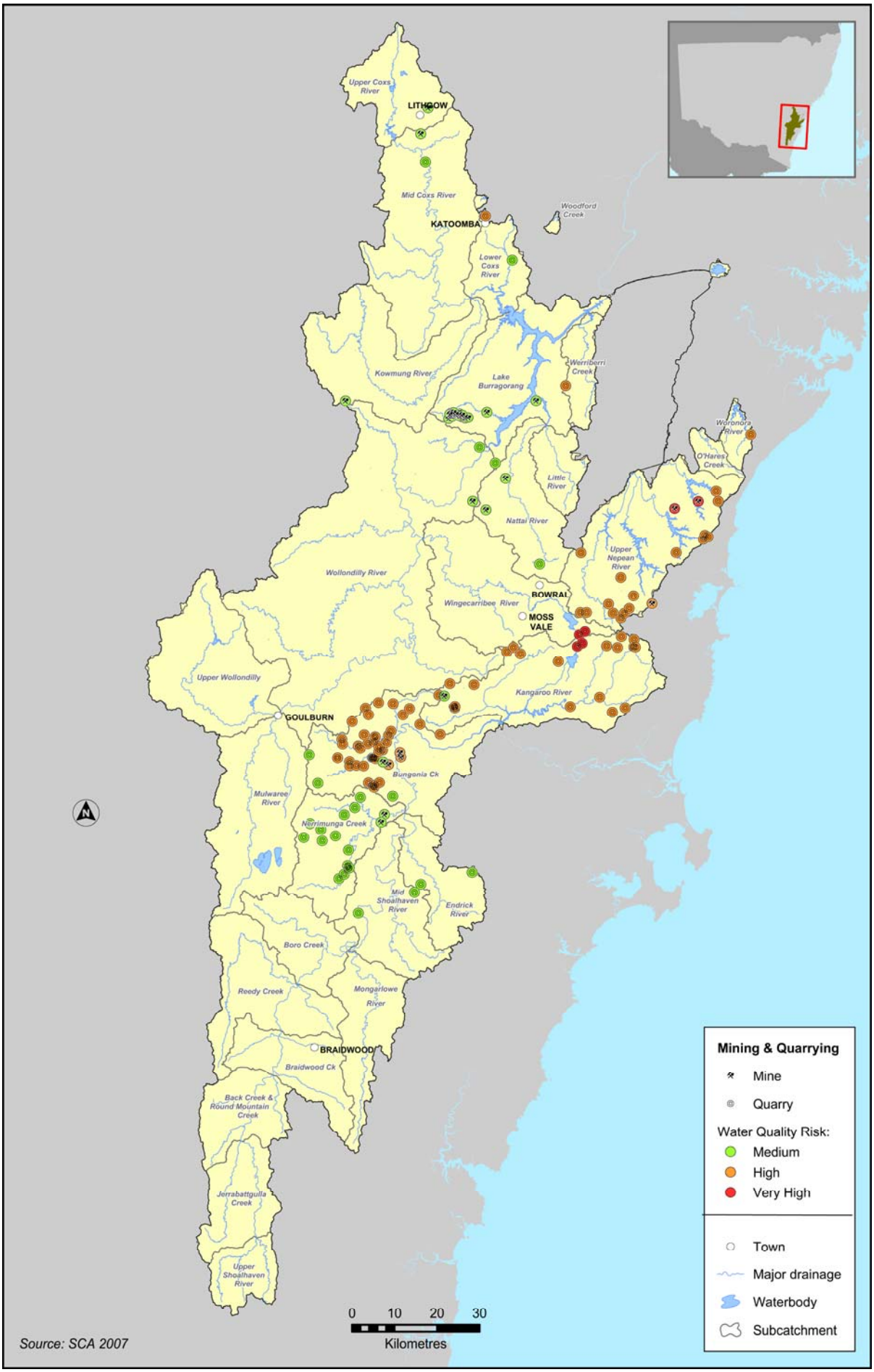
Table 5.1: Type and number of assessed sites in the Catchment rated by SCA as very high, high and medium risk to water quality

Type of site	Very High	High	Medium	Type of site	Very High	High	Medium
Intensive Horticulture/Forestry				**Sewage and Water Treatment**			
Vegetable growing		8	3	Sewage Treatment plant	1	2	9
Cropping			2	Sewage pumping station	6	5	52
Grapes	4	11	3	Effluent irrigation	1	1	10
Flowers		2	1	Biosolids disposal	3		3
Forestry			3	Swimming pool		1	1
Fruit Trees	3	11	21	Small STP	1	2	4
Nursery	1	5	5	Pit Toilet		2	
Olives	2	10	10	Recreation area		1	
Nuts		1	1	Water filtration plant	4		
Berries		1	2	Water Treatment Plant		1	4
Potatoes	2	9	1	Water pumping station	1		
Mushrooms			1				
Corn	1						
Glasshouse (Hydroponics)	1						
Waste Disposal				**Telecommunications and Energy Production**			
Operating Landfill	1	3	5	Substation		1	7
Former landfill	1			Power station			1
Recycling drop off	1	5					
Transfer station	1						
Commercial and Manufacturing Facilities				**Intensive Livestock Industries**			
Automotive sites			1	Aquaculture			1
Farm & grain supply	1			Dairy	20	5	9
Food manufacture		1		Feedlots		1	
Construction Industry		1	6	Saleyard	1	1	3
				Horses	2	7	8
				Piggery			4
				Poultry	1	5	1
				Domestic animals		3	
				Intensive animal production			2
Mines	2	1	3	**Quarries**	4	81	29
Derelict Mines		3	28				

Source: SCA 2007



Map 5.2: Sites of pollution or potential contamination assessed in 2007 with a medium, high or very high risk rating in the Sydney drinking water catchment



Map 5.3: Mines and quarries assessed in 2007 with a medium, high or very high risk rating in the Sydney drinking water catchment

Overall, the total number of assessed sites with potential for contamination in the very high, high and medium risk categories decreased during the 2007 Audit period by 17 per cent (Table 5.2). The number of assessed sites of potential contamination (other than mines and quarries) in the very high, high and medium risk categories decreased by 21 per cent during the 2007 Audit period (Table 5.2). There was, however, an increase in the number of assessed sites in the very high risk category. The majority of the assessed sites of potential contamination in the very high, high and medium risk categories are located in the Wingecarribee River (priority), Kangaroo River (priority) and Werriberri Creek (priority) sub-catchments (Map 5.2).

The majority of the assessed mines and quarries in the very high, high and medium risk categories are located in the Kangaroo River (priority), Bungonia Creek, Lake Burragorang, Nerrimunga River and Upper Nepean River sub-catchments (Map 5.3). There was a 35 per cent decrease in the number of assessed mine sites in the very high, high and medium risk categories. The number of assessed quarry sites in the very high, high and medium risk categories, however, increased slightly during the 2007 Audit period (Table 5.2).

The Yerranderie Silver Field is the number one site published in the (former) Department of Mineral Resources (DMR) top 50 derelict mine sites list of NSW. The Yerranderie Silver Field was rated as high risk to water quality by SCA during the 2005 Audit period. During the 2007 Audit period the risk rating of the Yerranderie Silver Field was reduced to medium, in the light of rehabilitation works undertaken.

Table 5.2: Number of sites in the very high, high and medium risk categories during the 2005 and 2007 Audit period and the percentage change

	Sites of potential contamination			Mines			Quarries			Total		
Risk Category	**2005**	**2007**	**% Change**	**2005**	**2007**	**% Change**	**2005**	**2007**	**% Change**	**2005**	**2007**	**% Change**
Very High	32	47	+32	3	2	-33	11	4	-64	46	53	+13
High	136	97	-29	12	4	-67	41	81	+49	189	182	-4
Medium	153	108	-29	42	31	-26	54	29	-46	249	168	-33
Total	321	252	-21	57	37	-35	106	114	+7	484	403	-17

Source: SCA 2007

Note: Cells highlighted in orange increased from the 2005 to the 2007 Audit periods; all other categories decreased.

Compliance levels of sites licensed under the POEO Act

DECC regulates major point sources of potential pollution using Environment Protection Licences issued under the POEO Act. Activities that require an Environment Protection Licence include industries in certain categories and at higher levels of activity, sewage treatment systems (STSs), electricity generation and waste facilities. The licences include requirements for pollution control, monitoring, and reporting. There are 88 sites in the Catchment that are licensed under the POEO Act. A summary of the non-compliances with discharge and volume limit requirements for licensed sites (other than STSs) during the 2003, 2005 and 2007 Audit period is presented in Table 5.3. Sewage treatment systems were examined in Chapter 3 of this report.

Four mines had non-compliances under their Environment Protection Licences during the 2007 Audit period (Table 5.3). The mine site non-compliances included exceedences of discharge limits for pH, BOD, TSS and oil and grease. Only three other licensees in the Catchment had non-compliances during the 2007 Audit period.

Table 5.3: Discharge and volume limit non-compliances for the 2003, 2005 and 2007 audit periods at sites licensed under the POEO Act.

		PH limit	Discharge	BOD	Conductivity	Total P	Total N	TSS	Oil & grease	Fe	Mn	Salt	Volume Limit
Angus Place Colliery	**2003-04**							X					
	2004-05	X											
	2005-06	X						X					
	2006-07	2X						2X					
Berrima Colliery	**2003-04**		X										
	2004-05												
	2005-06			X									
	2006-07*												
Enhance Place Colliery	**2003-04**	X						X	X	X			
	2004-05												
	2005-06												
	2006-07												
Springvale Colliery	**2003-04**	X											
	2004-05		X					X	X				X
	2005-06	X	X					3X					
	2006-07												
Wallerawang Colliery (now Pine Dale Mine)	**2003-04**	X						X					
	2004-05												
	2005-06												
	2006-07												
Appin Coal Seam Power Station	**2003-04**						X		X				
	2004-05								X				
	2005-06											X	
	2006-07												
Wallerawang Power Station	**2003-04**												
	2004-05												
	2005-06							X					
	2006-07												
Berrima Feedmill	**2003-04**	X	2X	2X		X		X					
	2004-05	X	X	2X		X		X	2X				
	2005-06	X		X				X	X				
	2006-07												X
Mittagong Sands	**2003-04**	X											
	2004-05	X											
	2005-06												
	2006-07												

Source: DECC 2007

Note: * non-compliance data not available until December 2007

There are 11 licensed quarries in the Catchment and none of these sites reported discharge or volume limit non-compliances during the 2003, 2005 or 2007 Audit periods. The risk rating at three licensed quarried increased and one decreased during the 2007 Audit period (Table 5.4).

Table 5.4: Quarries licensed under POEO Act in the Catchment and SCA's risk assessment

Quarry	EPA licence no.	Risk Rating	Quarry	EPA licence no.	Risk Rating
Braidwood Sand Pit	4483	Low	Marulan Pit – Bungonia Rd	944	Medium - High
Bunnygalore Quarry	4249	Low - Negligible	Penrose Sand Quarry	4720	Low
Exeter Quarry	870	High	Rivervale	3517	Low
Hartley Rhyolite Quarry	12323	Low - Medium	Soapy Flat Sand Pit	3132	Low
Kangaloon Flat Sand Pit	4232		Welby Quarry	2223	Low - Medium
Marulan Limestone Quarry	1371	High			

Source: SCA and DECC 2007

Note: For cells highlighted in orange the risk rating has increased from previous audit period; cells highlighted in yellow the risk rating has decreased from previous audit period.

There were two quarry-related development applications referred to SCA during the 2007 Audit period. One application was in the Endrick River sub-catchment and one in the Mongarlowe River sub-catchment.

Remediation and rehabilitation works

There are also four sites in the Catchment that are listed on the DECC's Contaminated Land Record under section 58 of the *Contaminated Land Management Act 1997*. The remediation orders to the waste oil storage facility in Larbert, the former shale oil refinery at Hartley Vale and the investigation order to the Joadja shale oil refinery were still current during the 2007 Audit period. The Hartley Vale shale and the Joadja shale mines are on the (former) Department of Mineral Resources Derelict Mine List as sites in need of remediation works to prevent contamination of waterways. The remediation of the former shale oil plant at Mittagong commenced in February 2005 and received funding in June 2005 from the Environmental Trust. A notice of the End of Declaration was issued to this site in June 2006.

Seven derelict mines were identified for rehabilitation as part of the EASI process. In 2005 a risk assessment of these seven derelict mines was carried out as part of an investigation into the derelict mines in the Catchment and a priority ranking of the sites was determined. The sites in decreasing rank order are Mulloon Copper Mine, Tuglow Copper Mine, Black Bob's Creek Coal Mine, Joadja Oil Shale Mine, Hartley Vale Shale Mine, Tolwong Mine and Nattai Shale Mine (Holden, 2005). A rehabilitation plan for Black Bob's Creek was also prepared as part of the investigation.

During the 2007 Audit period, the SCA jointly with DPI began rehabilitation of the Black Bob's Creek derelict coal mine (in the Wingecarribee River (priority) sub-catchment), carried out an initial assessment of the Mulloon Copper Mine site (in the Reedy Creek sub-catchment) and prepared a plan to rehabilitate the former Oakdale mining site (in the Werriberri Creek (priority) sub-catchment).

Black Bob's Creek derelict mine site is located at Belangalo State Forest in the Southern Highlands. The rehabilitation works included removing coal fines from old stockpile areas, concealing exposed coal seams, removing conveyor belts and rubbish, demolishing and removing the office block, brushmatting eroded and treated areas, constructing contour banks along access roads and improving drainage.

The Mulloon derelict mine is on private property about 20 kilometres east of Bungendore. The site lies adjacent to Mulloon Creek. There are five areas of concern, three of which occur on steep land and include tailings and open shafts. Elevated concentrations of various metals in the mine tailings, creek sediment, shaft water and creek water were found, and rehabilitation options will be negotiated with the landholder in the coming year.

Yerranderie silver mining field is located within the Warragamba Special Area adjacent to the Tonalli River, which runs into Lake Burragorang. During the 2007 Audit period, soil and water management works were successfully completed at four former processing sites within the Yerranderrie mine site: Silver Peaks; Colon Peaks; West Wollondilly; and Kerry's Shaft. Arsenic contamination of the tailings areas was also found, with concentrations of up to 36 per cent arsenic. These arsenic deposits are located on the surface and exposed to weather which increases the potential for them to run off into waterways. The SCA contributed $100 000 to DPI for the removal of 100 tonnes of materials with arsenic levels above two per cent. The tailings will be disposed of in a licensed treatment facility outside SCA catchment areas.

During the 2007 Audit period Lithgow Council continued remediation works on part of the former gasworks site in Mort Street, Lithgow.

Implications

There are a large number of activities in the Catchment with the potential to impact land condition and water quality if they are not appropriately managed. These sites are concentrated in the Kangaroo River (priority), Werriberri Creek (priority), Wingecarribee River (priority), Bungonia Creek, Lake Burragorang, Nerrimunga River and Upper Nepean River sub-catchments. Overall, the total number of assessed sites with the potential of contamination in the very high, high and medium risk categories decreased during the 2007 Audit period by 17 per cent. This was primarily due to a 35 per cent decrease in the number of assessed mine sites in the very high, high and medium risk categories.

Future directions

The SCA should continue to work with DECC, DPI, councils, operators and landholders to address sites identified as very high, high and medium risk to water quality. The assessment of actual risk at sites of potential pollution and contamination should be continued, and actions implemented to reduce risks where necessary. The risk of pollution and contamination at operational sites should be reassessed at a frequency commensurate with the inherent risk of the activity type, site specific risks and known performance history of the landholder/operator.

The SCA should be working with DECC, DPI, councils, landholders and operators to ensure there are pollution prevention or rehabilitation programs at sites identified as posing a risk to water quality or ecosystem health in the Catchment. The pollution prevention or rehabilitation programs should be formalised where necessary, through regulatory instruments such as Environment Protection Licences and Pollution Prevention Notices under the POEO Act, or through formal programs such as derelict mine programs. The SCA should therefore be continuing to develop the prevention or rehabilitation programs at each site in consultation with the landholders as well as with other relevant agencies such as DECC or councils, in accordance with the 2005 Audit recommendation that SCA develop pollution prevention or rehabilitation programs at sites identified as very high, high and medium risk to water quality, in consultation with relevant agencies, operators and landholders.

5.3 Soil erosion

Background

Soil erosion is a natural process that can be accelerated by human activities. The slow rate of soil formation means that soil is effectively a non-renewable resource. Increased rates of erosion can also impact water quality and aquatic ecosystems due to the deposition of sediments and nutrients.

The risk of erosion is linked to a range of factors, such as land use, geology, geomorphology, climate, soil texture, soil structure and the nature and density of vegetation in the area. The clearing of native vegetation and agricultural land-use activities have been major contributors to accelerated rates of erosion. The potential for soil erosion increases wherever vegetation cover is removed, soil is disturbed or exposed, and where high intensity rainfall or wind occurs. The main categories of soil erosion are sheet, rill, gully, tunnel, stream bank and wind erosion. The management of areas with erosion risk, and the remediation of areas that are affected by soil erosion, is important in protecting Catchment productivity, water quality and ecosystem health.

Estimated sheet and rill erosion was calculated by the National Land and Water Resources Audit (NLWRA 2001) using the Revised Universal Soil Loss Equation (RUSLE). The following attributes were used in the RUSLE: soil erodibility (data derived from NSW Soil and Land Information System and the Australian Soil Resource Information System); rainfall erosivity (data from National Rainfall erosivity surface); slope gradient and length (derived from the National Digital Elevation model); and ground cover (Satellite imagery from Normalised Difference Vegetation Index – NDVI).

Observed soil erosion is not currently mapped at regular intervals. The SCA has developed a new dataset to identify active gully erosion across the Catchment. This has been field tested and the total area of gully erosion in each sub-catchment has been derived.

Findings

The SCA estimates that the total area of the Catchment with observed gully erosion is 776 ha. Several gully erosion sites were visited during the Audit inspections (Figure 5.3 and 5.4). The sub-catchments with the greatest area of observed gully erosion were Wollondilly River (priority), Upper Wollondilly River (priority), Mulwaree River (priority), Bungonia Creek and Boro Creek sub-catchments (Map 5.4).

Figure 5.3: Gully erosion (Tarlo River NP)
Source: DECC 2007

Figure 5.4: Gully erosion
Source: DECC 2007

As presented in the 2003 and 2005 Audit report using information from the NLWRA, 11 per cent of the Catchment was estimated to have very high or high risk of sheet and rill erosion. Five per cent of the Catchment is estimated to have very high risk of sheet and rill erosion, including parts of the Upper Coxs River (priority) and Wollondilly River (priority) sub-catchments. The Upper Wollondilly River (priority), Mulwaree River (priority), Reedy Creek and Braidwood Creek sub-catchments (six percent of the Catchment) contained areas with high erosion risk.

The Catchment Protection Scheme, funded by SCA and CMAs, aims to repair severe gully, stream bed and stream bank erosion. During the 2007 Audit period, the following erosion management measures were undertaken in the Catchment:

- 5,223 ha was treated for moderate to severe gully erosion by H-N and SR CMAs
- 93 km of fences were constructed to protect severe gully and stream erosion from livestock by H-N CMA
- 63 flumes were constructed by H-N CMA
- 75 gully erosion control structures were built by H-N CMA.

The Auditor notes the apparent discrepancy between the quoted 776 ha of observed gully erosion, and the reported 5,223 ha of treated areas in the Audit period. The Auditor understands that the 'treated area' in a project is a much larger area than the area of 'observed gully erosion' being remediated, because the former area includes regraded, fenced and revegetated areas surrounding the immediate site of the erosion.

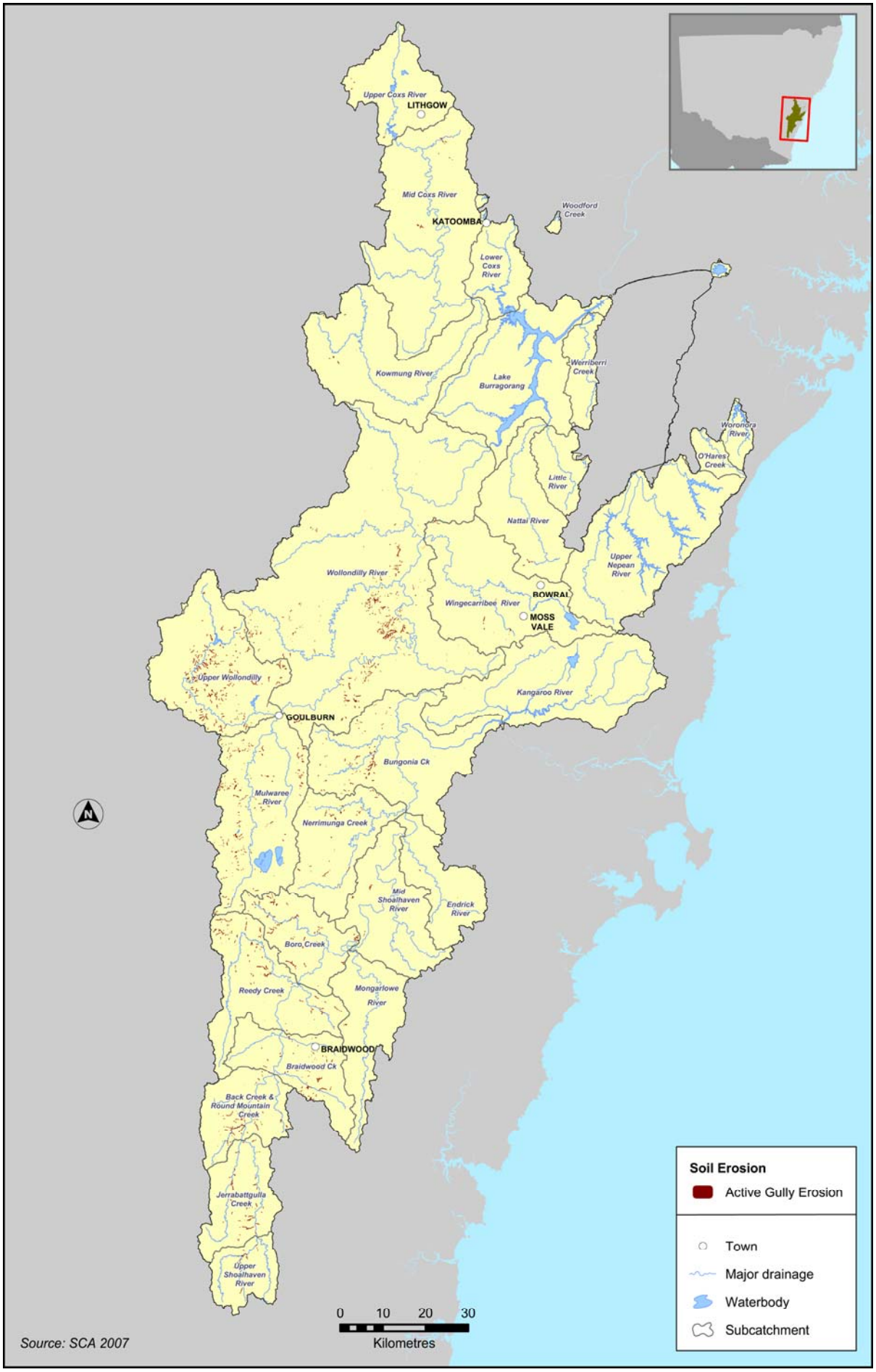
Implications

The Wollondilly River (priority), Boro Creek, Mulwaree River (priority), Upper Wollondilly River (priority) and Endrick River sub-catchments had the greatest observed area of gully erosion. Areas within the Upper Coxs River (priority), Reedy Creek and Braidwood Creek sub-catchments have been identified as the most susceptible to soil erosion. Programs addressing soil erosion need to specifically target these areas to ensure that appropriate strategies and management controls are in place to respond to actual cases of soil erosion and minimise the risk of erosion.

Future directions

Erosion management programs need to reduce the risks of erosion as well as manage and rehabilitate actual cases of erosion. Programs to manage the risk of erosion should also be integrated with programs to protect and rehabilitate native and riparian vegetation (see Chapter 6) to obtain multiple benefits from on-ground works.

There is inadequate information about the location of erosion management works in the Catchment (see 2005 Recommendation 19). The location, type and area of all erosion management works in the Catchment should be recorded on a centralised spatial information system to enable the co-ordination of erosion management works between programs and agencies and to maximise the potential for integrating erosion works with other potentially complementary programs such as nutrient reduction and riparian and native vegetation rehabilitation works (see Recommendation 6 and 12).



Map 5.4: Observed gully erosion in the Sydney drinking water catchment

Case Study – Gully erosion control at Arthursleigh

Arthursleigh is a 7,000-hectare farm near Goulburn, and is one of the oldest properties in the area. It was donated to the University of Sydney in 1979 by the late Eric Thomas William Holt. Prior to this time, the property was heavily grazed and poorly managed, and consequently experienced severe land degradation and erosion. Stephen Burgun has been manager of the property for 17 years, and has been quoted as saying that when he arrived, the property was scarred by a 12 km long erosion gully (NRM, 2006).

“There was one erosion gully that ran almost the whole length of the property. It had dry red and yellow walls and a raw lifeless creek at the base”.

Erosion gullies mobilise large volumes of sediment which are transported downstream during rain events, and then impact on water quality, stream structure and aquatic life.

During 2005-06 works began at Arthursleigh, as part of the joint SCA/CMA Catchment Protection Scheme (CPS) project which aims to restore eroded land and protect water quality in the Catchment.

On Arthursleigh, the remediation works have included an earth weir, a flume structure, fencing, and revegetation. The 2007 Audit Team inspected the site with an officer of the Hawkesbury-Nepean CMA, observed the weir actively trapping large volumes of sediment, and noted the improved conditions downstream where there had previously been large active erosion gullies.

Stephen Burgun has been quoted as saying, "Now the gully walls are green and a live creek runs through it, with native grasses covering the creek floor. These play a really important role in filtering water. We're in Sydney's catchment area, so it means we're making a significant difference to the quality of Sydney's water."

The works are estimated to have prevented 18,000 tonnes of sediment from entering the Wollondilly River (priority) sub-catchment.

Figure 5.5: Dam created behind the weir

Source: DECC 2007

Figure 5.6: Flume

Source: NRM 2006

5.4 Salinity

Background

Salinity can be a threat to the health and productivity of a catchment, as excessive salinity can be lethal to plants and soil organisms or severely limit their productivity. Salinity occurs when the natural balance and distribution of salt in the landscape is disturbed. The removal of native vegetation through land clearing and the adoption of unsuitable land uses and practices have resulted in rising groundwater tables in some locations. This allows naturally occurring salts to migrate close to the soil surface where they are concentrated by evaporation or discharged into surface waters. Discharges of saline waste water from mines, power stations and STPs are other sources of salts reaching waterways.

The risk of salinity was determined by the former DIPNR using the Soil Landscapes data for the Catchment. The risk was placed into three categories:

- widespread – areas where saline soils occur or where scalding, salt efflorescence, vegetation dieback, salt tolerant vegetation and water logging can be found
- localised – scattered areas of scalding and indicator vegetation have been noted, or
- no risk – small likelihood of salinity occurring.

During the 2005 Audit period, the Goulburn, Braidwood and Taralga 1:100,000 map sheets in the Catchment were surveyed for actual salinity as part of DNR's (now DECC) Surface Salinity Mapping Project.

Findings

From the Surface Salinity Mapping Project, the area of the Catchment with observed salinity cases was 2,157 ha (less than 0.2 per cent of the Catchment), and were located in the Wollondilly River (priority), Upper Wollondilly River (priority), Mulwaree River (priority), Nerrimunga River, Boro Creek, Reedy Creek and Bungonia Creek sub-catchments (Map 5.5). The area of the Catchment with a widespread risk of salinity is 3 per cent, located in the Boro Creek, Mid Shoalhaven River and Nerrimunga River sub-catchments (Map 5.5).

Thirty two hectares of salinity-affected land was treated during the 2007 Audit period under the Catchment Protection Scheme by the H-N CMA.

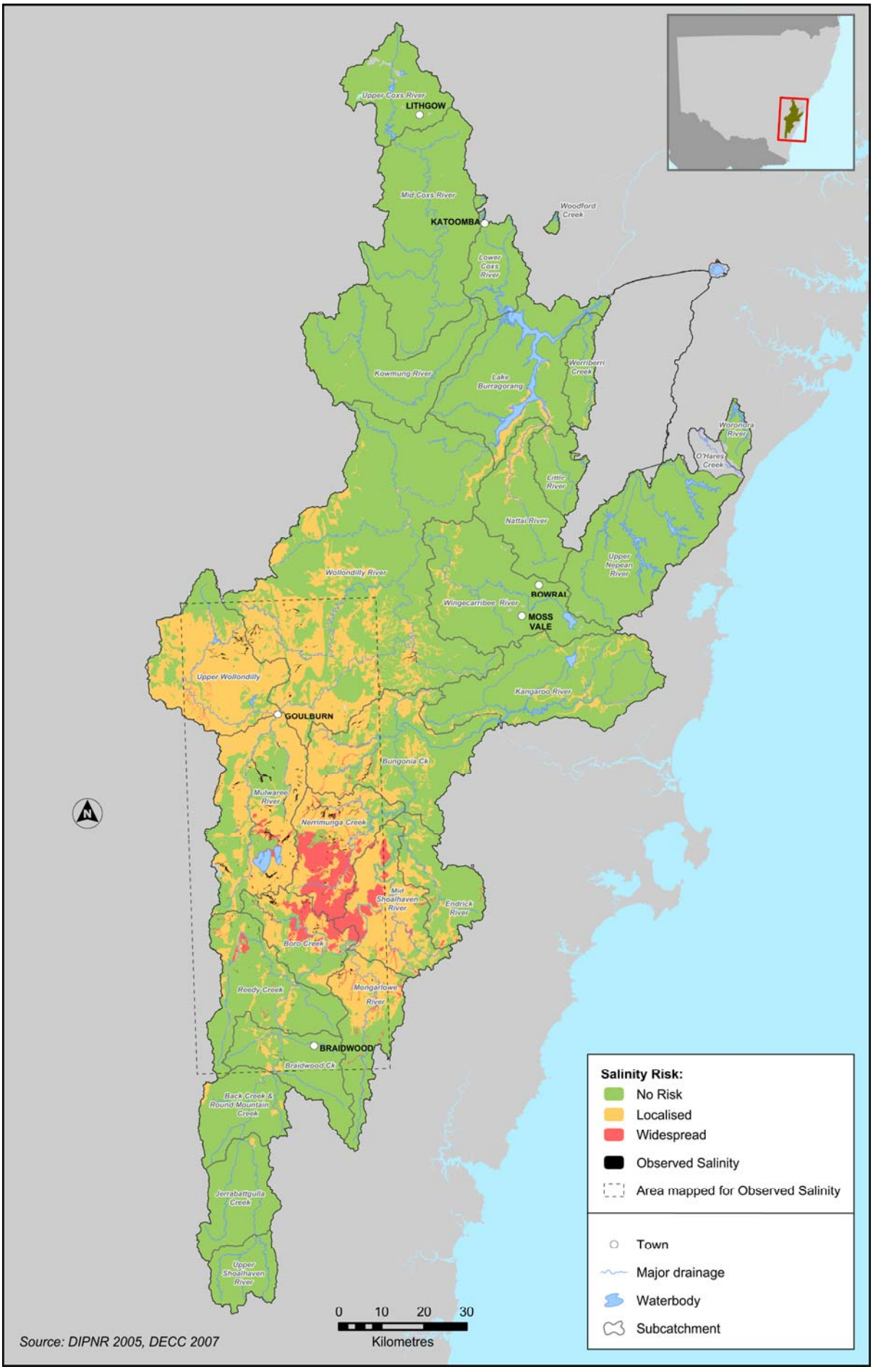
Implication

Areas within the Wollondilly River (priority), Upper Wollondilly River (priority), Mulwaree River (priority), Nerrimunga River, Boro Creek, Reedy Creek, Bungonia Creek and Mid Shoalhaven subcatchments have been identified as containing observed salinity or are the most susceptible to salinity in the Catchment. SCA, DECC and CMAs need to ensure that appropriate management action is taken to prevent salinity in high risk areas and also remediate existing areas of salinity to prevent salinity from becoming an issue in the Catchment. Programs to manage salinity should target these high risk areas, and other locations where land management practices increase the risk of salinity such as at sites where long term irrigation is practiced.

Future directions

There is no complete information about the location and extent of actual salinity cases over the entire Catchment, as recognised in the 2005 Audit (see 2005 Recommendation 19 that "The DECC develop systems in consultation with the SCA and CMAs for recording the location, nature and extent of actual cases of soil erosion and land salinity in the Catchment."). The Natural Resource Commission (NRC) has agreed on land salinity as a resource condition indicator, and considers that the size of salinity outbreaks should be re-measured every five to ten years and the intensity re-assessed during the re-measurement.

Salinity management programs need to reduce the risks of salinity as well as manage and rehabilitate actual cases of salinity. Programs to minimise the risk of soil salinity need to be developed for sub-catchments and specific locations identified as having widespread and localised risk of developing dryland salinity. The Auditor recommends that these programs should be integrated with other relevant on-ground programs.



Map 5.5: Salinity risk and observed salinity in the Sydney drinking water catchment

Recommendation 6: The SCA, DECC and CMAs should undertake programs that address soil erosion and salinity in the areas with identified and observed risk, and integrate them with other programs for riparian and vegetation management where possible.

The location, type and area of all dryland salinity management works in the Catchment should be recorded in existing spatial information systems to enable the coordination of dryland salinity management works (see Recommendation 12).

Actions and Response

Response to issue

The two primary responses to protecting and improving land condition are:

i) to ensure new activities in the Catchment incorporate appropriate measures to prevent pollution, contamination and land degradation

ii) where technically and economically feasible, to repair lands already degraded.

This section outlines the major actions aimed at protecting and improving land condition in the Catchment. These include:

- ***general programs to reduce land degradation from different land uses***
- ***programs to reduce land degradation from identified high risk industries***
- ***programs to manage areas of soil erosion***
- ***programs to manage areas of high salinity risk.***

General programs to reduce land degradation from different land uses

Land use planning

The regulation of land-use type and location within the Catchment is primarily guided by the *Environmental Planning and Assessment Act 1979*. Local councils also have a range of powers under the *Local Government Act 1993* and the POEO Act that can be used to manage specific land-use issues. Land-use planing instruments that cover the control and management of land uses include:

State Environmental Planning Policy 58 (SEPP 58) - SEPP 58 Protecting Sydney's Water Supply was gazetted in December 1998 and was introduced as an interim measure to ensure that development in the hydrological catchment from which Sydney draws its water did not have a detrimental impact on water quality. It was replaced by Regional Environmental Plan (REP 1) on 1 January 2007.

Drinking Water Catchments Regional Environmental Plan No.1 (REP 1) (SCA & DoP, 2007a) - The *Sydney Water Catchment Management Act 1998* requires an REP to be prepared. The plan designated REP 1 came into effect on 1 January 2007, and aims to:

- create healthy water catchments that will deliver high quality water while sustaining diverse and prosperous communities
- provide the statutory and non-statutory components in Sustaining the Catchments
- achieve the water quality management goals of:
  - improving water quality in degraded areas and critical locations where water quality is not suitable for the relevant environmental values
  - maintaining or improving water quality where it is currently suitable for the relevant environmental values.

Local Environmental Plans (LEP) – All councils within the Catchment have LEPs that specify the land-use zones and specific controls on land. LEPs must be consistent with relevant REP 1 or SEPPs.

Rectification Action Plans (RAPs) – The *Sydney Water Catchment Management Act 1998* requires the development of rectification action plans to rectify existing land uses that do not have a neutral or beneficial

effect on the quality of water, within certain time limits after the gazettal of the REP 1. The RAP Decision Support System will map and rank sources of four priority pollutants. The maps will inform the preparation of RAPs and the Healthy Catchments Program.

Strategic Land and Water Capability Assessments (SLWCAs) – REP 1 requires the SCA to prepare SLWCA for the Catchment. A SLWCA is an assessment of the physical capability of natural features of land and waterways to identify appropriate types and intensities of land use that will not adversely impact on water quality and catchment health. In 2006 the SCA developed a new and enhanced SLWCA model that utilises criteria directly available from the SCA spatial database. The model directly aligns with the standard template land-use table and local environmental plan zones. Local councils in the Catchment will be provided with Stage 1 SLWCA data during the next audit period. Stage 2 and the final SLWCA maps will be finalised during the next audit period.

Healthy Catchments Program (HCP) – has seven strategies including a land management and rural lands strategy, and uses tools such as grants and assistance schemes, education programs and regulation to improve land management practices. The HCP will be the primary SCA mechanism for implementing actions identified under RAPs.

Catchment Action Plans – The CMAs are required to develop Catchment Action Plans that consolidate and build on the existing native vegetation plans and catchment blueprints.

The Sydney Drinking Water Catchment Management (Environment Protection) Regulation 2001. This enables the SCA to exercise certain regulatory functions under the POEO Act with regard to non-scheduled premises and activities.

Neutral or Beneficial Effect on Water Quality Assessment Guidelines (NorBE) (SCA & DoP, 2007c) accompany REP 1, and provide guidance on the application of the NorBE principles. A neutral or beneficial effect can be demonstrated when the development:

- has no identifiable potential impact on water quality, or
- will contain any such impact on the site of the development and prevent it from reaching any watercourse, waterbody or drainage depression on the site, or
- will transfer any such impact outside the site by treatment in a facility and disposal approved by the consent authority (but only if the consent authority is satisfied that the water quality after treatment will be of the required standard).

The NorBE Guidelines include a range of current recommended practices which have been endorsed by the SCA. There are current recommended practices in place or under development in the areas of:

- wastewater management
- erosion and sediment controls in urban development
- erosion and sediment controls in non-urban development
- rural roads standards
- low density subdivision
- water sensitive urban design
- stormwater management
- waste and recycling
- agricultural management practice.

Case Study – Application of the NorBE test

To ensure land use in the Catchment protects water quality, the current Drinking Water Catchments Regional Environmental Plan No. 1 (REP 1) (2006-289) and its predecessor, the State Environmental Planning Policy 58 (SEPP 58) (1998-725) have required all developments that need consent under a council's local environmental plan to demonstrate a neutral or beneficial effect (NorBE) on water quality. NorBE Guidelines accompanying REP1 provide directions on the meaning of a neutral or beneficial effect on water quality, on how to demonstrate it, on how to assess a proposed development against the NorBE test, and on how the test will assist councils and proponents.

Example: Bowral sewage treatment plant (STP)

The augmentation of the Bowral STP was completed in the 2007 Audit period. Increasing sewage inflows could have caused increased frequency of overflows of the local sewer carriers, and increased loads of nutrients discharged in the treated effluent from the augmented plant to the local Mittagong Rivulet. The 2002 environmental assessment for the plant applied an earlier variant of the NorBE test required by SEPP58, whereby the post-development pollution load leaving the site should be the same or less than the pre-development load. To satisfy this test, the constructed works increased the STP's capacity to store wet weather inflows and reduce bypasses, increased the level of treatment to further reduce nutrient loads, and transferred treated effluent past the old discharge point in Mittagong Rivulet to the Wingecarribee River for direct discharge, thereby removing a dry weather impact in the Rivulet. Figures 3.4 and 3.5 in Chapter 3 of this report show that reductions in nutrient loads have been achieved in the Audit period, confirming that the Bowral STP augmentation met the requirements of the NorBE test, and delivered a positive environmental outcome in the Wingecarribee River (priority) sub-catchment.

Rural lands

A number of new guidelines have been developed for the sustainable management of agriculture during the 2007 Audit period:

- Best Practice Guidelines for using Poultry Litter on Pastures (DPI, 2007a) - These guidelines aim at ensuring that poultry litter is used wisely to optimise pasture production and minimise the risk of problems concerning stock health, stock feeding bans, pollution and the environment.
- Improving Water Quality in Catchments Using Compost (DPI & DEC, 2005a) – A fact sheet based on field trials at Bungonia in the Shoalhaven Catchment that demonstrated the effectiveness of composted mulch and soil conditioners in controlling sheet erosion and assisting vegetation establishment on degraded sites
- Spray Sense – Information for Uses of Agricultural Chemicals (DPI, 2006g) - Spray Sense is a series of leaflets which focus on providing up-to-date information on a range of pesticide issues. Everyone who is involved in the manufacture, sale, distribution, use of pesticides and provision of advice is encouraged to use this information to apply pesticides more effectively.
- Deep Litter Housing for Pigs (DPI, 2006b) – This fact sheet reviews deep litter housing for pigs including construction, controlled drainage and storage and treatment of spent litter. It also offers practical design, performance and process guidance.
- Farming Meat Rabbits in Australia (DPI, 2006c) - provides a brief overview of the meat rabbit industry in Australia and the requirements for the farming of meat rabbits in NSW.
- Recycled Organics in Catchment Management (DPI & DEC, 2005b) - The main aims of the project are, to determine desirable product specifications for composted recycled organics (RO) products for use in runoff and erosion control in water catchments in NSW.
- Best Management Practices for Temperate Perennial Pastures in NSW (DPI, 2006a) - provide a basis for sustainable management of grazing lands in the tablelands and adjacent high rainfall, temperate pasture areas of NSW. The BMP's primarily target dryland beef and sheep production on grazed pastures, but the principles will apply to other grazing enterprises in these areas.

- A Guide for Agricultural Development (SCA & DoP, 2007b) - provides advice on the definition of 'intensive plant growing' and the development assessment requirements for agriculture.
- Environmental Guidelines for Composting and Related Organics Processing Facility. (EPA, 2005). - The focus of these guidelines is on the appropriate environmental management of organics processing facilities. It lists the items to be included in an environmental management plan and the minimum performance and design requirements for the protection of waters.
- Nursery Industry Water Management Best Practice Guidelines. (NGIA, 2005) - A practical guide to sustainable water use, water use efficiency, recycling, nutrient management, responsible use of pesticides and site sediment and litter control.
- Wool Industry River Management Guide: High Rainfall Zones Including Tableland Areas. (IWA, 2006) - A guide to help woolgrowers improve and protect the health of water courses and riparian land on their farms and minimise the impacts of wool production on water quality and stream health.

Through the SCA's **Rural Lands Strategy** under its **Healthy Catchments Program**, SCA and DPI have commenced a grazier education partnership which supports graziers through education and follow-up activities. DPI has engaged a coordinator to manage the delivery of the accredited grazier training courses including LANDSCAN, PROGRAZE and Pasture Identification.

The Goulburn Mulwaree Council has also developed a **Rural Living Handbook** in partnership with SCA. This publication informs landholders of their rights and responsibilities when buying land in rural residential areas and can easily be adapted for use by all interested Catchment councils (Goulburn Mulwaree Council, 2006).

During the 2007 Audit period, the SR CMA provided capacity building courses for landholders including Property Management Planning workshop and Weed Removers Pasture Improvers Course as well as a number of field days.

The DPI and HN CMA's **Implementing Best Practice for Sustainable Grazing Management in the Hawkesbury-Nepean Catchment Project** began in April 2006. The project aims to recognise and improve the capacity of land managers to develop and implement grazing practices that lead to profitable, sustainable and productive enterprises, and which also contribute to drinking water quality and healthy catchments.

The DPI's **Sustainable Grazing Project** expands the above project to a larger geographical area (including Goulburn and Mulwaree) and works with graziers to provide access to training in CRPs and whole farm management to improve the area of land being managed within its capability.

The Blue Mountains City Council Environment Levy provides funding to spend specifically on additional environmental protection and natural resource management projects within the Blue Mountains local government area. The **Rural Practice Improvements Project** was funded from the Environmental Levy. The environmental objectives of this project are to improve weed and feral animal control in rural lands, adopt best practice pasture management strategies and protect significant remnant native vegetation communities in rural areas.

Special Areas

Strict access control is enforced over the Special Areas to protect water quality and ecology. Using these measures together with regular catchment patrols, the SCA has issued penalties for a number of offences, notices and warning letters under the *Sydney Water Catchment Management Regulation 2001* since 2002 (Table 5.5). There has been a decline in the formal regulatory action by the SCA over the period, due to an increase in educational activities related to access to the Catchment, an increase in signage, and construction of barriers. During the 2007 Audit period, SCA spent $180,000 to maintain and install new gates, barriers and warning signs to prevent illegal access in the Special Areas.

Table 5.5: Offences, notices and warning letters issued under the Sydney Water Catchment Management (Environment Protection) Regulation 2001 (2002-03 to 2006-07)

Type	2002-03	2003-04	2004-05	2005-06	2006-07
Clean up notices	5	8	19	17	6
Notices (s192) requiring Information / documents	2	4	2	1	2
Penalty infringement notices	10	7	7	8	1
Pollution prevention notices	1	-	-	-	3
Littering reports referred to DECC	28	190	154	45	12

Source: SCA 2007

The **Compliance Strategy** under the SCA's **Healthy Catchment Program** also aims to protect water quality in the catchment by regulating activities under the POEO Act. The SCA also contributed $35,000 to the Greater Southern Regional Illegal Dumping Squad to tackle illegal dumping in the Wingecarribee, Shoalhaven and Eurobodalla local government areas.

In accordance with Special Areas Joint Management Agreement and the Services Contract between the SCA and DECC, an **Annual Land Management Program** of land management activities within Special Areas (National Parks), which was jointly developed by DECC and the SCA to meet requirements of the **Special Areas Strategic Plan of Management (SASPoM).** The Annual Land Management Program encompasses the delivery of services within identified subprogram areas of the land management program. The subprograms included are pests; weeds; fire management; asset maintenance; cultural heritage; and ecosystem management.

The **Catchment Remote Area Fire Fighting Team (CRAFT)** program involves the engagement by DECC of experienced, dedicated fire fighters to provide an immediate and effective first response during the outbreak of a bushfire within, and threatening, all Special Areas during each annual fire season. The CRAFT funding assists with fire suppression activities, the deployment of the CRAFT helicopter to active fires and the employment of CRAFT staff for hazard reduction work, trail maintenance and upgrades. The approximate cost of this program is $1.5 million per annum.

Programs for high risk industries

Sites licensed under the POEO Act

DECC regulates major point sources using licences issued under the POEO Act. The licences include requirements for pollution control, monitoring and reporting. DECC negotiates **Pollution Reduction Programs (PRPs)** with licensees to address environmental issues and risks, and imposes the programs as formal licence requirements. Selected PRPs in force during the 2007 Audit period are summarised in Table 5.6.

Table 5.6: Pollution reduction programs for mines, quarries and miscellaneous activities licensed under the POEO Act for the 2007 Audit period.

Licensed Activities	PRP	Description
Goulburn Wool Scour	PRP2	Cease effluent irrigation and implement evaporation technology (completed)
Southern Meats	PRP3	Three stage programme investigation works to ensure effluent irrigation is sustainable
Woodlawn Mine	PRP8	Rectification works – leachate contamination of Stormwater Dam 2

Source: DECC 2007

Derelict mines

The Derelict Mine Committee sets priorities for the **Derelict Mine** program which is aimed at reducing the safety and environmental risks posed by derelict mines. The program is administered by the NSW DPI and overseen by the Derelict Mines Steering Committee. The aims of the program are to:

- manage risks to public health and safety
- stabilise sites
- manage sources of site contamination and address offsite contamination migration
- remove features limiting beneficial reuse of the site and its surroundings
- maintain or increase the biological diversity of species in the vicinity of the site
- conserve items of heritage value
- improve the visual amenity of sites and their surroundings.

Subsidence management

To address the issue of river bed cracking due to mine subsidence any mining activity that may cause subsidence must prepare a **Subsidence Management Plan (SMP)** in line with a new approval process under the *Mining Act 1992*. These plans must account for all possible impacts of potential subsidence to provide adequate protection for the natural and built environments. A SMP Review Committee has been established to review draft subsidence plans, provide advice on conditions of approval, and participate in ongoing monitoring of subsidence management. Alteration of habitat following subsidence due to long-wall mining has been listed under the *Threatened Species Conservation Act 1995* as a threatening process.

An **Independent Inquiry into the NSW southern coalfield** was set up during 2007 to investigate underground coal mining in the southern coalfields. The terms of reference for the inquiry are to:

- undertake a strategic review of the impacts of underground mining on significant natural features including rivers and streams, swamps and cliff lines, with particular emphasis on risks to water flows, water quality and aquatic ecosystems
- provide advice on best practice in regard to:
  - assessment of subsidence impacts
  - avoiding and/or minimising adverse impacts on significant natural features
  - management, monitoring and remediation of subsidence and subsidence-related impacts
- report on the social and economic significance to the region and the State of the coal resources in the Southern Coalfield.

Case Study – Mining under the Woronora sub-catchment

The NSW Southern Coalfield is the group of underground coal mines south and southwest of Sydney, principally located in the Illawarra Region, but extending southwest to Bargo and Berrima under the Catchment. Coal is a valuable resource; a one metre advance of a longwall face can cut coal worth approximately $70,000. The Coalfield is the most important source of coking coal in Australia, supplying both the Port Kembla steelworks and export markets. The coal industry also provides jobs for an estimated 12,500 NSW residents.

Longwall mining is now the predominant method used to extract coal. It is an automated form of underground mining characterised by high recovery and extraction rates using high powered cutting machines and a conveyer system. The mining takes place under movable roof supports that are advanced as the bed is cut. The roof in the mined-out area is allowed to fall (subside) as the mining advances.

Mining-induced subsidence has been associated with ground cracking at the surface, which can distort creek beds and affect surface flow, which disappears underground and may either leave the catchment or emerge further downstream polluted with minerals such as iron and manganese (CRC e-Water, 2006). These processes threaten ecosystems and water quality, and are especially problematic within a drinking water catchment.

The NSW Government now requires longwall miners to seek approval for each new panel extraction and to present a subsidence management plan (SMP) in support of the operation. In December 2006, the Government announced an independent inquiry to investigate underground mining in the Southern Coalfield. A panel of five experts was appointed to conduct the inquiry and hold public hearings. The findings of the inquiry are due for release in early 2008.

Waratah Rivulet

Waratah Rivulet is a major tributary in the catchment of the Woronora Dam, which is the sole water supply storage for Sydney's southern suburbs. The area is a declared 'Special Area' for water supply catchment purposes. Since 2000, longwall panels have been extracted beneath the area by Metropolitan Colliery. This has caused serious stream bed cracking, loss of surface flow and extensive rust-coloured iron discharges at groundwater exit points (CRC e-Water, 2007). The 2007 Audit Team inspected a section of the Rivulet and viewed widespread damage and modification to both the rivulet bed and the flow over it.

A collaborative research project between SCA and Parsons Brinkerhoff Pty Ltd on the 'Impact of longwall mining on subsidence, flow and water quality in the Waratah Rivulet' began in January 2007. This three-year study will assess land subsidence, water flow, water quality, and yield, as well as the interactions between surface waters and groundwater. Monitoring of water quality and surface flow has commenced. Results from both this project and the Independent Inquiry will inform governmental decisions about the future of longwall mining in Sydney's drinking water catchment.

Figure 5.7: Re-emerging water with iron staining
Source: DECC 2007

Figure 5.8: Bed cracking
Source: DECC 2007

Programs to manage soil erosion

The **Catchment Protection Scheme** is a joint project between CMAs and SCA that assists landholders to control severe and moderate erosion and repair severe gully, stream bed and stream bank erosion in the Upper Shoalhaven River and Kangaroo River (priority) sub-catchments. The scheme offers financial support and practical advice on erosion control and stock management. The types of activities supported by the scheme include:

- fencing of sensitive riparian areas
- revegetation of eroded areas with local native species
- stabilisation of creek stock crossings
- installation of off-stream watering points
- construction of stream bank and streambed erosion controls such as V notch log weirs and engineered log jams
- construction of diversion banks and dams (gully control structures)
- construction of flumes and rock chutes.

The SCA has developed a new dataset to identify active gully erosion across the Catchment, this has been field tested and the information will be used to model sedimentation rates across the Catchment. It is also proposed by SCA, that the information will be used to prioritise assessment of sites for the **Riparian Management and Assistance Program**.

The SR CMA's **Brogers Creek Erosion Control Project** involved a demonstration trial of engineered log jams to control large scale stream-bank erosion along a 300 m stretch of Brogers Creek, immediately upstream of the confluence with the Kangaroo River. Prior to these works, stream-bank erosion along this stretch of Brogers Creek was very active, with the bank height averaging about 3 m. SCA provided substantial funding towards this project.

The SR CMA's **Barrengarry Creek Erosion Control Project** site is 2.5 km upstream of the confluence with the Kangaroo River. Prior to the works, about 160 m of stream-bank was actively eroding, with the stream-bank measuring up to 7 m in height. Nine rock groynes and two log sills were constructed along this stretch of Barrengarry Creek during May 2007. These works should protect gazing land and significantly reduce the sediment load in Barrengarry Creek. SCA provided substantial funding towards this project.

The DPI and DEC 2005 factsheet **Improving water Quality in Catchments using compost** is based on field trials in the Bungonia Creek sub-catchment that demonstrated the effectiveness of composted mulch and soil conditioners in controlling sheet erosion and assisting vegetation establishment on degraded sites.

As part of SCA's grants for non-government community groups the Mt Alexandra Reserve Bushcare Group was awarded a grant to carry out erosion control along Nattai Creek.

Programs to manage salinity

The **National Action Plan for Salinity and Water Quality** (NAP) is a commitment by the Australian, state and territory governments to jointly fund actions tackling two major natural resource management issues facing Australia's rural industries, regional communities and our unique environment. The Plan commits $1.4 billion over seven years to June 2008 to support action by communities and land managers in 21 highly affected regions. NAP investment is largely facilitated at a regional level through regional planning. At this level, the NAP is jointly delivered with the Natural Heritage Trust.

The **NSW Salinity Strategy** is designed to achieve the below outcomes and thereby slow down the rate of increase in salinity:

- protect and manage our native vegetation
- use our land so less water goes into the watertable
- use water more effectively and efficiently
- use engineering solutions
- make better use of land affected by salt

- focus our efforts on priority salinity hazard landscapes.

The NSW Salinity Strategy has eight key tools to do this. Setting targets, Market-based solutions, Salinity-related business opportunities, Regulation, Government advice, Information, Scientific Knowledge and Planning Systems.

The **Local Government Salinity Initiative**, part of the NSW Salinity Strategy, is helping local council develop the capacity to manage urban salinity. It provides information, training and technical support for the development and implementation of salinity management strategies and land-use planning instruments. As part of the Local Government Salinity Initiative a Urban Salinity Planning Guide was developed. The **Land Use Planning and Urban Salinity guide** presents an overview of the way land-use planning can play an important role at council level in preventing and managing urban salinity.

DECC and CMAs are carrying out **Salinity Investigations in High Risk subcatchments.** The project aims to identify recharge areas through groundwater flow systems and salinity outbreaks in high risk sub-catchments such as the Mulwaree River (priority) sub-catchment.

The Salinity Research and Development Coordinating Committee has prepared a **Strategic Framework for Salinity Research and Development in NSW**. The framework identifies the key knowledge questions that need to be answered for effective salinity management in NSW and criteria that could be used to evaluate the potential for research proposals to answer those research questions. The framework seeks to inform research and development providers, purchasers and advisers such as CMAs, research and development corporations, universities, government agencies, and industry organisations.

Gaps in the response

There are a number of programs to reduce land degradation from different land uses. The gazettal of the REP 1 will lead to the much needed RAPs and SLWCAs which will provide direction for on-ground actions to reduce land degradation and rehabilitation areas of land that are already degraded in the Catchment.

The Independent Inquiry into the NSW Southern Coalfield and the results of research should better inform future management decisions on coal mining in the Catchment.

Active on-ground response programs need to be further developed and implemented in high risk salinity areas in the Catchment and in locations subject to actual salinity.

Chapter 6
Ecosystem Health

Key Points

	Indicator	Status of Indicator
6.1	Ecosystem water quality	The percentage of locations where water quality parameters exceeded ANZECC guideline values for aquatic ecosystem protection was higher in the 2007 Audit period than in the 2005 Audit period, for 7 out of the 12 parameters tested. The number of locations exceeding ANZECC water quality guidelines has increased for physical and toxicant parameters, and remained high for nutrient parameters compared to the 2005 Audit period.
6.2	Macroinvertebrates	There are fewer sampled locations with 'similar to reference' ratings compared to the 2005 Audit period. Macroinvertebrate assemblages at 39 per cent of the sampled locations in the Catchment were found to be 'significantly impaired' and 2 per cent of all sampled locations had a 'severely impaired' rating.
6.3	Fish	The invasion of introduced fish species is problematic throughout the Catchment and may indicate a moderate level of disturbance to native species, flows or riparian vegetation structure. The Wollondilly, Mulwaree and Jenolan Rivers may be in a disturbed condition.
6.4	Riparian vegetation	Riparian zones outside the Special Areas are likely to be under variable pressure due to little to no standing vegetation cover, stock access, and the presence of exotic species.
6.5	Native vegetation	Native vegetation covers approximately 50 per cent of the Catchment. Approved land clearances remained low during the 2007 Audit period.

Healthy and intact natural ecosystems play a crucial role in maintaining water quality as they provide processes that help purify water, and mitigate the effects of drought and flood. An overall picture of the ecological health of a catchment can be achieved using tools such as water quality assessment, habitat descriptions, biological monitoring and flow characterisation (Qld DNRM, 2001). Ecosystem health assessment has become more ecologically based in recent years with biological measures such as ecosystem structure and species diversity having been added to traditional physico-chemical water quality analysis to provide a more comprehensive picture of the condition of catchment health (Qld DNRM, 2001). This audit examines:

- traditional ecosystem water quality parameters
- aquatic communities, namely macroinvertebrate and fish communities
- terrestrial ecosystems of riparian and native vegetation communities.

Pressures in the Catchment

Sydney's drinking water supply is managed using a multiple barrier approach to control risks to water quality, including catchment management, storage management, delivery system management and treatment systems (SCA, 2005b). Natural systems in the Catchment and around storages contribute to this multiple barrier approach by reducing risks to water quality.

Many water supply authorities have tried to secure ecosystem processes by closing off, or in some way protecting, the hydrological catchments of their storages. The SCA has taken a similar approach through the Special Areas which comprise 370,000 hectares, or about a quarter of the total Catchment area. Special Areas are tracts of largely native vegetation in good condition around water storages and lands containing the SCA's canals and pipelines. The Special Areas are particularly important as part of the multiple barrier approach to protecting water quality. They act as a buffer against nutrients and other pollutants for ecosystems that in reasonably good condition and are near storages and bulk water off-take points. These barriers appear effective under low and moderate flow conditions when water can take several years to travel between the outer catchment and the dam wall. However, under periods of high flow, the barrier effect of the storage breaks down and the capacity of the ecosystem in the remainder of the Catchment becomes critically important. This capacity is strongly dependent on the integrity and health of the ecosystems across the entire Catchment. Pressures on ecosystem health therefore need to be managed across the entire Catchment.

Ecosystem health is affected by a number of natural and human induced pressures. Natural pressure on ecosystem health and condition include fire, flood and drought. The primary human induced pressures on ecosystem health in the Catchment are water demand and management (Chapter 4), land-use change and land management (Chapter 5). These human-induced pressures can directly disturb or destroy ecosystems, as well as indirectly affect ecosystem processes through impacts on water quality, flow regimes, and biodiversity.

Aquatic ecosystem health is a function of many factors including water quality, community structure and diversity (for example, macroinvertebrates and fish), and the extent and condition of riparian and native vegetation in the Catchment. All these factors contribute to the ability of aquatic ecosystems to support and maintain a balanced, integrated and adaptive biological system (CRCFE, 2002).

Chemical, nutrient and cold water pollution are some of the possible threats to aquatic ecosystems caused by human practices and land uses. Clearing of native vegetation and riparian zones can also affect land condition, biodiversity and runoff volumes which ultimately impact upon water quality and aquatic ecosystem processes. Riparian vegetation is particularly crucial for water quality and aquatic ecosystem processes, and also provides habitat for terrestrial fauna. Managing native vegetation clearing, particularly in riparian areas, is therefore important to maintaining ecosystem health.

The presence of exotic fauna is also a pressure on ecosystem health in the Catchment, with exotic species causing physical damage to soil and vegetation, and preying on native species and disrupting natural ecosystem processes. Exotic plant species can also affect ecological processes in vegetation communities.

State of the Catchment

6.1 Ecosystem water quality

Background

Healthy ecosystems generate and maintain good water quality. This audit examines 12 water quality parameters that signal whether the pressures in the Catchment are impacting on water quality required to maintain aquatic ecosystems. These parameters are assessed against the guideline values for ecosystem health in the Australian and New Zealand Environmental Conservation Council (ANZECC) and Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) guidelines (2000) (the ANZECC guidelines).

The ANZECC guidelines are split into ecosystem types. The ecosystem types present in the Catchment are upland rivers (>150m altitude) and lakes and reservoirs. Each sampled site in the Catchment is split into either an upland river or lake and reservoir site and assessed against that guideline (Table 6 and 7 in Appendix C). The ANZECC approach also allows for the use of alternative guideline values where locally available data suggest that is appropriate. The Auditor has applied an alternative value for turbidity based on historical data collected in the Catchment by the EPA (now part of DECC). The guideline value for total aluminium was based on trigger values applied to slightly – moderately disturbed systems, and the guideline value for total Iron was based on the Canadian guideline level, as insufficient data for Australia is available (ANZECC & ARMCANZ 2000). The advantages of using the ANZECC guidelines and its associated approach are that it provides a quick methodology that identifies areas for further investigation. There are, however, limitations in that the ANZECC numbers are trigger values that suggest investigation of exceedences are necessary and not that exceedences mean that an ecosystem is unhealthy.

Changes in ecosystem health over previous Audit periods are also assessed. The auditor used the same classifications as the 2003 and 2005 Audits to provide a visual representation of ecosystem water quality across the Catchment during the 2007 Audit period (Map 6.1). In the Audit classification system, the 12 parameters were combined into the following four groups:

- Physical – Turbidity (NTU), pH and Conductivity (µS/cm)
- Toxicants – Total Aluminium (Al) (mg/L) and Total Iron (Fe) (mg/L)
- Nutrients – Total nitrogen (µg/L), Total phosphorus (µg/L), Oxidised nitrogen (µg/L), Ammonia (µg/L) and Filtered phosphorus (µg/L)
- Chlorophyll- a (µg/L) and Dissolved Oxygen (%).

The parameter with the highest level of exceedence within a group then determined the rating for that group. The group ratings are:

- ‘very Poor’ when one or more parameters exceeded the guidelines in more than 75 per cent of samples
- ‘poor’ when one or more parameters exceeded the guidelines in 50 – 75 per cent of samples
- ‘fair’ when one or more parameters exceeded the guidelines in 25 – 50 per cent of samples
- ‘good’ when less than 25 per cent of samples for all parameters exceeded the guidelines.

Findings

Individual parameters

The percentage of sites with water quality samples that exceeded ANZECC guidelines increased for seven out of the 12 parameters during the 2007 Audit period (Figure 6.1).

The greatest increases were for Total Aluminium and Total Iron, which increased from 50 and 26 per cent of sites exceeding ANZECC guidelines for these parameters, to 78 and 71 per cent of sites respectively. During the 2005 Audit period these two parameters showed the largest decreases.

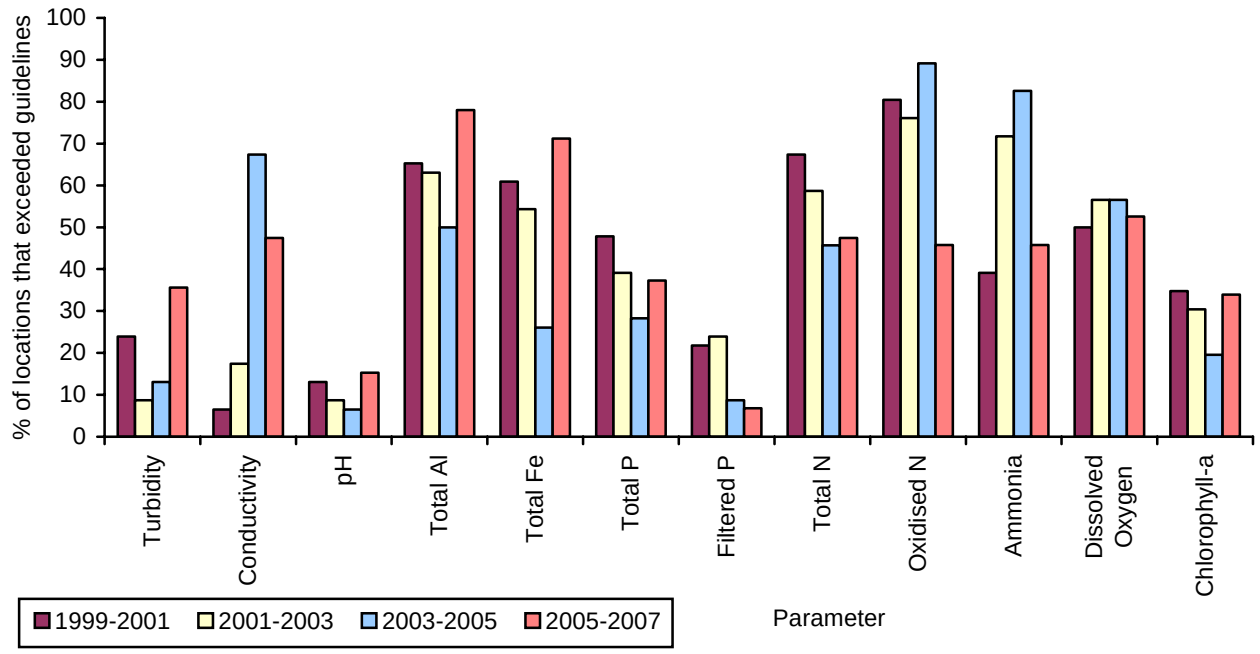
Other parameters for which ANZECC guidelines were exceeded at a greater percentage of sites during the 2007 Audit period include Turbidity, pH, Total Phosphorus, Total Nitrogen, and Chlorophyll-a (Figure 6.1).

There was a decrease in the percentage of sites with water quality samples exceeding ANZECC guidelines for five of the 12 parameters during the 2007 Audit period (Figure 6.1).

The largest decreases were for Oxidised Nitrogen, Ammonia and Conductivity. The percentage of sites where water quality samples exceeded ANZECC guidelines for Oxidised Nitrogen almost halved, from 89 per cent of locations during the 2005 Audit period, to 46 per cent in the 2007 Audit period. The percentage of sites exceeding ANZECC guidelines for Ammonia dropped from 83 per cent in the 2005 Audit period, to 46 per cent in the 2007 Audit period. Exceedences of ANZECC guidelines for Conductivity decreased during the 2007 Audit period, however, this parameter showed the largest increase between the 2003 and 2005 Audit periods.

There was also a decrease in exceedences of Filtered Phosphorus and Dissolved Oxygen guidelines. Exceedences at individual sites can be seen in Table 6 and 7 in Appendix C.

Figure 6.1: Percentage of locations that exceeded the ANZECC and ARMCANZ 2000 guidelines for ecosystem health for the 2001, 2003, 2005 and 2007 Audit periods



Source: SCA 2007

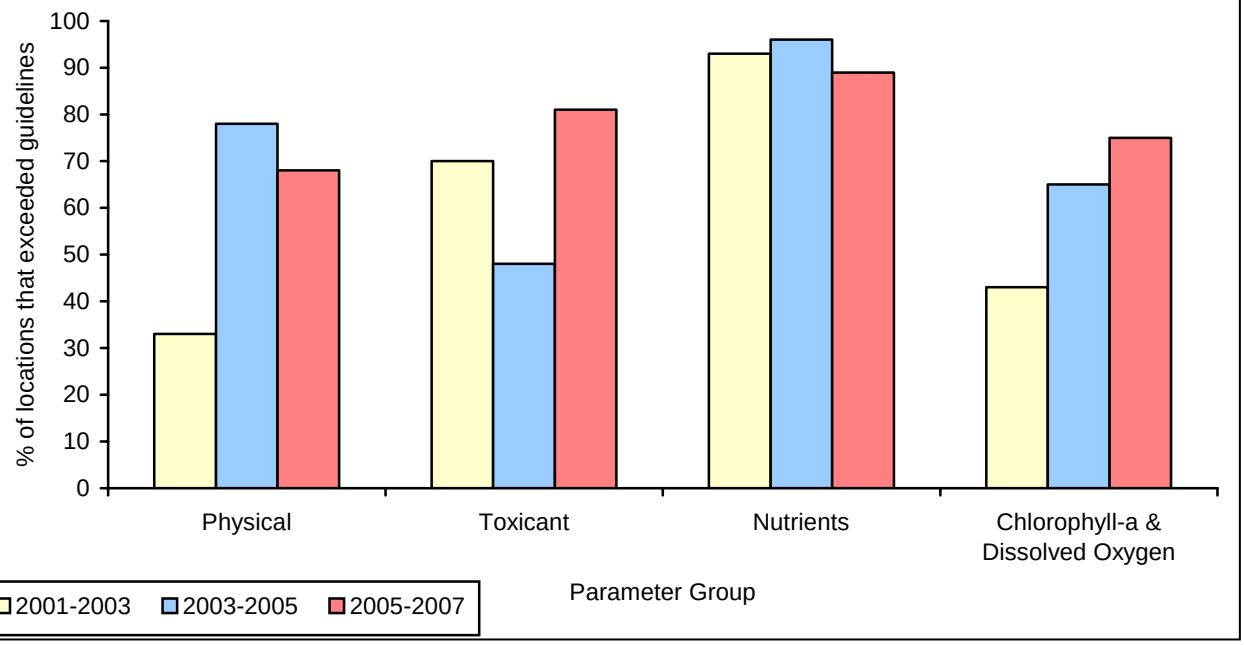
Parameter groups

Guideline exceedences for toxicant and chlorophyll and dissolved oxygen parameter groups increased during the 2007 Audit period (Figure 6.2). The percentage of sites exceeding chlorophyll and dissolved oxygen guidelines has steadily increased since the 2003 Audit period, from 43 to 75 per cent. Toxicant guideline exceedences showed a large increase in the 2007 Audit period, to 81 per cent of sites, despite having decreased from 70 to 48 per cent during the 2005 Audit period (Figure 6.2).

Exceedences of Physical and Nutrient parameter guidelines decreased during the 2007 Audit period (Figure 6.2). Nutrient exceedences have nevertheless remained high, occurring at 89 per cent of sites (Figure 6.2). Seventy-five per cent of sites exceeded Physical parameter guidelines during the 2007 Audit period.

During the 2003 and 2005 Audit periods, it was noted that the majority of the exceedences of water quality guidelines related to the Nutrient parameter group. The majority of exceedences during the 2007 Audit period were still for Nutrients; however the difference between the groups has slightly decreased from the 2005 Audit period. All four parameter groups now have guideline exceedences at more than 60 per cent of sites (Figure 6.2). Trends at individual sites are presented in Table 8 Appendix C.

Figure 6.2: Percentage of locations that exceeded the ANZECC and ARMCANZ 2000 guidelines for ecosystem health parameter groups for the 2001, 2003, 2005 and 2007 Audit periods



Source: SCA 2007

Individual sites

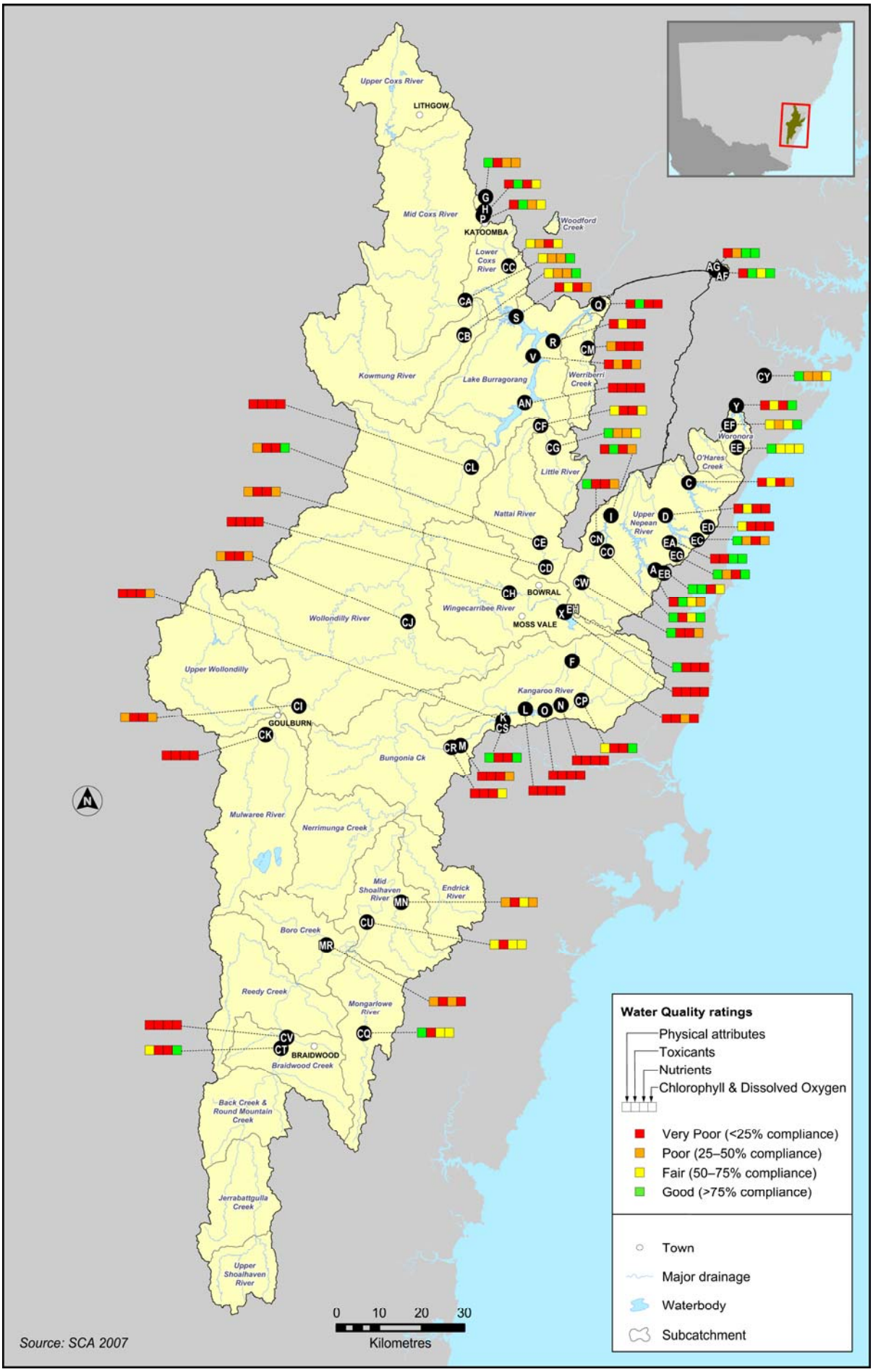
Nine out of 56 sites received 'very poor' water quality ratings for all four parameter groups in the 2007 Audit period. These sites were the Wingecarribee River (CH*), Gillamatong Creek at Braidwood (CV*), Lake Yarrunga in the Kangaroo River (priority) sub-catchment (L*, N* & O*), Wollondilly River (CL*), Lake Burragorang (AN*), Wingecarribee Lake (X*) and the Mulwaree River (CK*). During the 2005 Audit period, only a single site at Lake Yarrunga (L*) rated 'very poor' across all four groups.

There were no sites with 'good' ratings (less than 25% of samples with exceedences) for all four, or even three of the four parameter groups. Seven sites received 'good' ratings for two groups. These were Sandy Creek Inflow (EA*), Burke River at inflow to Lake Nepean (CO*), Flying Fox Creek No.3 (EB*) and Cordeaux River (EG*) in the Upper Nepean River sub-catchment, the Shoalhaven River downstream of Tallowa Dam (CS*) in the Kangaroo River (priority) sub-catchment, and Lake Prospect (AF* & AG*) (Map 6.1).

Waratah Rivulet (EE*) in the Woronora River sub-catchment was the only site that did not receive any 'poor' or 'very poor' ratings during the 2007 Audit period. It had one 'good' rating and three 'fair' ratings. In the 2005 Audit period, there were four sites with no 'poor' or 'very poor' ratings.

Five sites had one or two 'poor' ratings but no 'very poor' ratings. These included the Coxs River at Kelpie Point (CA*), Kowmung River at Cedar Ford (CB*), Little River at Fireroad (CG*), and two sites on the Woronora River (EF* & CY*) (Map 6.1).

* See Map 6.1 for locations of sampling sites and Table 10 in Appendix C for explanation of codes.



Map 6.1: Water quality monitoring sites showing the 4 parameter groups and percentage compliance in the Sydney drinking water catchment

Implication

During the 2007 Audit period, nearly 60 per cent of the water quality parameters exceeded ANZECC guideline values at over 40 per cent of locations, compared to 50 per cent of the water quality parameters at over 40 per cent of locations in the 2005 Audit period (Figure 6.1).

Since the 2005 Audit period, the percentage of locations in exceedence of Nutrient parameters has decreased only slightly from very high levels, and the number of locations at which Physical parameters were exceeded has also decreased. Exceedence of Chlorophyll-a and Dissolved Oxygen guidelines have increased, and exceedences for Toxicant parameters have dramatically increased, despite decreasing in the 2005 Audit period.

Oxidised nitrogen exceeded guidelines in 76–98 per cent of locations between 1999 and 2005. During the 2007 Audit period it decreased to 46 per cent. The number of locations at which ammonia levels exceeded guidelines has continually increased from 39 per cent between 1999 and 2001, to 83 per cent of locations during the 2005 Audit period. During the 2007 Audit period, however, it decreased to 46 per cent.

While an appropriate concentration of salts (measured by conductivity) is vital for aquatic plants and animals, salinity beyond the normal range can cause stress or death of aquatic organisms. Highly saline conditions can also affect the availability of nutrients to plant roots, and therefore disturb aquatic plant growth and aquatic ecosystems. During the 2007 Audit period, Streamwatch data from the Coxs River (priority) sub-catchments showed very high conductivity levels (> 1000 µS/cm) in Kangaroo Creek, Sawyer's Swamp Creek, Springvale Creek, Huon Creek, Neubeck's Creek, Coxs River, Pipers Flat Creek and Lamberts Gully Creek. Adverse in-stream biological effects are expected if salinity increases to 1500 µS/cm whereas much lower values around 800 µS/cm may make the water unsuitable for certain agricultural purposes (ANZECC & ARMCANZ, 2000).

The continued exceedence of dissolved oxygen guideline values in more than 50 per cent of locations from the 2003, 2005 and the 2007 Audit may be having a direct impact on aquatic biota. In addition, low dissolved oxygen levels can also cause changes in redox conditions, aiding the release of nutrients and metals from sediments into water.

The increase in turbidity and continued exceedence of dissolved oxygen guideline values may influence the concentration of iron and aluminium and therefore the Toxicant parameter group. There was also an increase in the number of locations exceeding the turbidity guideline. Metals may be adsorbed onto suspended solids (measured by turbidity) and be transported into waterways. The increases in the concentration of iron and aluminium may also indicate a greater influence of groundwater intrusions dominating low flows.

The SCA's water quality monitoring program is largely in the north-east region of the Catchment. There were 10 new sites in the 2007 Audit period. However, none of these new sites were in a sub-catchment that had no monitoring sites in previous Audit periods. There are several sub-catchments with few or no monitoring sites where water quality could be expected to be under stress. A number of the priority sub-catchments have only one or two water quality monitoring sites, and the priority sub-catchments of the Upper Wollondilly River and Upper Coxs River have no water quality monitoring sites. The current SCA water quality monitoring program does not give a comprehensive picture of water quality throughout the Catchment. The Streamwatch data from the Coxs River sub-catchments reinforces the need for more water quality monitoring sites.

Declining water quality is of concern and the Auditor recommends that SCA investigate the causes for this decline. The Auditor believes that this may not be simply related to drought conditions experienced during the 2007 Audit period, since similar conditions prevailed during the 2005 Audit period. It is important to understand the drivers of decreasing water quality. See Recommendation 7.

6.2 Macroinvertebrates

Background

'River health' is a concept that goes beyond suitability of water for particular uses and integrates a range of ecosystem values and functions. Macroinvertebrate assemblages integrate many aspects of the 'health' of streams and rivers, complementing the more traditional assessments of water quality.

Macroinvertebrates are typically visible with the naked eye and exist in a variety of habitats in streams, lakes and wetlands. Of all biological communities used to assess health, macroinvertebrate assemblages are most widely used, as they are abundant and diverse, sensitive to changes in water quality, flow regime and habitat conditions and they allow detection of impacts some time after the impact has occurred (Qld DNRM, 2001). Additionally, there is reasonably good taxonomic knowledge of freshwater macroinvertebrates, and they are relatively easy to collect.

The AusRivAS system is widely practised and supported for use in environmental audits by independent studies (SCA, 1999) and national water monitoring programs. The AusRivAS sampling protocols were developed as part of the National River Health Program's Australia-wide Assessment of River Health. Since 1994, more than 1500 reference sites across Australia have been sampled to build predictive models to interpret field sampling results. The AusRivAS system generates river health assessments by predicting the macroinvertebrates that would be present (expected) and compares this with the macroinvertebrates collected (observed) to create an index of health. The lower the observed/expected value, the more impaired the macroinvertebrate assemblage. The SCA is required by its Operating Licence to report annually on macroinvertebrate assemblages in Catchment waterways. The macroinvertebrate sampling is carried out in Spring, therefore the Spring 2007 AusRivAS data was unavailable for this audit.

This audit presents the 2001 to 2006 Spring AusRivAS scores at 73 sampling locations. Additional data was provided by the Sustainable Rivers Audit (SRA). The SRA is an audit of the health of the rivers within NSW, which uses the AusRivAS sampling method for its macroinvertebrate indicator. Thus the SRA data from sites in the Catchment was able to be combined with the data provided by the SCA.

The SCA macroinvertebrate monitoring program uses two core sites and one roaming site in each sub-catchment, to allow both trend analysis at fixed sites over time and a wider area of the Catchment to be monitored through the roaming sites. Hence the status of macroinvertebrate assemblages in the Catchment is discussed here in two sections. First, the trends over the years between 2001 and 2007 at the core sampling sites are described, and then a snapshot of each sub-catchment in the 2007 Audit period is presented, using the data from both the core and the roaming sites, as well as from the DECC SRA program.

Findings

Core sites – trends over time

During Spring 2006, the macroinvertebrate assemblages at 39 per cent of the sampled locations in the Catchment were significantly impaired, and 2 per cent of all sampled locations had severely impaired ratings. Thus over 40 per cent of sites in the Catchment had impaired macroinvertebrate assemblages (Map 6.2). Overall, between the 2001 Spring sampling and the 2006 Spring sampling:

- locations richer than reference decreased slightly, from 10 per cent in 2001 to 6 per cent in 2006
- locations with a similar to reference rating decreased, from 63 per cent in 2001, to 53 per cent in 2006
- locations with a significantly impaired rating have increased, from 23 per cent in 2001, to 39 per cent in 2006
- severely impaired locations have decreased slightly from 5 per cent in 2001, to 2 per cent in 2006.

Mulwaree River at the Towers $^{(MI*)}$ received an AusRivAS health rating of severely impaired during Spring 2006. It also received a severely impaired rating in Spring 2002, however the site had improved to reference condition in 2003, but has since deteriorated.

Woronora River at the Needles $^{(MT*)}$ was rated as severely impaired in Spring 2004 and 2005, but had improved slightly to significantly impaired in Spring 2006.

The Upper Tarlo River at Tarlo (MB*) also had a severely impaired rating in Spring 2004, but improved slightly to receive a significantly impaired rating in 2005 and 2006.

Werriberri Creek at the Oaks (OE*) had a significantly impaired macroinvertebrate assemblage in 2004, which subsequently improved to significantly impaired in 2005, and then to reference condition in Spring 2006 (Map 6.2).

Jacqua Creek at Lumley Rd (NZ*) received an AusRivAS health rating of severely impaired during Spring 2003. It improved to significantly impaired in Spring 2004, to reference condition in Spring 2005, then worsened to significantly impaired again in Spring 2006 (Map 6.2).

The Wingecarribee River at Berrima (ON*) received a severely impaired rating in 2001, and has received significantly impaired ratings in every year since.

Yosemite Creek upstream of Minnihaha Falls (NS*) received a severely impaired rating in 2002, but has moved back and forth between reference condition and significantly impaired ratings since. In 2006 it was significantly impaired (Map 6.2).

Kedumba River at Scenic Railway (NT*) received two severely impaired ratings in 2001 and 2002, but has not been sampled since. Thus no inferences can be drawn about the current state of the macroinvertebrate community in the Kedumba River, or whether it has improved or worsened in the intervening period.

Overall, eight sites have received consistently poor ratings (no more than a single rating at similar or greater than reference condition) across the 2001-2006 sampling periods. These were Gillamatong Creek at Braidwood (MS*), Bungonia Creek at Bungonia (OT*), Tonalli River upstream of Basin Creek (MU*), Blue Gum Creek along fire trail W41 (MW*), Mulwaree River at the Towers (MI*), Wingecarribee River at Berrima (ON*), Upper Tarlo River at Tarlo (MB*), and Woronora River at the Needles (MT*) (Map 6.2).

Twelve sites have received a consistently good (similar to or richer than reference) AusRivAS health rating across the 2001-2006 sampling periods. These include Shoalhaven River at Farringdon Crossing (NG*), Titringo Creek at High Forest (OU*), Boggy Creek upstream of Shoalhaven River (NA*), Kangaroo River at Hampton Bridge (ML*), Mongarlowe River at Monga (OI*), Shoalhaven River at Yarra Glen (MY*), Kowmung River at Cedar Ford (MD*), Little River at Fire Trail W41 (MX*), Kedumba River at Kedumba Crossing (ME*), Coxs River at Kelpie Point (MC*), Nattai River at the Crags (MF*), and Coxs River at Lidsdale (OV*) (Map 6.2).

Richer than reference ratings between Spring 2001 and Spring 2004 were recorded at Jerrabuttgulla Creek at Warragandra (NB*), Corang River at Meangora (MN*), Mongarlowe River at Monga (OI*), Shoalhaven River at Yarra Glen (MY*), Kowmung River at Kowmung fire trail (NE*), Coxs River at Kelpie Point (MC*) and Wollondilly River at Goonagulla (NK*) (Map 6.2). Kowmung River at Kowmung fire trail (NE*) was the only site which retained its richer than reference rating (from Spring 2004) through to Spring 2006.

In Spring 2005 and 2006, new richer than reference ratings were recorded at Nepean River at Maguires Crossing (NJ*), Kangaroo River at Hampton Bridge (ML*), Currumbene Creek at Krawaree Road Crossing (OL*), and Waratah Rivulet at Flatrock Crossing (OJ**) (Map 6.2).

A number of locations with a health rating of significantly and severely impaired macroinvertebrate assemblages in Spring 2007 also exceeded ANZECC (2000) guidelines in 3 or 4 groups of physico-chemical water quality (Maps 6.1 and 6.2). These locations include Woronora River at the Needles (CY-MT), Shoalhaven River at Fossickers Flat (CR-MP), Nattai River at Smallwood's Crossing (CF-MG), and Gillamatong Creek at Braidwood (CV-MS) (Maps 6.1 and 6.2).

Woronora River at the Needles has declined in AusRivAS health, from similar to reference in 2003, to significantly or severely impaired between 2004 to 2006. It has also declined in water quality compared to the 2005 Audit period for 3 out of 4 water quality parameter groups.

Shoalhaven River at Fossicker's Flat has similarly declined in AusRivAS health ratings, from similar to reference condition in 2004, to significantly impaired in both 2005 and 2006. The site has also experienced a concurrent decrease in water quality in 3 out of 4 water quality parameter groups since the 2005 Audit period (Maps 6.1 and 6.2).

* See Map 6.2 for macroinvertebrate sampling locations and Table 10 in Appendix C for explanation of codes.

The Nattai River at Smallwood's Crossing has maintained its high exceedences of water quality guidelines across all four parameters, and has declined in AusRivAS health ratings from similar to reference condition in 2004, to significantly impaired in both 2005 and 2006 (Maps 6.1 and 6.2).

Gillamatong Creek at Braidwood has remained in a similar state to the 2005 Audit period, with both high percentages of exceedences in water quality guidelines, and a continued AusRivAS health rating of significantly impaired (Maps 6.1 and 6.2).

Core and roaming sites – current state of the catchment within the 2007 Audit period

During the 2007 Audit period, four sub-catchments had good AusRivAS health ratings (all ratings either similar to or richer than reference condition) at both of their core sites, as well as at their roaming sites. These were Back and Round Mountain Creeks, Jerrabattagulla Creek, Upper Nepean River and Upper Shoalhaven River sub-catchments (Table 9 in Appendix C).

Four sub-catchments rated poorly across their core and roaming sites (with no more than a single similar to reference condition rating) during the 2007 Audit period. These were Boro Creek, Braidwood Creek, Lake Burragorang and Little River sub-catchments (Table 9 in Appendix C).

Twelve out of the 28 sub-catchments received at least one severely impaired AusRivAS health rating during the 2007 Audit period. Sub-catchments with a single severely impaired rating included Boro Creek, Braidwood Creek, Bungonia Creek, Endrick River, Mulwaree River (priority), Nerrimunga River, Upper Wollondilly River (priority), Werriberri Creek (priority), Wingecarribee River (priority), Wollondilly River (priority) and Woronora River sub-catchments. The Lower Coxs River (priority) sub-catchment received two severely impaired ratings in the 2007 Audit period, these were at two roaming sites, Jamison Creek at Dalrymple Ave $^{(PM*)}$, and Spring Creek at Kedumba Valley Road $^{(PN*)}$ (Table 9 in Appendix C).

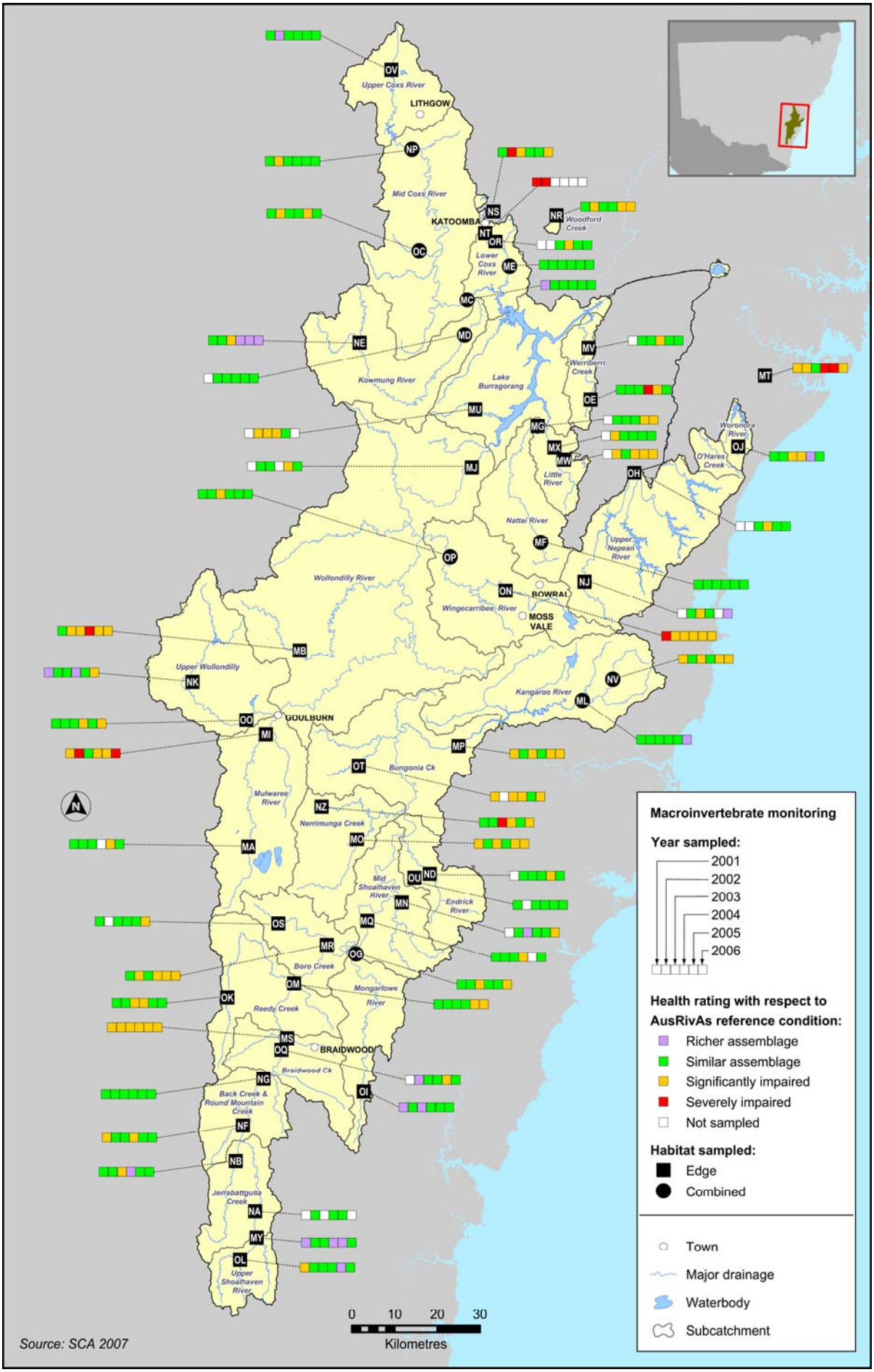
In the Woronora River and Mulwaree River (priority) sub-catchments, the severely impaired ratings occurred at core sites. In the other 11 sub-catchments which received severely impaired AusRivAS health ratings in the 2007 Audit period, those ratings occurred at roaming sites. This reinforces the importance of the use of roaming sites, as they provide a more complete assessment of the health of macroinvertebrate communities across the whole sub-catchment. Without these roaming sites these sub-catchments may have appeared to be in better health than they perhaps are.

Implication

In Spring 2006, the macroinvertebrate assemblages at 39 per cent of the sampled locations were either significantly or severely impaired, and 2 per cent of sites were severely impaired. In Spring 2004 these figures were 33 per cent and 6 per cent respectively. Whilst it may appear that in the short term there has been relatively little change, over the longer term the general trend is that the AusRivAS macroinvertebrate health ratings have declined since 2001. In Spring 2001, only 23 per cent of sites had severely impaired macroinvertebrate assemblages, whilst 5 per cent had significantly impaired assemblages. While this suggests overall diminishing health, it is unclear whether this is due to deteriorating water quality or drought conditions.

Sites with a richer than reference rating can occur because of either a naturally high biodiversity, or an impact such as mild nutrient enrichment (Barmuta *et al.* 2002). Thirteen sub-catchments had at least one 'richer than reference' rating between Spring 2001 and Spring 2007. All 'richer than reference' locations from the Spring 2004 sampling were adjacent or close to pasture land (see Map 5.1 for land use), although there is no water quality monitoring at these locations to assist with the interpretation. Follow up macroinvertebrate monitoring should be considered at all these locations to determine whether the AusRivAS health rating results from natural processes or human induced impacts.

The spatial coverage of macroinvertebrate monitoring across the Catchment is generally better than for the water quality monitoring assessed in Section 6.1, as more sub-catchments are monitored. The data reflected the wide range of states of macroinvertebrate assemblages across sub-catchments. The inclusion of annual roaming sampling sites allows a wider area of each sub-catchment to be monitored over time. However, it can also result in locations where impacts on macroinvertebrate are detected on one sampling year not being monitored in subsequent years. It is suggested that the causes of the decrease in stream health as measured by macroinvertebrates be investigated and that follow-up sampling at sites with high macroinvertebrate impairment ratings be done to aid in longer term analysis (see Recommendation 7). This will provide greater confidence in management responses to macroinvertebrate health ratings.



Map 6.2: Macroinvertebrate AusRivAS health rating for Spring 2001 to Spring 2006 in the Sydney drinking water catchment

Only four sub-catchments received similar to or better than reference condition ratings at all sampling sites in the Catchment. Four sub-catchments had mostly significantly or severely impaired ratings at all sites, and almost half of all sub-catchments received at least one severely impaired AusRivAS health rating.

In addition to follow-up macroinvertebrate monitoring, the integration of macroinvertebrate and water quality monitoring in the Catchment would be beneficial to provide capacity for a more comprehensive assessment of Catchment condition integrating across a number of indicators, and interpretation of results (see 2005 Recommendation 3). Such integration may also enable more focused management responses to identified changes in the condition of macroinvertebrate assemblages. See Recommendations 8 and 9.

Recommendation 7: The SCA should investigate the reasons and drivers for declines in both water quality and macroinvertebrate health in those sub-catchments where declines have been documented.

Recommendation 8: The SCA should review its water quality and macroinvertebrate monitoring program to ensure that appropriate integrated ecosystem monitoring is undertaken in all sub-catchments.

Recommendation 9: The SCA should undertake follow-up monitoring at macroinvertebrate monitoring locations that have significantly impaired or severely impaired AusRivAS ratings.

6.3 Fish

Background

The abundance and diversity of many native fish and crustacean species has declined in most regions of Australia since European settlement. The natural range of about one third of native inland-water fish has been significantly reduced. Continued pressures from habitat modification, introduced pests, pollution and harvesting continue to affect native fish species and fish communities. Fish populations in the Catchment are also likely to have been especially impacted by the modification of river flows and physical barriers caused by dams and weirs, the temperature of water released from dams, and competition with exotic fish species.

Dams and weirs modify and disrupt natural flows of rivers and streams by collecting variable flows and then releasing constant or regulated water-flows downstream. The modification of flows can affect a wide range of aquatic organisms, including fish, potentially reducing the species diversity and increasing the success of introduced species (Gehrke and Harris, 2001).

Water released from dams is also often colder than downstream flow, especially if the dam has a bottom valve off-take. Cold water pollution can affect fish growth and survival and can potentially limit the distribution of fish within rivers to warmer areas (NSW Fisheries, 2003).

Dams, weirs, and many types of in-stream works also act as significant barriers to fish passage, reducing the abundance and diversity of fish throughout a river system (CRCFE, 2000). Physical barriers prevent the upstream and downstream passage of migratory fish, and inhibit access of fish to other areas of rivers over shorter distances.

This indicator remains highly relevant as a measure of ecosystem health, as fish interact on many trophic levels and are sensitive to many kinds of human disturbance. Fish are also considered useful for environmental assessments due to their mobility and longevity. The abundance of fish individuals and species can decrease in areas with degraded riparian vegetation and poor water quality (Growns *et al.* 1998).

A significant amount of new data has become available since the 2005 Audit. The DPI has conducted several separate monitoring programs and provided the data to the audit.

This audit examines:

- numbers and proportions of native and exotic fish species present within each sampled water body
- cold water pollution
- barriers to fish migration.

Findings

There are five sets of localised data collected by the DPI Aquatic Ecosystems Unit during the 2007 Audit period. These include:

- Research into the distribution and critical habitat of the threatened Macquarie perch between August 2006 and May 2007, funded by H-N CMA
- A state-wide assessment of the diversity, distribution and abundance of fish in NSW rivers in October 2006
- Assessment of the fish community above and below Pheasants Nest weir in August and September 2006 and March 2007 prior to the proposed raising of the height of the weir
- Assessment of the fish community in the Shoalhaven River catchment prior to the proposed construction of a fishway on Tallowa Dam in November and December 2005
- Research into the distribution of the introduced redfin perch in the Wollondilly Catchment in May and June 2007, funded by H-N CMA.

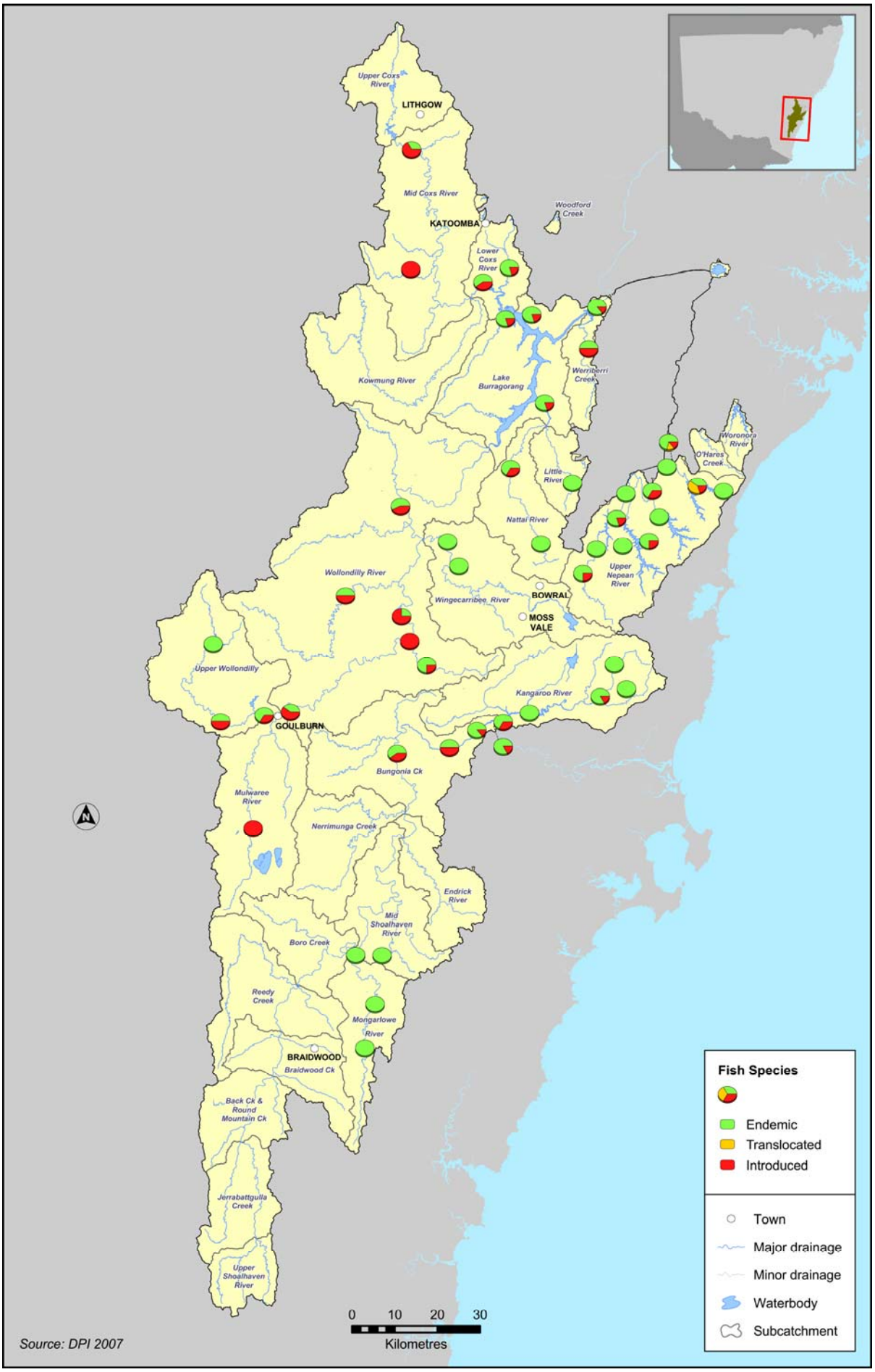
During the 2007 Audit period, 49 sites within 27 water bodies were sampled using a combination of electrofishing and bait trapping sampling techniques (Map 6.3 and Figure 6.3). A total of 6183 fish representing 22 species were captured (Table 6.1). Thirteen species of fish are endemic to the Catchment, two species have been translocated into the area from the Murray-Darling basin and seven species have been introduced from overseas.

Table 6.1: Fish species recorded in the Catchment during the 2007 Audit period.

Family	Scientific name	Common name	Status
Anguillidae	*Anguilla australis*	Shortfinned eel	Endemic
	Anguilla reinhardtii	Longfinned eel	Endemic
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherloach	Introduced
Cyprinidae	*Carassius auratus*	Goldfish	Introduced
	Cyprinus carpio	Common carp	Introduced
Eleotridae	*Gobiomorphus australis*	Striped gudgeon	Endemic
	Gobiomorphus coxii	Cox's gudgeon	Endemic
	Hypseleotris klunzingeri	Western carp gudgeon	Endemic
	Hypseleotris spp.	Unidentified gudgeon	Endemic
	Philypnodon grandiceps	Flathead gudgeon	Endemic
	*Philypnodon macrostomus**	Dwarf flathead gudgeon	Endemic
Galaxiidae	*Galaxias brevipinnis*	Climbing galaxias	Endemic
	Galaxias olidus	Mountain galaxias	Endemic
Percichthyidae	*Maccullochella peelii*	Murray cod	Translocated
	Maccullochella sp.	Unidentified cod	Translocated
	Macquaria australasica	Macquarie perch	Endemic, endangered
	Macquaria novemaculeata	Australian bass	Endemic
Percidae	*Perca fluviatilis*	Redfin perch	Introduced
Plotosidae	*Tandanus tandanus*	Freshwater catfish	Endemic
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia	Introduced
Retropinnidae	*Retropinna semoni*	Australian smelt	Endemic
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	Introduced
	Salmo trutta	Brown trout	Introduced
Terapontidae	*Bidyanus bidyanus*	Silver perch	Translocated

Source: DPI 2007.

Notes: * previously *Philypnodon* sp.1



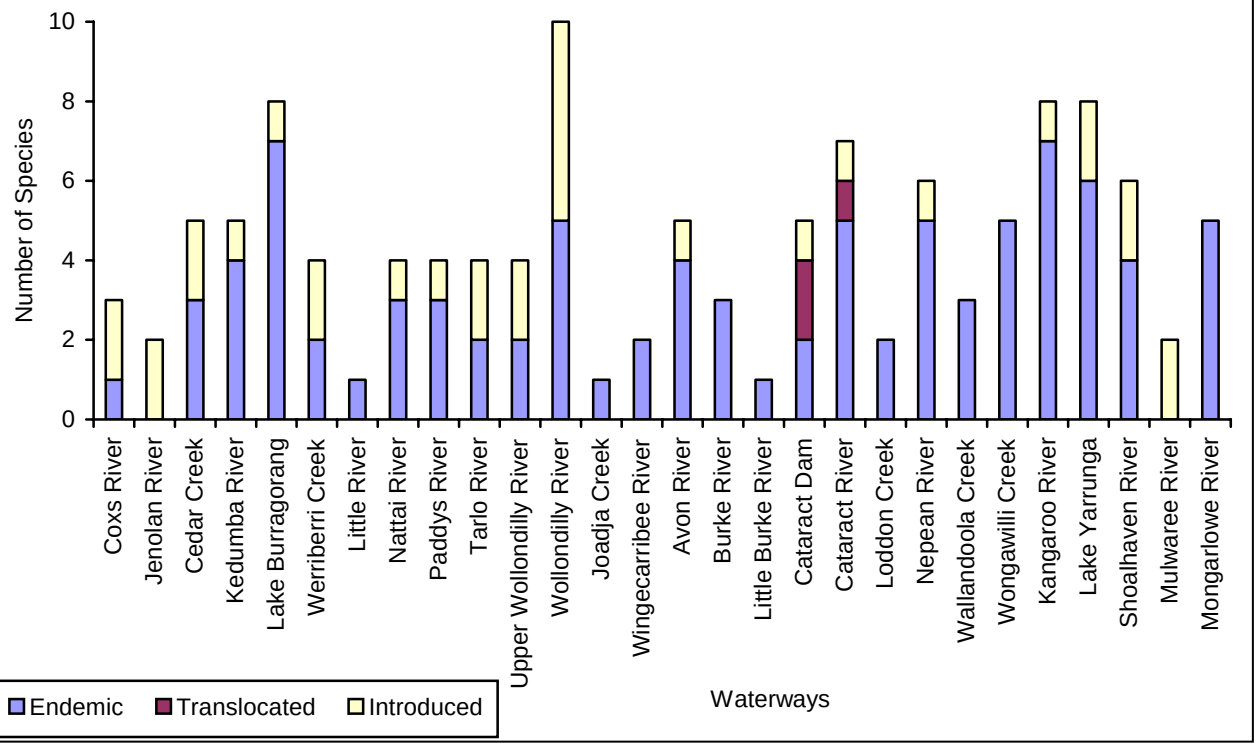
Map 6.3: Endemic, introduced and translocated fish species in the Sydney drinking water catchment

Direct comparisons of these catch data are restricted as they are derived from a number of projects in which sampling effort varied considerably among water bodies. It is noteworthy however, that introduced species were captured in 18 of the 27 water bodies (67 per cent), with the Wollondilly River having the greatest number (five) of these species (Map 6.3 and Figure 6.3). The largest number of introduced species at any other site was only two, suggesting that the Wollondilly River figure is comparatively high. Similarly, in both the Jenolan (Mid Coxs River (priority) sub-catchment) and Mulwaree Rivers, only two species were captured, both of which were introduced (Figure 6.3).

Conversely, a high species diversity and largely endemic species composition is suggestive of a relatively pristine condition. Both Wongawilli Creek (Upper Nepean River sub-catchment) and the Mongarlowe River showed a comparatively high species richness of five species each, and at both sites all species were endemic (Figure 6.3). The Kangaroo River, Lake Burragorang and Lake Yarrunga (Kangaroo River (priority) sub-catchment) all had higher species richness, at eight species each, however these sites also had at least one introduced species (one at Kangaroo River and Lake Burragorang, two at Lake Yarrunga) (Figure 6.3).

Other water bodies where only endemic species were caught include the Burke River (Upper Nepean River sub-catchment), Joadja Creek (Wingecarribee River (priority) sub-catchment), Little Burke River (Upper Nepean River sub-catchment), Little River, Loddon Creek (Upper Nepean River sub-catchment), Wallandoola Creek (Upper Nepean River sub-catchment), and the Wingecarribee River. It should be noted however that at these sites only one to three species were caught in total (Figure 6.3). Additionally, as sampling effort varied across water bodies it is difficult to compare species richness or composition across sites.

Figure 6.3: Numbers of endemic, translocated and introduced fish species caught in the Catchment during the 2007 Audit period.



Source: DPI 2007

The Macquarie perch is listed as a vulnerable species under the NSW *Fisheries Management Act 1994* and has been recorded from the Mongarlowe River, Coxs River, Kowmung River, Little River, Warragamba Dam (Lake Burragorang sub-catchment), Nepean, Avon, Cordeaux and Cataract Dams (all in the Upper Nepean River sub-catchment), and in the lower Nepean and Cataract River below the storages (also in the Upper Nepean River sub-catchment). The DPI surveyed for the presence of Macquarie perch at 24 locations in the Catchment between August 2006 and May 2007. The species was captured at five of these locations including the Loddon Arm of Cataract Dam, Wongawilli Creek, Loddon Creek above the Loddon Falls (all in the Upper Nepean River sub-catchment), Kedumba River at Kedumba Crossing (Lower Coxs River

(priority) sub-catchment), and Cataract River at Jordans Pass (Upper Nepean River sub-catchment). A total of 336 Macquarie perch were caught, 306 of which came from Cataract Dam.

Sites where high numbers of native species were caught include the Kangaroo River, where the majority of the catch was Australian Smelt (*Retropinna semoni*), the Nattai River, where the catch was largely mountain galaxias (*Galaxias olidus*), and Lake Yarrunga (in the Kangaroo River (priority) sub-catchment), which had mostly endemic species and a catch dominated by Australian smelt (*Retropinna semoni*) and flathead gudgeon (*Philypnodon grandiceps*).

Carp (*Cyprinus carpio*) is a noxious species in a number of Australian states. The DPI is currently undertaking research into the comparative age, sex and genetic analysis of carp populations. Carp were present in the Kangaroo River, Lake Yarrunga (Kangaroo River (priority) sub-catchment), Lake Burragorang, Shoalhaven River (in the Bungonia Creek sub-catchment) and the Wollondilly River.

The mosquito fish (*Gambusia holbrooki*) is a major pest species in the freshwaters of eastern New South Wales. Mosquito fish were the most numerous fish species caught in the Avon River (in the Upper Nepean River sub-catchment). Mosquito fish have been associated with the decline of abundance or range of 35 fish species worldwide, including Australian native species such as gudgeon, hardyheads and some rainbow fish (NPWS, 2003).

In the Wollondilly River, as previously mentioned, a large proportion of the catch was introduced. The majority of these fish were goldfish (*Carassius auratus*), although redfin perch (*Perca fluviatilis*) were also present. The redfin perch is an introduced species implicated in the decline of Australian freshwater fish including the vulnerable Macquarie perch. It was first detected in the Wollondilly River in May 2006 during the Macquarie perch surveys. Redfin perch are likely to disperse downstream into Warragamba Dam and may impact on the endemic aquatic fauna including the vulnerable Macquarie perch (See Redfin Perch Case Study).

In Cedar Creek (in the Lower Coxs River (priority) sub-catchment), a large number of Oriental Weatherloach (*Misgurnus anguillicaudatus*) were caught. Interestingly, the data suggests that different introduced species may dominate within different water bodies. This emphasises the need for targeted programs as no single pest reduction program is likely to be suitable to combat all exotics across all waterways.

Cold water pollution

The SCA monitors the temperature of water releases at a number of sites downstream of dams. During 2003 and 2004 the SCA monitored water temperature downstream of Woronora, Warragamba and Tallowa Dams. There was little difference between the median annual temperatures upstream and downstream of Woronora Dam. There were inconclusive results for releases from the Warragamba Dam due to confounding factors and variable results. Releases from Tallowa Dam were found to cause a decrease in Shoalhaven River temperatures with median annual water temperatures above Tallowa Dam ranging from 15°C to 21°C and median downstream temperatures of 14.6°C. Temperatures 10 degrees below ambient have been shown to have negative effects on some fish species and other organisms (NSW Fisheries, 2003).

The Tallowa Dam Aeration Project commenced on 31 October 2005. In order to measure the effectiveness of the aeration, sampling sites were established and probes that constantly measure temperature and dissolved oxygen were installed near the dam wall. The installation of the aerator has created mixing between the deeper, colder water and the warmer surface water, increasing the temperature of released water by 10°C. Similarly dissolved oxygen contents within the deeper section of the lake were found to be significantly higher in January 2006 than they were for the corresponding month in previous years (SCA, 2006a).

Disruption to fish passage

In south-eastern Australia, approximately half of all fish species migrate as part of their life cycle (NSW Fisheries, 2003). In-stream structures such as weirs, causeways and bed-control structures can prevent fish movement and migration, and cause disturbance to stream habitat that allows generalist exotic species to thrive where specialist natives cannot. The SCA confirmed the presence of 68 weirs in the Catchment. None of these weirs were found to provide effective fish passage.

The State Government agencies responsible for the health of rivers have recognised that there needs to be modification of barriers to improve fish passage as part of the program to deliver environmental flows.

DPI has recently undertaken several statewide projects that relate to fish passage, including two Environmental Trust-funded projects within the Hawkesbury Nepean and Shoalhaven River catchments. One project included a review of waterway crossings requiring fish passage remediation. The second project built on the outcomes of the NSW Initial Weir Review by undertaking detailed reviews of 80 high-priority fish passage barriers in NSW.

The study identified 35 barriers to fish passage which it classified as medium to high priority sites for remedial action in the Catchment. Three weirs in the Catchment were identified as high priority sites for remediation works; these were Mongarlowe Weir, Kangaroo River Weir and Braidwood Weir. The study also identified 18 medium and 14 high priority other structures that were acting as barriers to fish passage (mostly causeways), and made specific recommendations for each about appropriate remediation measures.

During the 2007 Audit period, a fishway was built on Black Bob's Creek (a DPI site of medium priority remediation work), which was undertaken in conjunction with other works to stabilise banks and improve instream habitat (Figure 6.4).

SCA continues to develop works to improve fish passage at Tallowa Dam. It is anticipated that works will be completed by December 2008.

Figure 6.4: Black Bobs Creek fishway and bank stabilisation works
Source: DECC 2007

Implication

In order to draw conclusions about the state of the fish populations in these water bodies, a unified sampling program needs to take place. Consistent sampling effort combined with baseline information for comparison would allow more conclusive assessment of the state of fish populations in the Catchment.

Introduced species can have devastating impacts on the endemic aquatic fauna. Introduced species often thrive in degraded habitats and hence may indicate that the Wollondilly River is in a disturbed condition. The newly available information about fish populations throughout the Catchment suggest that the invasion of exotic species is problematic, and may indicate a moderate level of disturbance to native species, flows or riparian vegetation structure in those areas where species diversity is low, and/or where a greater proportion of the species composition is introduced. The 2007 data suggests that the Wollondilly, Mulwaree and Jenolan Rivers may be in a disturbed condition.

Conversely, Wongawilli Creek, Mongarlowe River, Kangaroo River, Lake Burragorang and Lake Yarrunga all appear to be in relatively good condition. A more accurate assessment of the health of these water bodies would be possible with directly comparable information about expected species diversity and species composition in similar water bodies when healthy.

The large proportion of exotic fish species present throughout the Catchment was highlighted in the 2003 Audit Report as a priority and a number of management options discussed including managing the health of

riparian areas, and direct removal of exotic species through initiatives such as the 'daughterless carp' program. The 2003 Audit Report also suggested that management initiatives be prioritised to infested areas, particularly in storages and inflows to storages.

Case Study – The introduced pest fish: Redfin perch (*Perca fluviatilis*)

The Redfin perch (*Perca fluviatilis*), also known as European perch, Eurasian perch, and English perch, is a medium-sized freshwater fish native to northern Europe. Redfin were first introduced to Australia in the 1860s for angling, and are now widespread across much of southern Australia. Their distribution seems to be limited by an upper water temperature of around 31°C and they are rarely found in fast waters or high altitude areas.

Figure 6.5: Redfin perch (*Perca fluviatilis*)
Source: Günther Schmida.

Redfin are popular with some anglers because of their fighting qualities and taste. However, they often form very dense populations containing large numbers of stunted fish which are of poor angling quality. They are also voracious predators of other fish, predating on small fish as well as the eggs and fry of larger fish such as trout and native perch. This predation can seriously affect recreational fisheries for these species. Redfin may also devastate native fish populations by spreading disease (Epizootic Haematopoietic Necrosis). For these reasons, redfin are considered a serious pest in NSW.

In 2006 the NSW Department of Primary Industries (DPI) discovered new populations of redfin in the Wollondilly River (priority) sub-catchment. This area, which was previously free of redfin, supports some of the last known NSW populations of threatened native Macquarie perch. The recently discovered populations of redfin appear to have been introduced either deliberately or accidentally through contaminated batches of fish for stocking.

DPI is undertaking specific surveys to document the distribution, spread and abundance of redfin in the Wollondilly River (priority) sub-catchment and throughout other areas of NSW. A range of options has been considered for targeted control and/or containment of redfin to limit the impacts on threatened species. However, as with all pest fish in open waterways, it currently appears to be extremely difficult to eradicate redfin populations or prevent natural dispersal to new areas.

The Hawkesbury-Nepean CMA is funding a DPI project to look at options for excluding redfin from Macquarie perch habitats in the Wollondilly River (priority) sub-catchment and associated waterways including Warragamba Dam. DPI and the University of Sydney are jointly studying the disease carried by redfin in NSW and its impacts on native species. In addition, DPI has commenced an awareness raising campaign to alert anglers to the problems this fish can cause. The campaign has involved producing an educational poster that has been sent to all NSW fishing licence agents and recreational fishing clubs throughout NSW.

Source: DPI 2007

Future directions

A fish monitoring program that is integrated over the entire Catchment, and hence uses the same methods and amount of sampling effort per site, would provide information about the numbers of species and total numbers of fish caught at each site. Monitoring over time in this way would allow, for example, assessment of the impacts of control programs on exotic species, which would likely be measured in a reduction in the numbers of exotic fish present, rather than the number of species.

As indicated in the background of this chapter, fish interact on many trophic levels. They are mobile and have a lifespan which enables fish populations to be used to assess changes in ecosystem health over time. Integration with monitoring programs for water quality, macroinvertebrates and riparian vegetation, a fish monitoring program is likely to provide greater knowledge of Catchment health, and provide greater confidence that management responses address identified ecosystem health concerns.

The 2005 Audit recommended that sampling of fish at designated sites should be carried out approximately every 3 years to determine the status of, and changes in, the composition of fish communities and to measure the success of any exotic fish control initiatives. This timeframe is consistent with that used in the Sustainable Rivers Audit. It is recommended that the SCA liaise with the DPI to discuss the scope of fish monitoring in the Catchment with a view to ensuring that comprehensive data become available in future (see 2005 Recommendation 24). In addition the SCA should liaise closely with the DPI during 2007/08 to ensure that any fish monitoring planned under the NSW Monitoring, Evaluation and Reporting Strategy is integrated with monitoring programs in the Catchment. The 2007 Audit has received improved data on fish populations, and notes the progress since the 2005 recommendation was made.

The auditor believes that fish monitoring could be part of a future integrated catchment-wide monitoring program (see 2005 Recommendation 3).

6.4 Riparian vegetation

Background

Riparian zones typically consist of vegetated corridors adjacent to stream channels where the vegetation is influenced by the water. These areas can be effective barriers to pollution from land-based activities, including agriculture and urbanisation. The riparian zone also contributes to ecosystem health by providing shade, stabilising banks, minimising erosion, limiting downstream flooding, supporting fisheries, taking up and storing nutrients and contaminants and by providing habitat for a range of species.

Riparian zones are often the most fertile part of the landscape and are subject to many pressures from land management practice, land-use change and human activities. The primary pressures on riparian vegetation are removal of riparian vegetation, introduced plant species (eg. willows) and stock access. Willows are listed as a weed of national significance.

This Audit focuses on the extent and condition of riparian vegetation in the Catchment. The Audit also reports on the area of vegetation cleared in the riparian zone during the audit period, and provides information on restoration and protection programs in Actions and Responses.

Findings

The SCA estimated there is 81,125 ha of riparian zone in the Catchment of which native vegetation covers 54,787 ha and 23,806 ha is pasture (SCA, 2003a).The SCA estimates that 38,753 km (48 per cent) of watercourse in the Catchment is presently being, or has the potential to be, accessed by stock. This has increased since 2005, when 38 per cent of the riparian zone in the Catchment was reported as accessible to stock.

The SCA has remapped the riparian zone index using 2006 Landsat imagery across the Catchment and prioritised assessment of sites for the Riparian Management and Assistance Program. The focus for 2007 Audit period was on the:

- Upper Werriberri Creek (2 ha treated in 2005-06) in the Werriberri Creek (priority) sub-catchment
- Paddy's River, Uringall Creek and Long Swamp Creek in Wollondilly River (priority) sub-catchment

- Coxs River from Kanimbla to Blue Mountains National Park, Cullenbenbong Creek (14 ha treated in 2005-06) and Ganbenang Creek (7 ha treated in 2005-06) in Mid Coxs River (priority) sub-catchment
- Barrengarry Creek (52 ha treated in 2005-06) and Brogers Creek (56 ha treated in 2005-06) in the Kangaroo River (priority) sub-catchment.

The SCA has completed 39 km of weed management in riparian zones throughout the Catchment, the SR CMA has completed 20 km, the H-N CMA has completed 73.5 km under its River Restoration Project, and a further 1,904 ha have been treated for weeds through the Wetland Management Program. DECC has treated a further 200.7 km, in Special Areas and National Parks.

Willows are a primary pressure on the health of the riparian zone in many sub-catchments. The SCA has treated 1,590 ha of willow infestations during the 2007 Audit period, and the H-N CMA has treated an additional stretch of 1.2 km of riparian zone for willow infestation.

Fencing of watercourses restricts stock access and hence limits degradation of river banks and removal of riparian vegetation. The SCA has fenced 45.3 km of riparian land, the SR CMA 28.5 km and H-N CMA 5,073 km of riparian zone in the Catchment.

In efforts to improve the quality of riparian zones throughout the Catchment, the H-N CMA has planted 110,192 trees, and the SR CMA has completed 3 km of revegetation as well as a further 70 ha. Fifty-nine km of direct seeding was also completed by H-N CMA. The SR CMA has completed 71.19 km and 92 ha of rehabilitation, the H-N CMA has completed 585 ha of rehabilitation, and DECC has completed 21.2 km of rehabilitation of riparian vegetation.

The SR CMA has completed works to stabilise both stream beds and banks at 13 sites and along 45.9 km of riparian zone. The H-N CMA has completed similar works along 80 km of riparian land and at 19 sites.

Forty two off-stream watering sites for stock have been installed by the SR CMA, and 51 by the H-N CMA. These provide alternative water sources for stock which previously had access to stream banks, and this work is often partnered with programs to fence out stock.

The SCA have developed a riparian zone index to measure the proportion of standing vegetation (with no discrimination between native and exotics) in the riparian zones in the Catchment. Based on this index, riparian zones in National Parks and Special Areas have a good proportion of standing vegetation, while the Mulwaree River (priority), Upper Wollondilly River (priority), Braidwood Creek and Reedy Creek sub-catchments have little or no standing vegetation cover along riparian zones.

The SCA funded a Synoptic Biodiversity Survey in 2001, carried out by the CRC for Freshwater Ecology. This study found that three (7.5 per cent) sites had less than 25 per cent cover of native species. These three sites were located in urban areas at Lithgow, Bowral and Goulburn. Fifteen of the 40 sites (37.5 per cent) had 25–50 per cent native species in the riparian zone, many of which were in the priority sub-catchments of Upper Coxs River, Mid Coxs River, Wingecarribee River, Wollondilly River, Upper Wollondilly River and Mulwaree River. The Reedy Creek, Braidwood Creek, Back and Round Mountain Creeks and Jerrabattagula Creek sub-catchment also had sites with 25–50 per cent native species. Seven sites (17.5 per cent) had more than 75 per cent of native species in the riparian zone, and these sites are located in the Nattai River, Woronora River, Nerrimunga River, Mongarlowe River and Upper Shoalhaven River sub-catchments.

Implication

There are riparian areas in the Catchment with good proportions of standing vegetation and native vegetation cover, particularly in the Special Areas and National Parks. However, there are also riparian zones in the Catchment that are likely to be under a variety of pressures, from little to no standing vegetation cover, areas of pasture, stock access, and the presence of exotic species. These conditions can threaten ecosystem health and water quality.

Healthy riparian zones assist in maintaining the health of rivers and streams in the Catchment, acting as the first of the multiple barriers that protect drinking water quality. Riparian zones are particularly important for water quality in areas where the adjacent land is subject to activities such as agricultural or urban land use.

The Mulwaree River (priority), Upper Wollondilly River (priority), Braidwood Creek and Reedy Creek sub-catchments have little or no standing vegetation cover along riparian zones as shown by the SCA's Riparian Zone Index. Water quality and ecosystem health is potentially at risk in these sub-catchments.

Weed removal along riparian zones, such as willow elimination, can cause disturbance in the riparian zone and can lead to erosion and water quality impacts. Management of weed removal sites in the riparian zone should include follow up measures to prevent secondary impacts.

Future directions

It was recommended in the 2005 Audit report that integrated ecosystem monitoring program including riparian vegetation should be investigated (see 2005 Recommendation 3).

The SCA, CMAs and Councils all have programs which outline a number of on-ground works to protect and rehabilitate riparian zones. Future on-ground rehabilitation works should be targeted in the Mulwaree River (priority), Upper Wollondilly River (priority), Braidwood Creek and Reedy Creek sub-catchments, as these sub-catchments have little or no standing vegetation in the riparian zone.

There are many programs for restoration and rehabilitation of riparian zones, which are all likely to contribute to an improvement in the health of riparian zones and provide improved protection of water quality. While records are maintained by relevant agencies and organisations about individual programs for riparian management, there does not appear to be a systematic use of measures to record the extent of this work. The Auditor is therefore not able to report on the location of riparian restoration and rehabilitation across the Catchment. This information should be collected systematically across the Catchment to enable better information for both future audits and development and co-ordination of management decisions (see Recommendation 12, regarding systematic databasing of spatial data).

6.5 Native vegetation

Background

Native vegetation in the Catchment is important for maintaining the health of individual species of flora and fauna, ecosystem process and genetic diversity. The degradation or clearing of native vegetation can impact on critical ecosystem services such as the improvement of water quality, nutrient recycling and the provision of resources such as food and fibre. Impacts on native vegetation can also induce soil salinity and acidity, soil erosion, loss of nutrients, changes to flow regimes and climate change. The presence of exotic weed species can affect the condition of native vegetation and the extent to which it can provide habitat. The rate of biodiversity loss accelerates dramatically when a vegetation community declines below approximately 30 per cent of its original area.

Relevant weeds of national significance in the Catchment are blackberry, gorse, lantana and serrated tussock (Figure 6.6).

Figure 6.6: Serrated tussock in the Wingecarribee River (priority) sub-catchment.
Source: DECC 2007

Native vegetation mapping (Map 6.4) in the outer Catchment was undertaken during the 2005 Audit period by the former DIPNR. There are small areas in the Upper Coxs River (priority), Kowmung River and Upper Wollondilly River (priority) sub-catchments which are currently being mapped.

This audit examines the extent and condition of native vegetation in the Catchment, as well as the:

- area of vegetation protected in National Parks and Reserves
- area of weeds removed
- area revegetated and rehabilitated
- area of native vegetation cleared.

Findings

During the 2007 Audit period DECC acquired a total of 1,373 ha in the Catchment, including land in the Blue Mountains National Park, Burragorang State Conservation Area, Morton National Park and Nattai National Park.

The major outcomes of programs to treat weed infestations and improve native vegetation condition are outlined below:

- The SCA has treated an estimated 88,917 ha of serrated tussock and 4,825 ha of blackberry in the Catchment during the 2007 Audit period. The SR CMA has completed 165 ha of weed removal, the H-N CMA reported the treatment of 373 ha, and DECC has treated a further 468 ha. Other weeds that have been targeted by SCA are Cootamundra wattle, broom, privet and pampas grass.
- The SR CMA has fenced 8.5 ha of land, revegetated 40.3 ha, and undertaken the rehabilitation of 2,167 ha of native vegetation. The H-N CMA has planted 65,580 native trees, completed 96 km of direct seeding, and rehabilitated 1,075 ha of native vegetation.
- Native vegetation covered approximately 50 per cent of the Catchment in the 2005 Audit period, based on the 2005 mapping. The Kowmung River, Lower Coxs River (priority), Lake Burragorang, Little River, Nattai River, Woronora River, O'Hares Creek, Upper Nepean River and Upper Shoalhaven River sub-catchments have a large percentage of native vegetation cover (>80 per cent). The sub-catchments with the lowest percentage of native vegetation cover (<20 per cent) are the Upper Wollondilly River (priority) and Mulwaree River (priority) (Map 6.4).
- Approvals under the *Native Vegetation Act* 2003 (formerly the *Native Vegetation Conservation Act* 1997) were granted for the removal of 20.2 ha of native vegetation in the Catchment during the 2007 Audit period. This is less than the 30.96 ha cleared in the 2005 Audit period, and far less than the 728.76 ha of native vegetation removed from the Braidwood district alone during the 2003 Audit period.

During the 2007 Audit period, SCA created a series of vegetation indices to measure changes in vegetation condition over time. Mapping of the entire Catchment has not yet been completed.

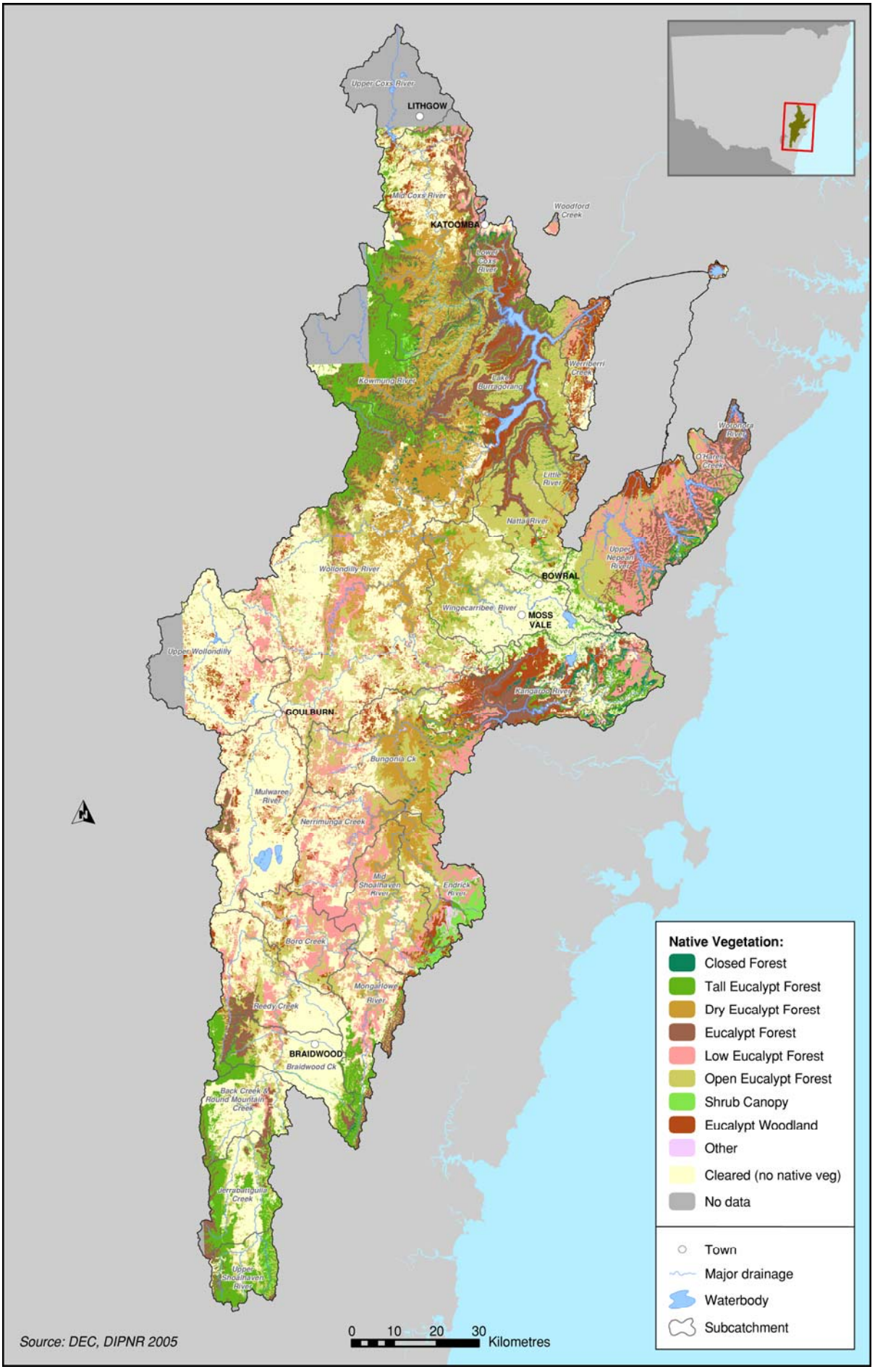
Restoration and protection programs are detailed in Actions and Response section of this chapter.

Implication

The area of native vegetation cleared with approval under the *Native Vegetation Act 2003* has remained low compared with the 2005 Audit period, which was a reduction from the amount of native vegetation cleared during the 2003 Audit period. This is a continued positive outcome for ecosystem health and protection of water quality in the Catchment.

The lowest percentage of native vegetation cover in 2005 was in the Upper Wollondilly River (priority) and Mulwaree River (priority) sub-catchments. The low percentage cover of native vegetation in these sub-catchments may put water quality and ecosystem health at risk.

Some areas of the Catchment play a particularly important role in preventing pollutants entering the water supply and proper management and ongoing monitoring of vegetation within these areas is clearly important in maintaining water quality and quantity. These areas include those in immediate proximity to the water storages, riverine corridors (over 18°) and flood prone lands.



Map 6.4: Native vegetation in the Sydney drinking water catchment

Future directions

Vegetation mapping is being addressed in the Catchment, however, the condition of that vegetation is still to be mapped outside of the Special Areas. Therefore, action on Recommendation 25 from the 2005 Audit report regarding the need for vegetation condition mapping needs to continue.

All on-ground works being undertaken in the Catchment to revegetate and rehabilitate native vegetation should be integrated and a spatial database of location, type and area of works created and maintained (see Recommendation 12). The auditor notes that progress is being made on the use of spatial database by agencies such as the CMAs in their operations in the Catchment, and encourages their ongoing development and use.

Actions and Response

Response to issue

There are many responses to the degradation of ecosystem health including programs to reduce the impacts of pollution (Chapter 3), new water management rules under statutory water sharing plans (Chapter 4) and programs to improve land management (Chapter 5). In addition there are specific responses to the degradation of ecosystem health, including programs to:

- ***monitor and maintain ecosystem water quality***
- ***monitor and maintain macroinvertebrate communities***
- ***maintain and enhance native fish communities***
- ***maintain and enhance riparian zones***
- ***maintain and enhance native vegetation.***

In 2006, the NSW Government released the NSW State Plan. The plan sets five areas of activity including the Environment for Living. Within the Environment for Living activity area there is a *Better outcomes for native vegetation, biodiversity, land, rivers, and coastal waterways* result area. Below are listed the targets under this result area of the NSW State Plan that are relevant to the audit (NSW Government, 2006a).

Targets

- biodiversity – by 2015 there is an increase in native vegetation extent and an improvement in native vegetation condition
- water – by 2015 there is an improvement in the condition of riverine ecosystems

Actions

- implementing the Catchment Action Plans of the CMAs
- actively managing weeds, fire and pests on national parks, reserves and crown land
- providing incentives to landholders for improved management through stewardship programs, native vegetation offsets and CMA incentives schemes to deliver state-wide and regional targets

New directions

- building and managing a comprehensive, adequate and representative reserve system which includes terrestrial parks to protect the state's unique biodiversity from current and future pressures.
- promoting voluntary conservation on private land and linking areas of prime habitat with corridors to mitigate the impacts of climate change.
- targeting resources to manage priority weeds in key locations through a NSW Invasive Species Plan
- support industry to increase adoption of low impact conservation farming systems such as minimum till, water efficient technology and uptake of R&D which impacts positively on the environment
- encourage the expansion of forest plantations for carbon sequestration, mine site rehabilitation, other environmental benefits and future timber supply.

Programs to monitor and maintain ecosystem water quality and macroinvertebrates communities

The SCA has both a **Water Quality Monitoring Program (WQMP)** and a **Macroinvertebrate Monitoring Program (MMP)**. The purpose of the WQMP is to understand the threats to water quality throughout the delivery system, including rivers and reservoirs, as well as showing long term trends (SCA, 2005c).

The aim of the WQMP is to:

- provide early warning of possible contaminants in the water to help protect the health of approximately four million consumers
- ensure that the untreated bulk water delivered to its wholesale customers such as Sydney Water Corporation is of an appropriate quality
- identify and target possible sources of contamination in the Catchment and storages
- identify emerging water quality issues and address them in forward planning.

The aim of the MMP is to (SCA, 2006d):

- determine ecosystem health through an assessment of aquatic macroinvertebrate communities at 27 SCA sub-catchments
- detect change in ecological health within the sub-catchments
- provide a reporting mechanism on the state of the catchments' aquatic ecosystems.

The purpose of the SCA's **Water Quality Risk Management Framework (WQRMF)** is to address risks to bulk raw water quality in the SCA supply systems. It identifies hazards to bulk raw water quality and assesses the risk of events that cause these hazards. The Framework also identifies and evaluates the controls to be used in dealing with the hazards throughout the SCA system (SCA, 2005b).

The **Streamwatch Program** is a community/school-based assessment of water quality and macroinvertebrates in local streams. The SCA supports 40 Streamwatch groups who collect water quality data from approximately 80 sites. In 2005-06 two more groups joined the program. Streamwatch groups help their broader communities to identify and act on local water quality issues.

The H-N CMA's **Hawkesbury-Nepean River Health Strategy (RHS)** provides a framework for identifying the priorities for action that will help achieve the state-wide targets for water. The RHS applies a systematic approach to identifying the values and threats of each river reach and then appropriate management actions (H-N CMA, 2007).

Programs to maintain and enhance native fish communities

The DPI carried out the following relevant programs for fish management:

- research into the distribution and critical habitat of the threatened Macquarie perch between August 2006 and May 2007
- a state-wide assessment of the diversity, distribution and abundance of fish in NSW rivers in October 2006
- assessment of the fish community above and below Pheasants Nest weir in August and September 2006 and March 2007 prior to the proposed raising of the height of the weir
- assessment of the fish community in the Shoalhaven River catchment prior to the proposed construction of a fishway on Tallowa Dam in November and December 2005
- research into the distribution of the introduced redfin perch in the Wollondilly Catchment in May and June 2007.

In 2006, DPI published reports on the outcomes of their **NSW Detailed Weir Review** and **NSW Road Crossing Review Projects** (DPI, 2006d, 2006e, 2006f). The **NSW Detailed Weir Review Project** built on the outcomes of the NSW Initial Weir Review (NSW, Fisheries, 2002) by undertaking detailed reviews for high-priority structures within the thirteen catchments of NSW. The review aims to facilitate future on-ground works by addressing the social, ecological, cultural and logistical issues that surround the modification of existing barriers. The primary objectives of the project were to:

- Identify high priority weir structures within each CMA region that have a major impact on fish passage and aquatic habitat condition
- Assess high priority weirs by reviewing social, ecological, cultural and logistical issues that are associated with each structure
- Rank high priority weirs within each CMA region
- Recommend remediation options to improve fish passage at each weir structure.

The **NSW Road Crossing Review Project** was developed to identify and prioritise waterway crossings for remediation action in all coastal-draining catchments of NSW (DPI, 2006d, 2006e). The primary objectives and outcomes of the project were to:

- identify and assess the impacts of road crossings on aquatic habitat
- complete a field inventory of road crossing obstructions and identify other environmental impacts on aquatic habitat associated with road crossings
- develop an aquatic habitat management database and establish environmental auditing protocols for assessing road crossings
- demonstrate options for remediation and improved management of road crossings
- encourage remediation of priority sites with structure owners, and promote 'fish-friendly' principles for application in future instream works
- establishment of remediation demonstration sites at two key road crossing sites
- increase awareness of the importance of fish passage and aquatic habitat management for road management authorities and the broader community.

Following on from the above review projects DPI began the **Bringing Back the Fish Project** in partnership with the H-N CMA, in June 2006. The project aims to remediate priority fish passage barriers by implementing on-ground works at weirs, road crossings and floodgates. To date, three road crossings on Black Bob's Creek have been modified to provide for fish passage.

DPI also produced a factsheet in 2006 outlining the **'Fish in Farm Dams'**. This document encourages the use of native fish and plants in farm dams and also identifies undesirable and pest fish species.

During the 2007 Audit period, a biodiversity partnership project between H-N CMA and DPI into **Macquaire perch habitat protection** (redfin exclusion) was initiated to investigate options for controlling redfin which was discovered in the Wollondilly River in early 2006.

New infrastructure is being built at Tallowa Dam to allow native fish passage and to improve the temperature of water released from the dam. The SCA continues to investigate a $7 million fishway and multi-level offtake point at Tallowa Dam. The fishway would enable migratory fish species to access the Shoalhaven and Kangaroo rivers, upstream of the 42 metre high dam wall at Tallowa. The SCA's **Tallowa Dam Aeration Project** is improving the temperature of the water released from the dam by mixing the deeper, colder water with the warmer surface water, increasing the temperature of the release water by 10ºC. Similarly, the dissolved oxygen contents in the deeper section of the lake were significantly higher in January 2006 than for the corresponding month in previous years.

In November 2001, the removal of large woody debris from NSW rivers and streams was listed as a key threatening process (KTP) under the *Fisheries Management Act 1994*. In June 2005, DPI produced a factsheet on the Removal of Large Woody Debris from NSW Rivers and Streams. The factsheet provides information on why large woody debris is important for native fish, which fish species are affected and the steps in producing a threat abatement plan.

Programs to maintain and enhance riparian zones

The SCA's **Healthy Catchment Program** includes a **Riparian Strategy** to improve the condition of riparian zones in the Catchment. The Strategy requires identification of the condition of the riparian zone within the Catchment and provides for grants and assistance schemes, education programs and regulatory processes in consultation with appropriate authorities (SCA, 2006c).

The SCA's **Riparian Management Assistance Program (RMAP)** under the SCA's Riparian Strategy provides financial assistance to property owners in priority stream catchments of Brogers and Barrengarry

Creek (Kangaroo River sub-catchment), Cullenbenbong and Ganbenang creeks (Mid Coxs River sub-catchment), Uringalla, Paddys River and Long Swamp (Wollondilly River sub-catchment) and Upper Werriberri Creek to maintain and improve the management of riparian zones for water quality. The **RMAP** granted 27 applications in 2005-06 with a total value $909,156. The works completed will minimise stock access along 35km of streams and gullies and over 23,000 trees have been planted to improve vegetation cover and bank stability.

The SCA has developed a method to map the extent of willows using multi-seasonal SPOT5 satelite imagery. The SCA and others intend to use this information to prioritise work under the **Riparian Management Assistance Program**.

The SCA's **Catchment Protection and Improvements grants for community groups** funded a number of projects to improve riparian vegetation, including:

- Berrima Bushcare Group
- Kangaroo Valley Environment Group
- Sydney Bushwalkers Association
- Kangaroo Valley Environment Group – riparian restoration of Village Gully
- Wingecarribee Landcare and Bushcare Network inc – revegetate riparian zone on Wingecarribee River west of Bong Bong Bridge, Moss Vale
- Restoration works on Iron Mines Creek to Gibbergunyah Creek by Wingecarribee Council, funded by Sydney Catchment Authority, Catchment Protection and Improvements Grants and the Wingecarribee Council's Environmental Levy.

During the 2007 Audit period, the SCA completed two riparian projects in the Coxs River sub-catchments. An area of Farmer's Creek was fenced, a stock crossing and stock water supply were built and the riparian area was replanted. The removal of 45 ha of willows and woody weeds was also completed between Jill's Crossing and the Blue Mountains National Park boundary, upstream of Warragamba Dam.

The H-N CMA's **River Health Program** recognises that the Hawkesbury–Nepean is a river of national significance and that its improved functioning is essential to the ability of the river to continue to deliver the many benefits it gives to a large number of Australians. It aims to provide funding for landholders and local government as the key partners in delivering on-ground action to positively influence the health of this river system.

The **River Restoration Project** under the H-N CMA's River Health Program provides funding for landholders to undertake activities to maintain and improve riparian area, instream habitat, riverine wetlands and bank stability. This project builds on two previous programs the **Hawkesbury–Nepean Riverbank Management Program** and **Warragamba Riparian Program**. The Hawkesbury-Nepean River Health Strategy links closely with the River Restoration Project and helps to identify priority management issues and locations for river restoration activities to maximise environmental outcomes. Landholders can apply for grants up to $15 000; and larger projects will also be considered under the River Restoration Project when a significant environmental outcome is clearly evident.

Wingecarribee Council was awarded funding during the 2007 Audit period through H-N CMA to complete the Berrima School to Wingecarribee River Restoration Project.

Wollondilly Shire Council has a number of riparian improvement programs including the Werriberri Creek Riparian improvement project and the Wattle Creek and Myrtle Creek Privet removal projects.

The SR CMA **Shaolhaven-Illawarra Riparian Rehabilitation Project**, involves the development of Voluntary Conservation Agreements with landowners. The project's on-ground aims are to fence off and conserve riparian vegetation, revegetate riverbanks, control weeds, stabilise streambeds and establish off-stream watering points.

Programs to maintain and enhance native vegetation

Actions to maintain and enhance native vegetation include formally protecting high value conservation areas, minimising clearing, removing weed infestation and revegetating cleared areas to restore biodiversity values.

The Australian Government **Envirofund** is the local action component of the Australian Government's $3 billion Natural Heritage Trust. It helps communities undertake local projects aimed at conserving biodiversity and promoting sustainable resource use. Community groups and individuals can apply for grants of up to $50,000 to carry out on-ground and other actions to target local problems.

During the 2007 Audit period, Wingecarribee Council completed works on the southern slope of Mount Gibraltar, funded through the **Envirofund** Grants program.

Programs to protect high conservation areas

A number of **nationally threatened species and ecological communities** under the *Environment Protection and Biodiversity Conservation Act 1999* are located in the Catchment. These include White Box – Yellow Box – Blakely's Red Gum grassy woodlands and derived grasslands, Temperate Highland Peat Swamps on Sandstone and Turpentine-Ironbark Forest of the Sydney Basin Bioregion. Funding is available for projects to recover threatened species and ecological communities under the Threatened Species Network Community grants and Envirofund grants.

DECC administers a number of mechanisms that enable landholders to formally protect conservation value, including native vegetation. These mechanisms are:

- voluntary conservation agreements (VCAs) which are a permanent legal protection for the property's special features, through an agreement between the landholder and the Minister for the Environment
- wildlife refuges, where specified land is legally declared a wildlife refuge, and the terms of the agreement can be changed over time
- land for wildlife, where information is provided to landholders to help conserve the bushland.

Other initiatives such as the SR CMA **Southern Rivers Bush Incentives Program** provide funding to landholders to support them in managing priority native vegetation for conservation purposes. The H-N CMA **Bushland Conservation Project** aims to maintain and improve native vegetation including native grasslands, woodlands and forests that are not directly associated with waterways. Funding is available for landholders in the rural local government areas (LGAs) of the Catchment: Wollondilly, Wingecarribee, Goulburn–Mulwaree, Upper Lachlan Shire, Greater Lithgow, Oberon and Blue Mountains. Priority funding will be offered to projects that target endangered ecological communities, threatened species habitat and regionally significant vegetation communities as indicated in the Catchment Action Plans.

The SR CMA has also implemented in the 2007 Audit period, a comprehensive **voluntary biodiversity conservation scheme** for south-east NSW, as well as projects to protect biodiversity in the southern part of the Catchment and revegetation of the Braidwood Granites.

Programs to manage vegetation clearing

The *Native Vegetation Act 2003* sets a legal framework for ending broadscale clearing unless it improves or maintains environmental outcomes, encouraging revegetation and rehabilitation of land with native vegetation, and rewarding farmers for good land management. Landholders seeking to clear native vegetation are now required to either submit a development application, or enter into a legally binding agreement with the local CMA called a Property Vegetation Plan. This plan outlines the planned clearing of native vegetation on a property for up to 15 years.

Weed control programs

On 1 March 2006, the amended *Noxious Weeds Act 1993* came into force (via Noxious *Weeds Amendment Act 2005*). There have been a wide variety of changes in the new Act that will have an impact on local government, as both a land manager and as the Local Control Authority.

The objects of this Act are:

- to reduce the negative impact of weeds on the economy, community and environment of this State by establishing control mechanisms to:
  - prevent the establishment in this State of significant new weeds
  - restrict the spread in this State of existing significant weeds
  - reduce the area in this State of existing significant weeds
- to provide for the monitoring of and reporting on the effectiveness of the management of weeds in this State.

The **Australian Weeds Strategy** provides a framework to establish consistent guidance for all parties, and identifies priorities for weed management across the nation with the aim of minimising the impact of weeds on Australia's environmental, economic and social assets. The Australian Weeds Strategy emphasises the importance of preventing new weeds from establishing themselves in the area and the need to respond quickly to incursions.

A central component of the strategy is the identification of **Weeds of National Significance** and the resultant coordinated actions across all States and Territories. Relevant weeds of national significance within the Catchment are Blackberry, Gorse, Lantana, Serrated Tussock and Willows. A Strategic Plan and a Weed Management Guide has been developed for each of the weeds of National Significance in the Catchment. The weed management guides outline the identification of the weed and the best ways to manage the weeds.

The **National Weed Awareness Action Plan** focuses on improving awareness as a prerequisite to achieving acceptable long-term management of weeds. Increased awareness depends on participation by landowners, land managers, industry, the wider community and local, state and Australian governments. The goal is a targeted, well-resourced and consistent national weed awareness program that increases community and whole-of-government understanding of the weed crisis.

A **National Weed Spread Prevention Action Plan** (currently being developed) will establish a framework to prevent weed spread. The draft objectives are to identify and address all pathways for weed spread; achieve national consistency in weed spread prevention; minimise the spread of weeds by human agency; and meet the requirements of the National Weeds Strategy.

The **NSW Weeds Strategy** defines the major objectives and activities required to achieve a sustainable reduction of weeds in New South Wales. It explains ways stakeholders can improve the effectiveness and coordination of the fight against weeds. The strategy is linked to: the National Weed Strategy; weeds strategies in other states; and weed control and other environmental plans by local government, government and private landholders.

The **NSW Invasive Species Plan 2007-2015** is being developed in line with the **NSW State Plan,** will replace the current **NSW Weeds Strategy,** and will incorporate the management of weeds, vertebrate pests, invertebrate pests and freshwater and marine aquatic pests. It will provide a comprehensive set of objectives with key priority actions to deliver measurable outcomes in invasive species management in NSW.

Crown Lands Office is also involved in the development of regional weed management plans, the federal weeds of National Significance initiative and Recovery Plans for Threatened Native Species.

The SCA's **Pest and Weed Control Program for Special Areas** focuses on the control of blackberry, serrated tussock, pampas, willows and privet in the Special Areas. In addition to this program there is a **Pest and Weed Management Operational Plan Warragamba and Blue Mountains Special Areas 2004 -2009** which is the basis for all pest and weed control planning in the Blue Mountains and Warragamba Special Areas. In response to a severe infestation of privet beside the Kangaroo River, including the entire foreshore of Lake Yarrunga, the Shoalhaven Special Area Privet Management Project was commenced in 2006. The Shoalhaven City Council is contracted to remove the privet. Approximately 40 per cent of the primary privet control work has been completed.

The SCA also has a **Wingecarribee Swamp and Special Area Plan of Management 2007 (WSSAPoM)** which establishes management targets in order to reach a longer term vision. The management targets include water quality, ecosystem management and pests and weeds. The SCA will continue to implement the Draft Pest and Weed Management Plan for the Wingecarribee Swamp. As part of this Plan the SCA has implemented a **Wingecarribee Swamp weed control program**. The program aims to achieve sustainable management of willows and blackberry within four years. Significant progress has been made against the deepest weed infestations (SCA, 2007d).

Case Study – Weeds in the Wingecarribee Swamp

Wingecarribee Swamp is the largest upland peat swamp in mainland Australia. The swamp previously played an important role in filtering the runoff entering Wingecarribee Reservoir from the surrounding 4000 hectare rural catchment area. It also held significant biodiversity and conservation values, as it was home to a number of complex vegetation types, habitats, species and communities listed under the *Threatened Species Conservation Act 1995* (TSC Act).

The swamp was first mined for peat in the 1960s. Operations were finally halted in 1998, in response to loud opposition voiced in support of the ecological and archaeological values of the area. This halt came too late for the swamp however, which suffered a massive structural failure and collapsed during heavy rains in August 1998. Large volumes of peat flowed into Wingecarribee Reservoir, temporarily impacting on the quality of water stored there. A channel formed down the centre of the swamp during the collapse, which has compromised the water-filtering role previously played by the swamp.

The Wingecarribee Swamp and Special Areas Plan of Management 2007 provides for the mitigation of some of the worst current threats to the ecology of the swamp. These include the widespread invasion of weeds such as willow and blackberry, which threaten ecosystem biodiversity and compete with native species.

An estimated 1 million willows now infest the swamp. The 2007 Audit Team inspected the swamp, and observed the extent of the infestation.

The SCA has allocated significant resources to a four-year weed control program over the entire area of Wingecarribee Swamp. The first year of the program has been deemed a considerable success, with weed control contractors able to work effectively in the difficult swamp terrain. Extensive areas of the largest willow monocultures in the swamp are now controlled. There have been no recorded spills or environmental incidents caused by the weed control activities, and monitoring has not detected any pesticides in the adjacent waters since the program commenced. The success to date increases the SCA's confidence that willow and blackberry populations in Wingecarribee Swamp can be managed, if not eradicated.

Figure 6.7: Wingecarribee Swamp with young willows in the background

Source: DECC 2007

Land and Water Australia produced a **River and Riparian Land Management Technical Guideline for Controlling Willows along Australian Rivers** (Land and Water, 2006). This guide provides information about willows and their management. Willow sawfly (*Nematus oligospilus*) has recently arrived in Australia and may be a potential biological control for willows. Willow Sawfly larvae feed on willow leaves and can completely defoliate large willow trees and cause tree death as a result of several defoliation events over a period of two or more seasons (VIC DPI, 2006).

Other initiatives to combat weeds in the Catchment are:

- The **Shoalhaven Corridor Weed Management Plan** directs annual riparian weed control activities around Tallowa Dam, Kimberley Park and the Kangaroo River arm of the Shoalhaven system in Morton National Park
- SR CMA's **Broom Management Program** focuses on the control and eradication of broom and other weeds from the Shoalhaven River and its tributaries

- As part of the H-N CMA's biodiversity partnership project the H-N CMA and DPI are developing a **Catchment Weeds Strategy** following extensive consultation with stakeholders
- Roadside weed control works by the Upper Lachlan Council have continued to be focused on the control of serrated tussock and African lovegrass in the Taralga areas
- Goulburn Mulwaree Council began blackberry spraying during the 2007 Audit period along the Wollondilly and Mulwaree rivers
- The HN CMA has prepared a gorse strategy and offered funding to assist landholders to control gorse.

Native vegetation management programs

Property Vegetation Plans (PVPs) are a negotiated process between the CMA and the landowner. An officer from the CMA will carry out field surveys over the proposed clearing and offset areas to determine their environmental values. The data is then entered into the PVP assessment tool and the environmental values before and after clearing determined. As well as approving clearing, PVPs can also be used to identify areas of regrowth vegetation on a property, giving landowners greater security to plan and invest.

CSIRO developed a handbook in 2007, entitled **Motivating Change in the Catchment**. It is a guide to revegetation design and incentives for catchment management bodies, which is intended to be used by catchment managers as a guide to assessing whether or not and what type of incentive program is appropriate for biodiversity enhancement in their catchment (CSIRO, 2007c).

Revegetating the Braidwood Granites and Upper Shoalhaven Project was carried out by SR CMA during the 2007 Audit period. The Braidwood Granite Basin comprises approximately 40,000 ha of extensively cleared farmland, with less than 100 ha of remnant bushland. Much of the country is highly susceptible to wind erosion, particularly during dry periods. This project aims to re-establish native vegetation across the granite basin.

The SCA's **Catchment Protection and Improvements grants for community groups** funded a number of projects to improve vegetation, including:

- Casurina Gully – Chinamans Creek Bushcare Group – stabilisation of Forty Foot Falls
- Gibbergunyah Creek Bushcare Group – weed control to improve water quality of Gibbergunyah Creek
- Kedumba Creek Bushcare – rehabilitate bushland above creek and repairing stormwater controls
- Moss Vale Landcare Group – weed control and removal, and rehabilitation of Whites Creek
- Mt Alexandra Reserve Bush care Group – Bush regeneration along Iron Mines Creek
- Mt Gibraltar Landcare and Bushcare – removal of primary weeds at Mount Gibraltar Reserve
- National Trust of Australia – Regeneration works in bushland section of Everglades Gardens at Leura
- Nerriga Landcare Group – to protect the Corand Callitris Pine and vegetation by installing a fence to create a vegetative buffer along the Corang River.

Local councils undertake or facilitate many on-ground works for restoring and maintaining native vegetation in the Catchment. A few examples follow.

- Shoalhaven City Council has undertaken extensive privet control throughout the catchments of the Kangaroo River and its tributaries. This work has been funded through SR CMA and SCA. During the period from July 2005 to June 2007, this project undertook major works along Brogers Creek, Barrengarry Creek and Lake Yarrunga.
- Taralga Landcare group received $11,507 funding from Round 1 of the Australian Government's Community Water Grants to remove willows from Woolshed Creek, revegetate three hectares with native species, and increase the size of a water storage pond.
- A new Tarago and District Landcare group formed in November 2006 and is the first landcare group in the headwaters of the Hawkesbury-Nepean catchment. The group aims to address local weed problems, pest animal control, education and sustainable agricultural practices. The group's first projects include planting at Crisps Creek Woodlawn mining site; and rehabilitating the banks of the creek of the recreation reserve in Tarago.

- Gorse Eradication Program continued throughout the Coxs River Catchment to ensure that control was carried out on all mapped infestations on public lands and 80-90 per cent of mapped infestation on private lands.
- Over 500 trees and shrubs were planted throughout the Farmers Creek, Lake Pillans, and the Lithgow township as part of the 'Greening Lithgow Program' in partnership with Lithgow Tidy Towns and Lithgow Oberon Landcare Association.
- $6,000 of weed control carried out on broom, pussy willow, gorse and serrated tussock as part of the 'Weed Resilient Landscapes Program' in partnership with the DPI.
- Mt Gibraltar Landcare/Bushcare group – 10-year anniversary of volunteers working to restore this 120 hectare bushland reserve. In 2005-06, the group undertook 1,500 volunteer hours and since 1993 have received $470,000 in funding to undertake a project worth $850,000.
- Moss Vale Landcare Group undertook restoration of riparian zone of Whites Creek including 1,000 volunteer hours in 2005-06 with $44,000 funding.
- Wingecarribee Council was awarded funding during the 2007 Audit period through the SCA, Catchment Protection and Improvements Grants, to complete bushland restoration in the Berrima Weir Reserve.

Landcare and Bushcare groups operate in the Catchment, undertaking work to protect and restore native vegetation. The **Mt Kanimbla Landcare Group** has planted 20,000 native trees during the 2007 Audit period, as part of an effort to establish wildlife corridors connecting the Kanimbla Valley to the Coxs River. Wingecarribee Council set up two new Bushcare Group in Moss Vale and Welby Tip Site in the Catchment.

The Blue Mountains City Council Environment Levy provides funding to spend specifically on additional environmental protection and natural resource management projects within the Blue Mountains local government area. A number of projects have been funded from the Environmental Levy including:

- **New Bushcare Groups -** The Medlow Bath Bushcare group were established, additional training opportunities for bushcare groups were provided and biodiversity workshops have been conducted.
- **Comprehensive Bush Regeneration –** aims to provide a healthy resilient bushland protecting the head of catchments throughout the Blue Mountains and creekline restoration. During the 2007 Audit period gorse was removed from creek banks at Pope's Glen, Blackheath and control of broom and blackberry at Upper Kedumba Creek, Katoomba were carried out.
- **Habitat Conservation Network -** The network provides high-level technical and material support to landowners achieving significant conservation outcomes. Objectives are improved weed control on non-council managed land, improved protection of bushland on non-council managed land and improved protection of endangered ecological communities and other significant vegetation. To date there are 17 Habitat Conservation Network participants.

Local Provenance Seed Strategy – CMAs and local government have a strategy that all regeneration work should use species of local provenance. Local provenance refers to seed collected from natural populations growing in the same vegetation community and position in the landscape within a reasonable (closest possible) distance of the area being restored.

Gaps in the response

The monitoring of ecosystem water quality, macroinvertebrate and fish communities provide useful information about the state of the Catchment. Actions that respond to and investigate reduced water quality and impaired macroinvertebrate and fish communities now need to be developed and implemented based on this monitoring information.

There are many programs for the restoration of riparian and native vegetation which contribute to improved ecosystem health. These programs need to be coordinated across the Catchment to ensure priority areas are targeted for funding and on-ground works. Spatial data on the extent of native vegetation and weeds and the location of rehabilitation and revegetation works in riparian and other areas of the Catchment need to be available and accessible to all land managers. See Recommendation 12.

Chapter 7
State of the Sub-catchments

Priority sub-catchments

Kangaroo River

Kangaroo River is one of the sub-catchments with the greatest export potential of phosphorus loads, and has a moderate export potential of nitrogen loads. It also has several unsewered villages with high peak season equivalent populations, which can place pressure on the local sewage disposal methods and increase risk of overflows. The Kangaroo River sub-catchment is therefore likely to be under pressure from nutrient loads.

Algal levels varied amongst sites and water bodies in the sub-catchment. Bendeela picnic area decreased in the incidence of total and toxic cyanobacteria during the 2007 Audit period, suggesting an overall improvement. Within Lake Yarrunga, increases in the incidence of total cyanobacteria occurred at Lake Yarrunga at 100m from dam wall. This site is furthest from the township of Kangaroo Valley. Lake Yarrunga at Kangaroo and Yarrunga Junction decreased in overall (total) cyanobacteria but increased in toxic cyanobacteria. Lake Yarrunga at Kangaroo River increased in both total and toxic cyanobacteria during the 2007 Audit period. This site is close to the urban development of Kangaroo Valley. Within Fitzroy Falls Reservoir and at Fitzroy Falls, there were decreases in the incidence of toxic cyanobacteria.

The Kangaroo River sub-catchment is under pressure from the extraction of surface and ground water, as a large volume of water is permitted to be extracted under water access licences, and there is also a large number of farm dams and groundwater bores in this sub-catchment.

A large number of the sites of potential contamination in the very high, high and medium risk categories are located in the Kangaroo River sub-catchment. The majority of the quarries in the very high, high and medium risk categories are also located in the Kangaroo River sub-catchment. There is also a mine and a small area of gully erosion in the sub-catchment.

There are seven water quality monitoring sites in the Kangaroo River sub-catchment. Three of the four sites (all at Lake Yarrunga) rated very poorly across all four groups of water quality parameters. Of the other four sites in the Kangaroo River sub-catchment, two sites had very poor ratings across three groups and a single poor rating in the remaining group. This included the site at Fitzroy Falls Reservoir. The other two sites had two very poor ratings each (these sites were both on the Kangaroo River). Overall this suggests that the ecosystem water quality in the Kangaroo River sub-catchment is degraded.

In contrast to the water quality data, both macroinvertebrate and fish indicators suggest that the waterbodies in the Kangaroo River sub-catchment are in good condition. There were no sites with severely impaired macroinvertebrate ratings in the Kangaroo River sub-catchment, and there were two with richer than reference condition ratings. Out of eight species of fish caught in the Kangaroo River, seven were endemic, and one introduced, and in Lake Yarrunga, out of eight species caught, six were endemic and only two introduced. However, carp are present in both water bodies.

Barrengarry Creek and Brogers Creek in the Kangaroo River sub-catchment were identified as priority sites for the SCA Riparian Management and Assistance Program. The Kangaroo River was identified by the SCA's Riparian Zone Index as a sub-catchment with good standing vegetation cover along its riparian zones.

Mulwaree River

The Mulwaree River sub-catchment is one of the sub-catchments with the greatest export potential of phosphorus loads, and has the second highest export potential of nitrogen loads. It also has a sewage treatment plant and an unsewered village. Thus nutrient loads are likely to be a major pressure in the sub-catchment.

The Mulwaree River sub-catchment is under pressure from the extraction of surface and ground water, as a moderate volume of water is permitted to be extracted under water access licences, and there is a large number of farm dams and groundwater bores in this sub-catchment.

There is a large urban area at Goulburn in the Mulwaree River sub-catchment. However there were no sites of pollution or potential contamination, mines or quarries in this sub-catchment. The sub-catchment has a large area of pastureland and a large area of observed gully erosion and observed salinity cases.

Water quality, macroinvertebrate and fish indicators all suggest that the waterbodies in the Mulwaree River sub-catchment are in a disturbed condition. The single water quality monitoring site in the sub-catchment had exceedences in more than 50 per cent of samples for all four groups of water quality parameters. Three out of six macroinvertebrate samples in the Mulwaree River sub-catchment received significantly or severely impaired AusRivAs health ratings. Only two species of fish were caught in the Mulwaree River, both of which were introduced.

The Mulwaree River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with little or no standing vegetation cover along its riparian zones and less than 20 per cent of the Mulwaree River sub-catchment is covered by native vegetation. This indicates that water quality and ecosystem health is potentially at risk in this sub-catchment, which was confirmed by the water quality, macroinvertebrate and fish indicators.

Werriberri Creek

The Werriberri Creek sub-catchment had moderate exports of nitrogen and phosphorus loads. There was also a sewage treatment plant in this sub-catchment, Warragamba STP (since closed), close to Lake Burragorang. There has also been recent sewering of The Oaks and Oakdale in this sub-catchment. *Giardia* was detected at the single pathogen monitoring site in this sub-catchment.

The Werriberri Creek sub-catchment may be under pressure from the extraction of surface and ground water, as a moderate volume of water is permitted to be extracted under water access licences, and there is a small number of farm dams and a moderate number of groundwater bores in the sub-catchment.

There was a moderate number of sites of pollution or potential contamination, mines and quarries in the medium, high and very high risk categories in the Werriberri Creek sub-catchment. There was no observed gully erosion in the Werriberri Creek sub-catchment.

Water quality, macroinvertebrate and fish indicators all suggest that the waterbodies in the Werriberri River sub-catchment are in a disturbed condition. There was a single ecosystem water quality site in the Werriberri Creek sub-catchment. It had exceedences in greater than 50 per cent of samples for all four parameter groups. Macroinvertebrate assemblages were rated as significantly or severely impaired in four out of six samples and two of the four fish species caught there were introduced, and two endemic.

In contrast to the water quality, macroinvertebrate and fish indicators, Werriberri Creek was identified by the SCA's Riparian Zone Index as a sub-catchment with good standing vegetation cover along its riparian zones.

Wingecarribee River

The Wingecarribee River sub-catchment is one of the sub-catchments with the greatest export potentials of both phosphorus and nitrogen loads. This suggests that nutrient loads may be an important pressure in this sub-catchment. The Wingecarribe River sub-catchment has four Sewage Treatment Plants (STPs) discharging to Wingecarribee River. This sub-catchment also has two unsewered villages (Robertson and Sutton Forest) with high estimated equivalent populations. Cyanobacteria was present at both monitoring sites in the sub-catchment. The monitoring site at Sheepwash Bridge may be affected by the water quality in the dam as it is just downstream from the dam wall. Pathogens were not detected at the single monitoring site in the sub-catchment.

The Wingecarribee River sub-catchment is under pressure from the extraction of surface and ground water, as a large volume of water is licenced to be extracted under water access licences, and there is also a large number of farm dams and a moderate number of groundwater bores in this sub-catchment. The Wingecarribee River receives large volumes of bulk water from Wingecarribee Reservoir for downstream transfer to the Wollondilly River and Warragamba Dam.

There are two large urban areas at Bowral and Moss Vale and a large area of pastureland in the sub-catchment. There was also a small area of land affected by gully erosion in Wingecarribee River sub-catchment.

There is a moderate number of sites of pollution or potential contamination in the sub-catchment and the majority of these sites are located along Wingecarribee River and Wingecarribee Reservoir. There are no mines or quarries in this sub-catchment.

Water quality and macroinvertebrate indicators suggest that the waterbodies in the Wingecarribee River sub-catchment are in a disturbed condition. There were three ecosystem water quality sites in the Wingecarribee River sub-catchment. All three sites had exceedences in greater than 50 per cent of samples for Toxicant, Nutrient, Chlorophyll and Dissolved Oxygen parameters; and just two had exceedences in greater than 50 per cent for Physical parameters. Macroinvertebrate assemblages were rated as significantly or severely impaired in four out of seven samples and the Wingecarribee River at Berrima has received severely impaired ratings in every year since 2001.

In contrast to the water quality and macroinvertebrate indicators, the fish indicator findings suggest that waterbodies in the sub-catchment may be in a moderately undisturbed state for fish. Two endemic species of fish were caught in the Wingecarribee River and a single endemic fish species was caught in Joadja Creek.

The Wingecarribee River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with moderate standing vegetation cover along its riparian zones. This indicates that water quality and ecosystem health is potentially at risk in this sub-catchment, which is reflected in the findings for the water quality and macroinvertebrate indicators.

Lower Coxs River

The Lower Coxs River sub-catchment has relatively low phosphorus and nitrogen export potentials. In the Lower Coxs River sub-catchment, there is a single alga and a single pathogen monitoring site. Cyanobacteria was present, but no pathogens were present.

A small volume of water is licensed to be extracted by water access licences and there is a small number of farm dams in the sub-catchment, suggesting that surface water extraction is not a major pressure in this sub-catchment. There is also a moderate number of groundwater bores in the Lower Coxs River sub-catchment.

There is a large urban area located at Katoomba in the Lower Coxs River sub-catchment. There was a small number of sites of pollution and potential contamination, mines and quarries in the Lower Coxs River sub-catchment.

The single water quality monitoring site in the Lower Coxs River sub-catchment had exceedences in more than 50 per cent of samples for Toxicant and Nutrient parameters, but not for Physical parameters or Chlorophyll and Dissolved Oxygen. Three out of eight macroinvertebrate samples received significantly or severely impaired AusRivAs ratings. Cedar Creek had five species of fish caught, of which three were endemic and two introduced, and in the Kedumba River, five species were caught, of which four were endemic and one introduced.

The Lower Coxs River was identified by the SCA's Riparian Zone Index as a sub-catchment with one of the highest percentages of standing vegetation cover along its riparian zones and greater than 80 per cent native vegetation cover.

Mid Coxs River

The Mid Coxs River sub-catchment has moderate phosphorus and nitrogen export potentials, one STP, and two unsewered villages, suggesting that nutrient loads may be a pressure in this sub-catchment. *Giardia* was detected at the single pathogen monitoring site in this sub-catchment.

The Mid Coxs sub-catchment may be under pressure from surface and ground water extractions, as there is a large number of farm dams in the sub-catchment and a moderate number of groundwater bores. There is however, only a small volume of water permitted to be extracted under water access licences.

There is a small number of sites of pollution and potential contamination, and a single mine and a single quarry in the very high, high and medium risk categories. A small area of land in the Mid Coxs River sub-catchment is also affected by gully erosion.

The single water quality monitoring site in the Mid Coxs River sub-catchment had exceedences in more than 50 per cent of samples for Toxicant and Nutrient parameters, but not for Physical parameters or Chlorophyll and Dissolved Oxygen. Four out of twelve macroinvertebrate samples in the Mid Coxs River sub-catchment received significantly or severely impaired AusRivAs health ratings, suggesting that macroinvertebrate assemblages in the sub-catchment may be under pressure. In the Coxs River in the Mid Coxs River sub-catchment, three species of fish were caught, of which one was endemic and two were introduced. In the Jenolan River, only two species of fish were caught, both of which were introduced. This suggests that the Coxs and Jenolan rivers may be in a disturbed condition.

The Mid Coxs River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with moderate standing vegetation cover along its riparian zones. This indicates that ecosystem health is potentially at risk in this sub-catchment, which is reflected in the findings for water quality, macroinvertebrates and fish indicators.

Upper Coxs River

The Upper Coxs River sub-catchment is one of the sub-catchments with the greatest export potential of Phosphorus, and Nitrogen loads. The sub-catchment also has two STPs. During the 2007 Audit period, the Lithgow STP was the largest contributor of Phosphorus to the Catchment.

The Upper Coxs River sub-catchment may be under pressure from the extraction of surface and ground water, as a large volume of water is permitted to be extracted under water access licences by Delta Electricity, and there are also a moderate number of farm dams and groundwater bores in this sub-catchment.

There is a large urban residential area at Lithgow in the sub-catchment. There was a small number of sites of pollution and potential contamination in the medium risk category, and a single mine in this sub-catchment. A few of these sites were located close to Lake Wallace and the Coxs River. There was a small area of land in this sub-catchment affected by gully erosion.

Two out of seven macroinvertebrate sites received significantly or severely impaired AusRivAs ratings. The Upper Coxs River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with moderate standing vegetation cover along its riparian zones. This indicates that water quality and ecosystem health is potentially at risk in this sub-catchment.

Wollondilly River

The Wollondilly River sub-catchment has the greatest export potentials of both phosphorus and nitrogen loads in the whole Catchment. This suggests that nutrient loads are a major pressure in this sub-catchment. There was an important decrease in the nitrogen and phosphorus discharged during the 2005 Audit period, due to the beneficial reuse of the Goulburn STP's effluent on agricultural lands in the vicinity. *Cryptosporidium* was present at the single pathogen monitoring site in the Wollondilly River sub-catchment.

The Wollondilly River sub-catchment is under pressure from the extraction of surface and ground water, as a large volume of water is permitted to be extracted under water access licences, and there is also a large number of farm dams and groundwater bores in this sub-catchment.

There are large areas of pastureland and rural residential in this sub-catchment. There is a moderate number of sites of pollution and potential contamination in this sub-catchment, and one mine and one quarry. Wollondilly River sub-catchment has the largest area of land affected by gully erosion in the Catchment and also has observed cases of salinity.

Water quality and macroinvertebrate indicators suggest that the waterbodies in the Wollondilly River sub-catchment are in a disturbed condition. There were three ecosystem water quality sites in the Wollondilly River sub-catchment. All three had exceedences in greater than 50 per cent of samples for all four parameter groups, and macroinvertebrate assemblages were rated as significantly or severely impaired in six out of eight samples

In Paddys River four species of fish were caught, of which three were endemic and one introduced. In the Tarlo River four species were caught, of which two were endemic and two introduced. In the Wollondilly River ten species of fish were caught, five of which were endemic and five introduced. Goldfish were present in large numbers in the Wollondilly River. The Wollondilly and Tarlo Rivers may be in a disturbed condition.

The Wollondilly River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with moderate standing vegetation cover along its riparian zones. This indicates that water quality and ecosystem health are potentially at risk in this sub-catchment, which is reflected in the findings for water quality, macroinvertebrates and fish indicators.

Upper Wollondilly River

The Upper Wollondilly River sub-catchment is one of the sub-catchments with the greatest export potential of both phosphorus and nitrogen loads. This suggests that nutrient loads may be an important pressure in this sub-catchment.

The sub-catchment is under pressure from the extraction of surface and ground water, as a large volume of water is permitted to be extracted under water access licences and there is a large number of groundwater bores in this sub-catchment.

There is a large area of pastureland and a moderate area of observed gully erosion in this sub-catchment. There were no sites of potential contamination, mines or quarries in this sub-catchment.

Macroinvertebrate assemblages were rated as significantly or severely impaired in five out of nine samples, suggesting that macroinvertebrate assemblages in the sub-catchment may be under pressure. In the Wollondilly River in the Upper Wollondilly sub-catchment, four species of fish were caught, of which two were endemic and two introduced. This suggests that this part of the Wollondilly River may be in a disturbed condition.

The Upper Wollondilly River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with little or no standing vegetation cover along its riparian zones and less than 20 per cent of the sub-catchment is covered by native vegetation. This indicates that water quality and ecosystem health is potentially at risk in this sub-catchment, which is reflected in the findings for the macroinvertebrates and fish indicators.

Other sub-catchments

Back & Round Mountain Creeks

A relatively large volume of water is licensed to be extracted by water access licences in this sub-catchment, and there is a moderate number of farm dams, suggesting that surface water extraction may be a pressure in this sub-catchment. There is only a small number of groundwater bores.

Sites of pollution and potential contamination were not a major pressure in this sub-catchment, as there was only one site of potential contamination. There was a small area of land affected by gully erosion.

All six macroinvertebrate samples in Back and Round Mountain Creeks sub-catchment received either similar to or richer than reference condition AusRivAs ratings, suggesting little disturbance to aquatic ecosystem health. In contrast, Back and Round Mountain Creeks was identified by the SCA's Riparian Zone Index as a sub-catchment with moderate standing vegetation cover along its riparian zones. This indicates that water quality and ecosystem health is potentially at risk in this sub-catchment.

Grose – Blue Mountains

The Grose sub-catchment had relatively low phosphorus and nitrogen export potentials and no unsewered villages. It therefore does not appear to be under pressure from nutrient loads. No algae was detected at any of the three monitoring sites in the Grose sub-catchment. There are only two sites of pollution or potential contamination in the sub-catchment, and a single quarry.

Water quality and macroinvertebrate indicators suggest that the waterbodies in the Grose sub-catchment are in a disturbed condition. There were three ecosystem water quality sites in the Grose sub-catchment, two of which had exceedences in greater than 50 per cent of samples for Physical parameters, one site for Toxicant parameters, all three sites for Nutrient parameters, and one site for Chlorophyll and Dissolved Oxygen. Macroinvertebrate assemblages were rated as significantly or severely impaired in four out of six samples. However, Grose was identified by the SCA's Riparian Zone Index as a sub-catchment with good standing vegetation cover along its riparian zones.

Boro Creek

The export potential of phosphorus in Boro Creek sub-catchment was low, whilst the export potential of nitrogen was at a moderate level.

There was a moderate number of farm dams and a small number of groundwater bores in this sub-catchment, suggesting that neither surface nor groundwater extraction were major pressures.

There were no mines or quarries in the Boro Creek sub-catchment. Thus sites of pollution or potential contamination are not a major pressure in this sub-catchment. There is a large area of observed gully erosion, cases of observed salinity, and a widespread risk of salinity in this sub-catchment.

Water quality and macroinvertebrate indicators suggest that the waterbodies in the Boro Creek sub-catchment are in a disturbed condition. The single water quality monitoring site in the sub-catchment had exceedences in more than 50 per cent of samples for all four groups of water quality parameters, whilst macroinvertebrate assemblages were either significantly or severely impaired in five out of six samples.

Boro Creek was identified by the SCA's Riparian Zone Index as a sub-catchment with moderate standing vegetation cover along its riparian zones, which indicates that water quality and ecosystem health are at risk. This is reflected in the findings for the macroinvertebrates and fish indicators.

Braidwood Creek

The export potential of phosphorus in the Braidwood Creek sub-catchment was low, whilst export potentials of nitrogen were moderate. There is also a sewage treatment plant at Braidwood.

A relatively small amount of water is permitted to be extracted through water access licences. There is a large number of farm dams, and a small number of groundwater bores.

There are no mines or quarries in this sub-catchment. Thus sites of pollution or potential contamination are not a major pressure in the Braidwood Creek sub-catchment. There was, however, a small amount of land in the Braidwood Creek sub-catchment affected by gully erosion.

Water quality and macroinvertebrate indicators suggest that the waterbodies in the Braidwood Creek sub-catchment are in a disturbed condition. There were two ecosystem water quality sites within the sub-catchment. One of these sites had exceedences in greater than 50 per cent of samples for Physical parameters, both sites for Toxicant parameters, both sites for Nutrient parameters, and one site for Chlorophyll and Dissolved Oxygen. Macroinvertebrate assemblages were either significantly or severely impaired in five out of six samples. Both water quality and macroinvertebrates were monitored at Gillamatong Creek at Braidwood, with exceedences in more than 50 per cent of samples for all four water quality monitoring groups, and significantly impaired AusRivAs macroinvertebrate ratings during the 2007 Audit period. This suggests that Gillamatong Creek is in a disturbed condition. This site is immediately downstream of the urban centre of Braidwood.

Braidwood Creek was identified by the SCA's Riparian Zone Index as a sub-catchment with little or no standing vegetation cover along its riparian zones, which indicates that water quality and ecosystem health are at risk in this sub-catchment. This is reflected in the findings for the macroinvertebrates and fish indicators.

Bungonia Creek

The export potential of phosphorus in the Bungonia Creek sub-catchment was low, whilst export potentials of nitrogen were moderate. There is also an unsewered village in the Bungonia Creek sub-catchment, however no algae was detected at the monitoring site in this sub-catchment.

The Bungonia Creek sub-catchment may be under pressure from the extraction of surface and ground water, as a small volume of water is permitted to be extracted under water access licences, but there is a large number of farm dams and a moderate number of groundwater bores in this sub-catchment.

There is a small number of sites of pollution and potential contamination, and a large number of mines and quarries in the very high, high and medium risk categories in this sub-catchment. There was a moderate area of land in the sub-catchment affected by gully erosion, and there were cases of observed salinity.

Water quality and macroinvertebrate indicators suggest that the waterbodies in the Braidwood Creek sub-catchment are in a disturbed condition. There were two ecosystem water quality sites in the Bungonia Creek

sub-catchment, both of which had exceedences in greater than 50 per cent of samples for Physical, Toxicant, and Nutrient parameters, and one site for Chlorophyll and Dissolved Oxygen. Macroinvertebrate assemblages were either significantly or severely impaired in four out of six samples in the Bungonia Creek sub-catchment. The site on the Shoalhaven River at Fossickers Flat had exceedences in more than 50 per cent of samples for three water quality parameter groups, and also had significantly impaired AusRivAs macroinvertebrate health ratings during the 2007 Audit period.

In contrast to the water quality and macroinvertebrate indicator findings, fish communities in the Shoalhaven River in the Bungonia Creek sub-catchment appeared to be in moderately good condition, as four out of six species caught were endemic, and two were introduced. Also, the Bungonia Creek sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with good standing vegetation cover along its riparian zones.

Endrick River

The Endrick River sub-catchment has relatively low phosphorus and nitrogen export potentials, and it has a single unsewered village. Thus it is does not appear to be under pressure from nutrient loads.

Only a small volume of water is licensed to be extracted by water access licences and there is a relatively small number of farm dams in the sub-catchment, suggesting that surface water extraction is not a major pressure in this sub-catchment.

There are two quarries in the sub-catchment, and a minimal area of observed gully erosion.

Out of five macroinvertebrate samples at three sites in the sub-catchment, one site received an AusRivAs rating of significantly impaired, and one received a severely impaired rating, suggesting that macroinvertebrate assemblages in the sub-catchment may be under pressure.

However, the Endrick River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with good standing vegetation cover along its riparian zones.

Jerrabattagulla Creek

The export potential of phosphorus in the Jerrabattagulla Creek sub-catchment was low, and nitrogen was at a moderate level.

Only a small volume of water is licensed to be extracted by water access licences and there is a relatively small number of farm dams in the sub-catchment, suggesting that surface water extraction is not a major pressure in this sub-catchment. There is also a minimal number of groundwater bores.

There were no sites of pollution or potential contamination, mines or quarries in the sub-catchment, but there was a small area of land affected by gully erosion.

All five macroinvertebrate samples in the Jerrabattagulla Creek sub-catchment received either similar to or richer than reference condition AusRivAs ratings, suggesting that aquatic ecosystems in this sub-catchment are in good condition.

However, Jerrabattagulla Creek was identified by the SCA's riparian zone index as a sub-catchment with moderate standing riparian vegetation cover, which indicates that ecosystem health and water quality may be at risk.

Kowmung River

The Kowmung River sub-catchment has moderate phosphorus and nitrogen export potentials, and no unsewered villages. No pathogens were detected at the single monitoring site in this sub-catchment.

Only a small volume of water is licensed to be extracted by water access licences and there is a relatively small number of farm dams and groundwater bores, suggesting that surface and ground water extraction are not a major pressures in this sub-catchment.

There was one site of potential contamination, and one mine in the Kowmung River sub-catchment, and a small area of land affected by gully erosion.

The single water quality monitoring site in the sub-catchment had exceedences in more than 50 per cent of samples for Toxicant and Nutrient parameters, and no exceedences for Physical parameters or Chlorophyll and Dissolved Oxygen. Out of nine macroinvertebrate samples in the sub-catchment, three sites received

significantly or severely impaired AusRivAs ratings, suggesting that macroinvertebrate assemblages in the sub-catchment may be under pressure.

However, Kowmung River was identified by the SCA's Riparian Zone Index as a sub-catchment with a high percentage of standing vegetation cover along its riparian zones, and has greater than 80 per cent native vegetation cover.

Lake Burragorang

The Lake Burragorang sub-catchment had low phosphorus and nitrogen export potentials, and two unsewered villages. Cyanobacteria was present at three out of five algal monitoring sites in the sub-catchment, but no pathogens were detected at the single pathogen monitoring site.

Only a small volume of water is licensed to be extracted by water access licences and there is a small number of farm dams and groundwater bores in the sub-catchment, suggesting that surface and ground water extraction are not major pressures in this sub-catchment.

There is a small number of sites of pollution or potential contamination, but a large number of mines and quarries in the medium, high and very high risk categories in this sub-catchment. There was no observed soil erosion.

All five ecosystem water quality monitoring sites had exceedences in more than 50 per cent of samples for Physical, Nutrients and Chlorophyll and Dissolved Oxygen parameter groups. Two out of the five sites had exceedences in more than 50 per cent of samples for Toxicant parameters. This suggests that ecosystem water quality may be degraded in the Lake Burragorang sub-catchment. Three out of four macroinvertebrate samples received significantly or severely impaired AusRivAs ratings, suggesting that water bodies in this sub-catchment are in a disturbed condition.

In contrast to the water quality findings, the fish indicator suggests that Lake Burragorang may be in a relatively undisturbed condition. Eight species of fish were caught, of which seven were endemic, and one was introduced. Lake Burragorang was identified by the SCA's Riparian Zone Index as the sub-catchment with the highest percentage of standing vegetation cover along its riparian zones and greater than 80 per cent native vegetation cover.

Little River

The Little River sub-catchment has relatively low phosphorus and nitrogen export potentials, and two unsewered villages, one of which (Buxton) is one of the largest remaining unsewered villages in the Catchment. No pathogens were detected at the single monitoring site in the Little River sub-catchment.

Only a small volume of water is licensed to be extracted by water access licences and there is a relatively small number of farm dams and groundwater bores in the sub-catchment, suggesting that surface and ground water extraction are not major pressures in this sub-catchment.

There was a small number of sites of pollution and potential contamination, and no mines, quarries or soil erosion in the sub-catchment.

The single water quality monitoring site in the Little River sub-catchment had exceedences in more than 50 per cent of samples for Toxicant and Nutrient parameters, but not for Physical parameters or Chlorophyll and Dissolved Oxygen. Four out of five macroinvertebrate samples in the Little River sub-catchment received significantly or severely impaired AusRivAs ratings, suggesting that macroinvertebrate assemblages in the sub-catchment may be under pressure. A single endemic species of fish was caught in Little River.

Little River was identified by the SCA's Riparian Zone Index as a sub-catchment with one of the highest percentages of standing vegetation cover along its riparian zones and has greater than 80 per cent native vegetation cover.

Mid Shoalhaven River

The Mid Shoalhaven River sub-catchment had low phosphorus and nitrogen export potentials, and no unsewered villages.

Only a small volume of water is licensed to be extracted by water access licences and there is a relatively small number of farm dams and groundwater bores, suggesting that surface and ground water extraction are not major pressures in this sub-catchment.

There is a single site of potential contamination and two quarries in the Mid Shoalhaven River sub-catchment. There is a small area of land affected by gully erosion, and the Mid Shoalhaven River sub-catchment has been identified as having widespread risk of salinity.

There were two ecosystem water quality sites in the sub-catchment. One of these sites had exceedences in greater than 50 per cent of samples for Physical parameters, both sites for Toxicant parameters, neither site for Nutrient parameters, and one site for Chlorophyll and Dissolved Oxygen. Two out of six macroinvertebrate samples received significantly or severely impaired AusRivAs ratings.

The Mid Shoalhaven River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with good standing vegetation cover along its riparian zones.

Mongarlowe River

The Mongarlowe River sub-catchment had low phosphorus and moderate nitrogen export potentials, and one unsewered village.

Only a small volume of water is licensed to be extracted by water access licences and there is a relatively small number of farm dams and groundwater bores in the sub-catchment, suggesting that surface and ground water extraction are not major pressures in this sub-catchment.

There is a small number of sites of pollution and potential contamination, but no mines or quarries. A small area of land is affected by gully erosion.

Water quality, macroinvertebrate and fish indicators all suggest that the waterbodies in the Mongarlowe River sub-catchment are in good condition. There was a single water quality monitoring site in the Mongarlowe River sub-catchment, which had exceedences in over 50 per cent of samples for the Toxicant parameter group. Only one out of seven macroinvertebrate samples from the Mongarlowe River received an impaired AusRivAs rating, and five species of fish were caught in the Mongarlowe River, all of which were endemic.

Mongarlowe River was identified by the SCA's Riparian Zone Index as a sub-catchment with moderate standing vegetation cover along its riparian zones. This indicates that water quality and ecosystem health is potentially at risk in this sub-catchment, however this is not reflected in the findings for the water quality, macroinvertebrate and fish indicators.

Nattai River

The Nattai River sub-catchment had low phosphorus and moderate nitrogen export potentials, and one sewage treatment plant. Pathogens were detected at one of the three monitoring sites in the Nattai River sub-catchment.

Only a small volume of water is licensed to be extracted by water access licences and there is a relatively small number of farm dams in the sub-catchment, suggesting that surface water extraction is not a major pressure in this sub-catchment. However, there was a moderate number of groundwater bores, which indicates that groundwater resources may be under pressure.

There is a small number of sites of pollution and potential contamination, two mines and a single quarry in the sub-catchment, and a small area of the sub-catchment is affected by gully erosion.

All three water quality monitoring sites had exceedences in more than 50 per cent of samples for Toxicant and Nutrient parameters. Two sites had exceedences in more than 50 per cent of samples for Physical parameters, and one site Chlorophyll and Dissolved Oxygen. This indicates that water quality in the Nattai River sub-catchment is degraded. Four of the eight macroinvertebrate samples received significantly or severely impaired AusRivAs ratings, suggesting that some parts of the water bodies in the sub-catchment may be in a disturbed condition. The Nattai River at Smallwood's Crossing had poor ecosystem water quality (exceedences in more than 50 per cent of samples for two of the parameter groups) and also poor macroinvertebrate health (significantly impaired AusRivAs health ratings) during the 2007 Audit period.

Four species of fish were caught from the Nattai River, of these three were endemic, and one was introduced, which suggests that the Nattai River may be in relatively good condition for fish.

Nattai River was identified by the SCA's Riparian Zone Index as a sub-catchment with a high percentage of standing vegetation cover along its riparian zones and has greater than 80 per cent native vegetation cover.

Nerrimunga River

The export potential of phosphorus in the Nerrimunga River sub-catchment was low, and nitrogen was at a moderate level.

Only a small volume of water is licensed to be extracted by water access licences, however there was a large number of farm dams in this sub-catchment, indicating that surface water extraction may be a pressure in this sub-catchment. There was a small number of groundwater bores.

There is a large area of rural residential in the Nerrimunga River sub-catchment. There is only one site of pollution or potential contamination, but a large number of mines and quarries, and a small area of land affected by gully erosion. Nerrimunga River sub-catchment also has observed salinity cases, and widespread risk of salinity.

Five out of six macroinvertebrate sites received significantly or severely impaired AusRivAs ratings, suggesting that water bodies in the sub-catchment may be in a disturbed condition.

The Nerrimunga River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with moderate standing vegetation cover along its riparian zones. This indicates that water quality and ecosystem health is potentially at risk in this sub-catchment, which is reflected in the findings for the macroinvertebrate indicator.

O'Hares Creek

A small volume of water is licensed to be extracted by water access licences in the O'Hares Creek sub-catchment, and there is a small number of farm dams in this sub-catchment. This sub-catchment has greater than 80 per cent native vegetation cover.

Reedy Creek

The export potential of phosphorus in the Reedy Creek sub-catchment was moderate, whilst the export potential of nitrogen was one of the highest in the whole Catchment.

Only a small volume of water is licensed to be extracted by water access licences, and there is a small number of groundwater bores. However, there was a large number of farm dams in this sub-catchment, indicating that surface water extraction may be a pressure in this sub-catchment.

The Reedy Creek sub-catchment has a large area of pastureland. There is a small number of sites of pollution and potential contamination, and no mines or quarries. There is a moderate area of land in this sub-catchment affected by gully erosion, and cases of observed salinity.

Two out of six macroinvertebrate sites received significantly or severely impaired AusRivAs ratings. The Reedy Creek sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with little or no standing vegetation cover along its riparian zones. This indicates that water quality and ecosystem health is potentially at risk in this sub-catchment.

Upper Nepean River

The Upper Nepean River sub-catchment had low phosphorus and moderate nitrogen export potentials, and two unsewered villages. No cyanobacteria was detected at any of the five monitoring sites in the sub-catchment.

Only a small volume of water is licensed to be extracted under water access licences, and there is a relatively small number of farm dams in this sub-catchment, indicating that surface water extraction is not a major pressure in this sub-catchment. However, there was a moderate number of groundwater bores, indicating that groundwater resources may be under pressure in this sub-catchment. Large volumes of bulk water are transferred from Wingecarribee Reservoir to Nepean Dam via local creeks in the sub-catchment suggesting that those creeks may be impacted by these artificial flow regimes.

There was a moderate number of sites of pollution and potential contamination, and a moderate number of mines and quarries, suggesting that these may be important pressures in this sub-catchment. However, there is no observed gully erosion in this sub-catchment.

There are twelve ecosystem water quality monitoring sites in the Upper Nepean River sub-catchment. Five of these sites had exceedences in greater than 50 per cent of samples for Physical parameters, seven sites for Toxicant parameters, nine sites for Nutrient parameters, and eight sites for Chlorophyll and Dissolved

Oxygen. This suggests that the ecosystem water quality in the Upper Nepean River sub-catchment is degraded.

In contrast with the water quality indicator findings, the macroinvertebrate and fish indicators suggest that waterbodies in the sub-catchment are in good condition. All six macroinvertebrate samples within the sub-catchment received similar to or richer than reference condition AusRivAs ratings.

Fish sampling occurred in nine major water bodies in the Upper Nepean River sub-catchment. Five species of fish were caught in the Avon River, of which four were endemic and one was introduced. Three species of fish were caught in the Burke River, all of which were endemic. Five species of fish were caught in Cataract Dam, of which two were endemic, two were translocated, and one was introduced. Seven species of fish were caught in the Cataract River, of which five were endemic, one was translocated, and one was introduced. A single endemic species of fish was caught in the Little Burke River. Two species of fish were caught in the Loddon Creek, both of which were endemic. Six species of fish were caught in the Nepean River, of which five were endemic and one was introduced. Three species of fish were caught in the Wallandoola Creek, all three of which were endemic. Five species of fish were caught in the Wongawilli Creek, all five of which were endemic. On the whole the fish populations in the Upper Nepean River sub-catchment appear to be largely composed of endemic species, suggesting that the water bodies in this sub-catchment may be in a relatively undisturbed condition.

The Upper Nepean River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with good standing vegetation cover along its riparian zones and has greater than 80 per cent native vegetation cover.

Upper Shoalhaven River

The Upper Shoalhaven River sub-catchment has relatively low phosphorus and nitrogen export potentials.

Only a small volume of water is licensed to be extracted by water access licences, and there is a moderate number of farm dams in this sub-catchment suggesting that surface water extraction is not a major pressure in this sub-catchment. A small area of the sub-catchment is affected by gully erosion.

All seven macroinvertebrate samples received similar to or richer than reference condition AusRivAs ratings, suggesting that the Upper Shoalhaven River sub-catchment may be in a relatively undisturbed condition.

The Upper Shoalhaven River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with good standing vegetation cover along its riparian zones and has greater than 80 per cent native vegetation cover.

Woronora River

The Woronora River sub-catchment has relatively low phosphorus and nitrogen export potentials. No cyanobacteria was present at the single monitoring site in the sub-catchment.

Only a small volume of water is licensed to be extracted by water access licences and there is a minimal number of farm dams and groundwater bores in the sub-catchment, suggesting that surface and ground water extraction are not major pressures in this sub-catchment.

There was a small number of sites of pollution and potential contamination, a single quarry, and no observed gully erosion in the Woronora River sub-catchment. Bed cracking has occurred in Waratah Rivulet, a major tributary, in an area subject to underground long wall coal mining.

Two out of four water quality monitoring sites had exceedences in more than 50 per cent of samples for Toxicant and Nutrient parameters. One site had exceedences in more than 50 per cent of samples for Physical parameters, and no sites for Chlorophyll and Dissolved Oxygen. Four out of six macroinvertebrate samples received significantly or severely impaired AusRivAs health ratings, suggesting that the Woronora River sub-catchment may be in a disturbed condition. During the 2007 Audit period, Woronora River at the Needles had poor ecosystem water quality (exceedences in more than 50 per cent of samples for two of the parameter groups) and also poor macroinvertebrate health (a severely impaired AusRivAs health rating in 2005 and a significantly impaired AusRivAs health rating in 2006).

The Woronora River sub-catchment was identified by the SCA's Riparian Zone Index as a sub-catchment with a high percentage of standing vegetation cover along its riparian zones and has greater than 80 per cent native vegetation cover.

Chapter 8
Management Overview

Raw Water Quality

The findings highlighted that there are many potential point and diffuse sources of nutrients in the Catchment. A range of programs are necessary to achieve needed nutrient reductions across the Catchment, using tools ranging from strategic land-use planning through control of both point and diffuse sources, to on-ground works.

STSs in the Catchment need to be continually managed to protect water quality in the Catchment, including establishing clear strategies for upgrading and augmenting STPs and reticulation systems to accommodate anticipated growth and to improve current treatment and disposal practices where practicable. The strategies need to plan for a range of potential growth scenarios, include funding options and seek to minimise nutrient load growth through treatment upgrades and effluent re-use opportunities in appropriate timeframes.

At the on-ground level, reduction in nutrient export from diffuse sources can be achieved through good land-use management practices as well as through specific riparian vegetation, erosion control and streambank stabilisation projects. Diffuse source nutrient control programs should therefore be integrated with programs for riparian management and erosion control to obtain multiple water quality, land management and ecosystem health benefits where possible. This requires significant coordination across organisations and landholders that are involved in funding and managing these types of programs. Relevant organisations therefore need to be collaborating to ensure programs are complementary and target high priority nutrient areas and locations.

A better understanding of the magnitude and pattern of delivery of nutrient loadings is required to further optimise management strategies to reduce nutrient loads and mitigate impacts. As a first step, nutrient budgets are being constructed by SCA to determine the relative contributions from sources, such as sewage, stormwater, agricultural runoff and erosion, as well as the in-stream stocks, such as sediment deposits, to the yield of nutrients reaching reservoirs.

Most of the nutrient delivery off catchment lands takes place in association with rainfall events. Therefore, it is important to understand the quantitative relationship between these natural processes and nutrient delivery. Nutrient budgets will be informed not only by tracing tools, but also with data from event-based sampling programs.

Predictive models may be helpful in investigating the source of pathogens in the Catchment. When modelling the fate of pathogens in the environment, the inactivation rates must be appropriate for the temperature of the climate in question and where the river intrusion is because this is where the pathogens are likely to be. Sampling in the reservoir should target the river intrusion to facilitate the best measure of pathogen risk.

Studies have found that fully protected catchments have by far the highest water quality even during rain events. This demonstrates the value of catchment protection and access exclusion policies. Intensive agricultural development in less than 5 per cent of a catchment area leads to a doubling in pathogen concentrations and risk. Even during baseline/small storm events, source water quality has been found to be heavily degraded in unprotected agricultural/urbanised catchments.

A large number of programs to investigate and understand nutrient sources (point and diffuse), algal blooms and pathogens have been underway in the Catchment during the 2007 Audit period. There are also a number of programs to reduce point and diffuse sources of nutrients to the Catchment. Reducing nutrient sources will reduce algal blooms, however, with the increased knowledge of nutrients and algal blooms in the Catchment, on-ground programs are needed that target areas which continue to be at risk of algal blooms. The development of a pathogen budget to prioritise land uses and rectification actions to further reduce public health risks from pathogens is also needed in the Catchment.

Managing Water Resources

Better quantification of actual extraction volumes and the impact of different extraction levels on ecosystem health are required to guide sustainable water resource allocation decisions in the Catchment. This is particularly important in drought conditions where water supplies and ecosystem health are likely to be under pressure and knowledge about trade offs is required in water resource management decisions.

A Water Sharing Plan for the Greater Metropolitan Region is presently being developed. This plan will include rules on surface water extraction by irrigators and other water uses. A program to require monitoring of actual extraction volumes in the Catchment has also commenced.

The specific dynamics of the interaction between surface and groundwater systems in the Catchment is not well documented or understood. This interaction is particularly important to groundwater dependent ecosystems, to base flow and possibly to surface water quality during low flow and drought conditions.

The decision to reduce environmental flows as a drought response highlights that the water resource is limited and that environmental flows need to be well managed to protect Catchment health. Under the Metropolitan Water Plan improved regimes of environmental releases will be gradually implemented at SCA storages, and will be reflected in the Water Sharing Plan. The river reaches below SCA's four upper Nepean dams in the Catchment are expected to show environmental benefits from new flow release arrangements. The Water Sharing Plans will be critical to securing water for the environment and in maintaining aquatic and riparian ecosystem health in the Catchment. Continued assessment of flow regimes, water quality and riparian and aquatic ecosystem health should inform periodic reviews of the Water Sharing Plans.

The current bulk water transfers through natural watercourses in the Catchment are a risk to ecosystem health. Increasing flow releases can improve downstream water quality in the river, but can adversely impact on landholders, on aquatic life and on riverbanks. These need to be managed, and some of the impacts can be mitigated, through channelisation, bank protection and pipework.

Programs in the Catchment address the drought, encourage more efficient water use and manage water resources in the Catchment. However, the completion of Water Sharing Plans, implementation of NSW Water Extraction Monitoring Policy and measures to minimise the impact of the bulk water transfers need to be finalised.

Coordinated research into the impact of different extraction levels and flow regimes on riparian and aquatic ecosystems in the Catchment is needed. This research should seek to improve the understanding upon which Water Sharing Plans and other water resource initiatives in the Catchment are developed, reviewed and refined. A Water Sharing Plan for the Catchment is required as soon as practicable.

Land Condition

Changes in land use, particularly those changes leading to the removal of native vegetation and disruption of soil almost inevitably lead to increased impact on land condition and water quality. However, with appropriate design and management, such impacts can be minimised and potentially lead to overall improved outcomes especially where degraded landscapes are rehabilitated and best practice water sensitive design principles are implemented.

There is a large number of activities in the Catchment with the potential to impact land condition and water quality if they are not appropriately managed. The assessment of actual risk at sites of potential pollution and contamination should be continued, and actions implemented to reduce risks where necessary. The risk of pollution and contamination at operational sites should be reassessed at a frequency commensurate with the inherent risk of the activity type, site specific risks and known performance history of the landholder/operator.

The continuation of effective and rigorous application of neutral or beneficial effects criteria in REP 1 to new activities in the Catchment provides a framework for on-ground actions to reduce land degradation, pollution and to achieve better management of land that are already degraded in the Catchment.

Management programs need to reduce the risks of erosion and salinity as well as manage and rehabilitate actual cases on the ground. Programs to manage the risk of erosion and salinity should also be integrated with programs to protect and rehabilitate native and riparian vegetation to obtain multiple benefits from on-ground works. There has been inadequate recording of information about the location of erosion

management works in the Catchment, in particular. The location, type and area of all erosion management works in the Catchment should be recorded on a centralised spatial information system to enable the co-ordination of erosion management works between programs and agencies and to maximise the potential for integrating erosion works with other potentially complementary programs such as nutrient reduction and riparian and native vegetation rehabilitation works.

Ecosystem Health

There are several sub-catchments with few or no monitoring sites where water quality could be expected to be under stress. The current water quality monitoring program does not give a comprehensive picture of water quality throughout the Catchment.

The spatial coverage of macroinvertebrate monitoring across the Catchment is generally better than for the water quality monitoring, as more sub-catchments are monitored. The integration of macroinvertebrate and water quality monitoring in the Catchment would be beneficial to provide capacity for a more comprehensive assessment of Catchment condition, and interpretation of results. Such integration may also enable more focused management responses to identified changes in the condition of macroinvertebrate assemblages.

The monitoring of ecosystem water quality, macroinvertebrate and fish communities provide useful information about the state of the Catchment. Integrating these three strands of monitoring should be a priority. Given the current initiatives to develop an Integrated Monitoring Program for the Hawkesbury-Nepean River and the development of a Monitoring Evaluation and Reporting program for a Rivers Theme under the NSW MER Strategy, now is the time to ensure that those various initiatives integrate with the need for monitoring information in the Catchment. Actions that respond to and investigate reduced water quality and impaired macroinvertebrate and fish communities also now need to be developed and implemented based on the monitoring information.

Healthy riparian zones assist in maintaining the health of rivers and streams in the Catchment, thereby enhancing the first of the multiple barriers in protecting drinking water quality. Riparian zones are particularly important for water quality in areas where the adjacent land is subject to activities such as agricultural or urban land use.

Some areas of the Catchment play a particularly important role in preventing pollutants entering the water supply and proper management and ongoing monitoring of vegetation within these areas is clearly important in maintaining water quality and quantity. These areas include those in immediate proximity to the water storages, riverine corridors and flood prone lands.

There are many programs for restoration and rehabilitation of riparian zones, which are all likely to contribute to an improvement in the health of riparian zones and provide improved protection of water quality. While records are maintained by relevant agencies and organisations about individual programs for riparian management, there does not appear to be a systematic use of measures to record the extent of this work. This information should be collected systematically across the Catchment to enable better information for both future audits and development and co-ordination of management decisions. All on-ground works being undertaken in the Catchment to revegetate and rehabilitate native vegetation should be integrated and a spatial database of location, type and area of works created and maintained.

Climate Change in the Catchment

The CSIRO produced reports in 2006 on Climate Change in the Hawkesbury-Nepean and Southern Rivers catchments for the NSW Government (CSIRO 2007a, 2007b). The following text is reproduced from these reports.

Since 1950, the Hawkesbury-Nepean and Southern Rivers regions have experienced warming of around 0.8ºC and a significant drop in annual rainfall at a rate of approximately 20–50 mm per decade, depending on location. The report states that although changes in average temperature, rainfall and evaporation will have long-term consequences for the Catchment, the impacts of climate change are more likely to be felt through extreme weather events. Projections suggest that there will be more hot days, bushfires, droughts and intense storms.

The future climate of the Hawkesbury-Nepean Catchment is likely to be warmer and for the Southern Rivers catchment warmer and drier. Such climate changes would also increase evaporation, increase heat waves,

extreme winds and fire risk. Nevertheless, despite this trend toward drier conditions, there is also potential for seasonal increases in extreme rainfall events in both catchments.

Water

Changes in rainfall and higher evaporation rates are likely to lead to less water for streams and rivers in the Hawkesbury-Nepean and Southern Rivers catchments, which will have downstream consequences for storages and place strains in the catchment's water resources. Various studies of stream flows in NSW indicate that climate change is likely to reduce flows in the future. This has implications not only for water users in the catchments, but also for neighbouring Sydney, which derives the majority of its drinking water from the Hawkesbury-Nepean and Southern Rivers catchments. Lower flows and higher temperatures may also reduce water quality within the Catchment. For example, low flows, higher temperatures and elevated nutrients create a more favourable environment for potentially harmful algal blooms. Greater fire activity could contaminate water catchments with sediment and ash.

The impact of water-sharing plans is expected to be positive for the environment. However, the expected drying of south-eastern Australia due to climate change is a major risk factor for environmental flow regimes and, therefore, for the health of riverine ecosystems, because it is likely to increase the frequency of dry years. Other risk factors for flow regimes are afforestation programs, groundwater extraction, changes to irrigation water management, farm dams and bushfires.

Land

Heavy rains and winds from storm events also contribute to crop damage and soil erosion. The reduction of soil erosion rates will require the wider adoption of sustainable land management, better preparation for droughts, and the remediation of past degradation. The wider adoption of more-sustainable practices will also assist in addressing a number of other land-management issues, including land clearing, riparian vegetation management, dryland salinisation, soil structure decline and soil acidification. Taken together these measures to reduce soil erosion will help deliver multiple outcomes towards soil health, biodiversity and river health.

Farms

The key consequence of climate change on farming will be rainfall. Any reduction in rainfall will place most farms under stress, particularly when linked to higher temperatures. For dryland cropping, reductions in rainfall and increases in evaporation directly contribute to reductions in soil moisture. Meanwhile, irrigated agriculture is likely to be affected by tighter constraints on water allocations.

The dairy and horticultural industries in the Southern Rivers catchment are likely to be affected by reductions in water availability meaning that water efficiency will be increasingly important. Warmer temperatures will increase heat stress on dairy cattle, reducing milk production unless management measures such as shade sheds and sprinklers are adopted (CSIRO, 2000). Indirect impacts due to changes in weeds, pests and international markets may also place farms under stress.

Biodiversity

Changes to the climate will have significant effects on the catchment's plants and animals. Although currents threats to the catchment's biodiversity are largely a product of historical land clearing, climate change is likely to increase the need for conservation efforts. Climate change is likely to drive changes to the distribution of some plant and animal species, driving some species out of the catchment or enabling invaders to move in. Meanwhile, even those species capable of coping with climate change alone may succumb to the cumulative effects of multiple stressors.

Reductions in flows in streams within the catchment are likely to have a negative impact on aquatic biodiversity and wetland ecosystems. Plants and animals may become stranded in isolated remnants of vegetation due to changing climate and continued development in the catchment. More frequent droughts and fires are likely to increase stress on plants and animals.

Forests

The forests, woodlands and natural vegetation of the catchment are a significant asset that is managed for biodiversity conservation, maintenance of water quality, recreation and other purposes. Climate change is likely to lead to changes in the distribution of tree species, possible increased invasion by pests, and changes

to the habitat that those areas provide for local plants and animals. This will raise new challenges in managing forest areas for biodiversity conservation.

Some potential adaptation measures in response to climate change relevant to the Catchment include:

- linking national parks and remnant vegetation to support migration of species
- developing best practice for environmental management
- improving water-use efficiency
- changing to crops that are more tolerant of heat and drought
- changing planting times and practices for crops
- providing more shade and cooling for livestock
- reviewing flood and fire management arrangements

Chapter 9
Audit Recommendations

9.1 Overview

Chapter 2 of this report described how the 2007 Auditor undertook a review of the progress made on 25 recommendations made by the 2005 Auditor. Chapters 3 to 6 examined the state of the Catchment within each of the four Audit themes in the 2007 Audit period, and the Auditor made recommendations as the need arose on a range of matters that emerged from the findings and implications within those four themes.

The purposes of this concluding chapter are to:

- record the outcomes of the review of the 2005 Audit recommendations and their status in 2007
- record the retention of 2005 recommendations where relevant
- record new recommendations where sufficient progress had not been achieved since 2005
- record new recommendations arising from the 2007 Audit
- compile all the above recommendations into a single set of 2007 recommendations to support the successful delivery of future catchment audits.

9.2 Review of the 2005 Recommendations

To review the 2005 Audit recommendations, the 2007 Auditor sought responses from resource management agencies in the Catchment on the nature and extent of actions they had undertaken in line with those recommendations. The Auditor then assessed those responses for their adequacy and effectiveness in addressing the original recommendations.

Table 9.1 summarises the outcomes of the review, and presents the status of all 25 recommendations from the 2005 Audit at the end of the 2007 Audit period. The 2007 Auditor's responses are also presented.

Table 9.1: Progress of the 2005 Audit Recommendations

	2005 Recommendation	Status in 2007	Auditor's response
1	DEC, the SCA and the NRC give further consideration to integrating catchment and natural resource management audit processes and NSW State of the Environment reporting.	under way SCA anticipates that the review of the *Sydney Water Catchment Management Act 1998* (the Act) will progress this.	The Auditor notes that the next review of the Act will be in 2009. Next SoE report is in 2009, coinciding with the next Audit, and with the first natural resource (MER) reporting through the SoE process. Further action is required. See later in this Section for recommendation(s).
2	The SCA work with DNR and councils to establish a spatial information system to track and record the date, type and location of all on-ground works being undertaken or funded by Government for the purpose of water quality and ecosystem health management in the Catchment.	under way A Land Management Database (LMD) is already used by H-N CMA. SCA is investigating options for spatial information systems including LMD.	The Auditor notes that progress is being made, but spatial information on works in the Catchment under various programs was not yet available for the Audit. Further **coordinated** action is required. See Chapter 6 Section 6.2 for recommendation(s).

	2005 Recommendation	Status in 2007	Auditor's response
3	The SCA examine the potential for, and benefits of, integrating ecosystem water quality, macroinvertebrate, fish (when developed) and riparian vegetation condition monitoring programs.	under way SCA will consider during its review of the water quality monitoring program in its Operating Licence.	The Auditor notes that the current monitoring program runs to the end of 2009, and that the SCA is developing a strategy and timeframe for further improving the monitoring program by 30 November 2007. The Auditor believes that further examination of integration is required, in SCA's planned November 2007 work. It is necessary, also, to consider how SCA monitoring intersects with monitoring programs being developed under the NSW MER Strategy and the Hawkesbury-Nepean Integrated Monitoring Program being developed by the DECC. See Chapter 6 Section 6.2 for recommendation(s).
4	The SCA further develop L-THIA nutrient modelling for all sub-catchments to assist in prioritising nutrient reduction programs.	not adopted SCA relies on risk assessment methodology to prioritise nutrient reduction programs.	The Auditor notes that SCA has moved to a risk assessment methodology, as described in its 'Water Quality Risk Management Framework' document provided to the Audit. The Auditor notes that modelling is a part of the SCA's management process. See Future Directions in Section 3.1 for further comment. No further action is required on the specific recommendation.
5	The SCA focus its programs for nutrient reduction from diffuse sources on the Wingecarribee River (priority), Wollondilly River (priority), and Mulwaree River (priority) sub-catchments, and encourage other organisations undertaking related programs to focus on these same sub-catchments where possible.	under way SCA Catchment Planning Process has produced a list of priority issues and actions in the identified areas, for implementation through partnerships under the Healthy Catchments Program.	The Auditor notes that identified issues and actions are reported in the SCA's 'Report on Catchment Management and Protection Activities' provided to the Audit. Continued action is required to address the prioritised nutrient reduction issues.
6	The SCA identify the cause of exceedence of the Bulk Water Supply Agreement (BWSA) for turbidity, pH and algae at water filtration plants.	completed SCA, Department of Health and Sydney Water investigations concluded that the drought was responsible. The ability of filtration plants to produce drinking water to standards was not compromised.	The Auditor found increased compliance with BWSA requirements in the 2007 Audit period. Continued action is required to address exceedences reported in the 2007 Audit.
7	The SCA identify the cause of the 'high' incidences of algal blooms in the Kangaroo River (priority), Wingecarribee River (priority), Mid Coxs River (priority) and Lake Burragorang sub-catchments and develop specific management strategies for each location.	completed SCA has Cyanobacterial Risk Management Strategy, and Rectification Action Planning identifies these sub-catchments as very high risk.	SCA has provided its 'Cyanobacterial Risk Management Strategy' document to the Audit, and management strategies have been formulated. However, the specific cause of the incidences has not been identified. The Auditor found that the presence of algal blooms persisted in the water storages. Further action is required. See Chapter 3 Section 3.3 for recommendation(s).

	2005 Recommendation	Status in 2007	Auditor's response
8	The SCA investigate the source of *Cryptosporidium* oocysts at Gibbergunyah Creek and Prospect WFP and the source of *Giardia* cysts at Gibbergunyah Creek, Kedumba Creek, Wollondilly River at Jooriland and Murray's Flat, and develop a management response at each location to reduce the incidence of C*ryptosporidium* and *Giardia* oocysts and cyst presence.	under way Further monitoring and collaborative research have been done to validate the results that generated this recommendation.	SCA has provided the 2007 Audit with a list of research undertaken on this matter. No investigation has been undertaken on source identification. The Auditor notes the persistent presence of pathogens in certain creeks. Investigation of the **causes** is required. See Chapter 3 Section 3.4 for recommendation(s).
9	The DNR undertake research into the impact of different levels of water extraction and harvesting of water in farm dams on flow regimes and ecosystem health within the Catchment, focussing on the sub-catchments most under pressure from water extraction and water harvesting.	completed SCA states that DWE did a study that indicated 'no significant impact' on flow regimes and ecosystem health. DWE describes preparation of draft Greater Metropolitan Region water sharing plan, in which hydrological stress attributable to farm dams was not addressed, rather than completed and assessed as 'not significant'.	The Auditor notes the agencies' expressed positions on this recommendation. The Auditor also notes work in a recent unpublished report on the distribution of farm dams in the SCA's area of operations provided to the Audit by the SCA. The report includes internal SCA recommendations for examining knowledge gaps in farm dam proliferation and environmental impacts, which the Auditor endorses for continued action.
10	The DNR use the results of research and improved knowledge about the impacts of water extraction and water harvesting in periodic reviews of Water Sharing Plans in the Catchment.	not applicable SCA notes that Water Sharing Plans have not yet been finalised. DWE describes how hydrology modelling used in the preparation of the draft Greater Metro Region Water Sharing Plan has used available understanding and local knowledge to develop draft access rules, extraction limits and environmental flows.	Noted. See Chapter 4 Section 4.3 for recommendation(s).
11	The DNR require groundwater extraction volume metering and reporting with a priority for implementation on licences in the Southern Highlands, Kangaroo River (priority), Werriberri Creek (priority) and Wingecarribee River (priority) sub-catchments.	under way SCA reports that DWE is rolling out a program of metering water extraction across the State over a number of years. DWE undertakes to consider the listed sub-catchments as priorities in its program.	The Auditor accepts that satisfactory progress is being made on this recommendation. However, the Auditor notes that there is no specific commitment by DWE that the nominated sub-catchments will be given priority status. Continued action is required on this issue.

	2005 Recommendation	Status in 2007	Auditor's response
12	The DNR give consideration to locating new monitoring bores in the Southern Highlands, Kangaroo River (priority), Werriberri Creek (priority) and Wingecarribee River (priority) sub-catchments.	under way SCA reports that DWE will include these areas for consideration when setting drilling priorities over the next 2 years. DWE reports that it has considered these sites, but new bores will not proceed at this time, due to a lack of drilling resources. DWE notes that it will receive data from new SCA monitoring bores in the Southern Highlands.	The Auditor accepts that satisfactory progress is being made on this recommendation, and continued action is required.
13	The DNR develop a hydrological model that investigates the interaction between surface and groundwater systems and that can be used to manage surface and ground water extraction from the Catchment.	not adopted SCA reports that development of this model is not a DWE priority. DWE reports that groundwater investigations in the Catchment are being led by SCA, and its submission indicates that monitoring rather than modelling is the primary tool for assessing surface / groundwater interaction.	Noted. The Auditor accepts the agencies' views that a different investigative approach is being used but notes that this issue remains one of high priority.
14	The DNR develop and implement systems for measuring and reporting of flow and flow variability for all sub-catchments to support the implementation of extraction rules and periodic review of the Water Sharing Plans.	under way SCA reports that DWE will address this during the implementation of the Water Sharing Plans (once they're finalised). DWE reports that a new State-wide water information communications system is being developed. Data from the SCA's river flow and storage gauges will contribute. However, there's no commitment to cover all subcatchments.	Noted. See Chapter 4 Section 4.3 for recommendation(s).
15	The SCA implement measures recommended by the Wetlands and Woodlots for rock armoury and vegetative stabilisation in Doudles Folly Creek and Glenquarry Creek as an interim measure to reduce streambank erosion caused by bulk water transfers.	under review Action depends on outcomes of Metro Water Plan investigations on bulk water transfers.	The SCA has provided the Auditor with a 2006 assessment of bulk water transfers that concludes that hard structural measures to stabilise the channel were not necessary or appropriate. The Auditor accepts this conclusion.

	2005 Recommendation	Status in 2007	Auditor's response
16	The SCA and the Department of Planning prepare a detailed land use map at five year intervals. The resolution and categorisation should be sufficient so that change from the previous map can be determined.	under way SCA is preparing updated land use mapping, with a review of land use classes.	The Auditor notes that progress is being made, and that DECC is a partner in producing this work. However, updated mapping was not available in time for this Audit. Continued action is required on this recommendation.
17	The SCA identify high risk activities where there is no documented best practice benchmarks, and work with relevant agencies, industries and landholders to develop and implement recommended management practices.	under way SCA notes that development of recommended practices is a Regional Environmental Plan requirement, and that there are 28 documented practices to date.	The Auditor accepts that the action to date is a satisfactory response to the recommendation. Periodic review of the coverage of high risk activities by documented recommended practices is required.
18	The SCA develop pollution prevention or rehabilitation programs at sites identified as very high, high and medium risk to water quality, in consultation with relevant agencies, operators and landholders.	under way SCA has identified 23 very high risk drainage units for certain pollutants.	The Auditor notes the satisfactory progress reported in the SCA's 'Report on Catchment Management and Protection Activities' provided to the Audit. Continued action is required on this recommendation.
19	The DNR develop systems in consultation with the SCA for recording the location, nature and extent of actual cases of soil erosion and land salinity in the Catchment.	under way SCA's Catchment Protection Scheme partnership with CMAs address high active erosion areas, and results are reported in LMD (2005 Recommendation 2). Land salinity mapping is not a priority.	The Auditor notes that salinity data was provided to the Audit for the H-N CMA area only. Continued action is required on this recommendation.
20	Programs addressing soil erosion and salinity in the Catchment target areas with identified risk, and integrate with other programs for riparian and vegetation management where possible.	under way SCA reports that active erosion mapping has been completed for the whole Catchment, and a list of issues and corresponding actions produced. Erosion programs will be implemented through partnerships under Healthy Catchments Program.	The Auditor notes the progress reported in the SCA's 'Report on Catchment Management and Protection Activities' on soil erosion projects provided to the Audit. Continued action is required on this recommendation.
21	The SCA review its water quality monitoring program to ensure that appropriate ecosystem water quality monitoring is undertaken in all sub-catchments.	under way SCA will consider as part of monitoring program review required by its Operating Licence.	The Auditor believes that the review should take place in November 2007 when the SCA undertakes planned strategy development work for further improving the monitoring program. See Chapter 6 Section 6.2 for recommendation(s).
22	The SCA review its macroinvertebrate monitoring program to ensure that monitoring is further integrated with water quality monitoring (i.e. the sites are monitored for both macroinvertebrates and water quality parameters).	under way SCA describes existing macroinvertebrate sampling program. 2006 sampling reporting (due in May 07) will inform a review of overlapping sites.	The Auditor believes that there are still too few overlapping sites to achieve an appropriate level of integration. Further action is required. See Chapter 6 for recommendation(s).

	2005 Recommendation	Status in 2007	Auditor's response
23	The SCA consider follow-up monitoring at macroinvertebrate monitoring locations that have significantly impaired or severely impaired AusRivAS ratings.	under way SCA advises that an impaired rating is one of the criteria for determining roaming site selection.	The Auditor believes that the SCA's approach does not address the issue adequately. See Chapter 6 for recommendation(s).
24	The NSW DPI, in consultation with SCA, develop a fish community monitoring program for the Catchment to assist the management of aquatic ecosystem health.	under way SCA notes that a new environmental monitoring program for the Hawkesbury-Nepean is being collaboratively developed, that includes a fish monitoring component.	The Auditor notes that DPI has commenced a fish monitoring program that includes sites in the Catchment. Data from the program was provided to the Audit (Chapter 6). Continued action is required on this recommendation.
25	The DNR, DEC and SCA jointly undertake vegetation condition mapping of areas outside the Special Areas.	under way SCA reports that 1:100,000 veg mapping has been completed, but it doesn't deal with condition. Initiative to standardise methods of vegetation information management is under way.	The Auditor accepts that satisfactory progress has been made on this recommendation. Continuing action is required on this recommendation.

Note: DWE has assumed the functions of the former department of Natural Resources (DNR) therefore any reference to the DNR is a now a reference to the DWE.

It would be of benefit to future audits if timeframes were established by the relevant parties for implementation of Audit recommendations, to assist future audits in assessing the timeliness of progress being made.

As indicated in the responses in Table 9.1, the Auditor believes that further actions on 2005 Recommendations 1 and 2 are required. New recommendations for these purposes are put forward below.

2005 Recommendation 1: Integration of reporting processes

DEC (now DECC), the SCA and the NRC were to give further consideration to integrating catchment and natural resource management audit processes and NSW State of the Environment (SoE) reporting.

The intended focus of this recommendation was on better alignment of the timing of the processes. The next Catchment Audit and the next SoE Report are due in 2009. The first reporting of the natural resources monitoring (MER) process will occur by the end of 2008, and it will be presented in the SoE 2009 Report. The Auditor understands that the current three year frequency of SoE reporting has been recently confirmed at an inter-agency level for the foreseeable future.

Therefore, better alignment of the Audit with other catchment reporting processes would be achieved if the frequency of Audit reporting was extended to 3 years. This changed frequency could be implemented from 2009, and it would require an amendment to Section 42 of the Sydney Water Catchment Management Act 1998. The SCA advised the Auditor prior to publication of this report that a Bill to amend the Act to give effect to this recommended frequency change is currently being prepared.

Recommendation 10: The frequency of the Audit should be changed to every three years, instead of two years, from 2009 to align with State of Environment (SoE) and Monitoring, Evaluation and Reporting (MER) timeframes.

Opportunities for further integration would be in the form of common or complementary indicators. DECC has a lead role in MER strategy development and implementation, and the NRC is a contributor. However, the SCA is not represented in the committee driving the MER strategy. The SCA is a stakeholder in the development of MER indicators that would relate to the Catchment, and should maintain a watching brief to

identify any practicable opportunities for integration and/or sharing of indicators between the two reporting processes that may impact on the SCA's monitoring and reporting activities.

The Auditor notes that the NRC will audit progress against State-wide natural resource management standards and targets under the State Plan, and that there could be some synergy in securing a greater NRC contribution to future catchment audits.

Recommendation 11: Opportunities for the development of common or complementary indicators between the Audit SoE and MER reporting processes should be examined.

2005 Recommendation 2: Spatial information system

The Land Management Database (LMD) was developed by DECC (formerly DNR) for recording on-ground works with linkages to government funded projects. LMD provides a standardized approach to mapping and recording of funded on-ground activities and reporting on project outcomes. Data is spatially recorded and stored in geodatabases. Currently the primary user is the CMAs. The Auditor has made numerous references in this report to the absence of such information, and to the resulting lost opportunities for land managers to have an effective tool for recording and reviewing locations of past actions when planning and prioritising new programs and activities to improve the state of the catchment. Accordingly, the Auditor believes that insufficient progress has been made on the 2005 recommendation, and that it needs to be renewed.

Recommendation 12: The SCA, DECC and CMAs should work together to establish a spatial information system to track and record information on all on-ground works being undertaken or funded by Government for the purposes of water quality and ecosystem health management in the Catchment.

9.3 Compilation of the 2007 Audit Recommendations

The following twelve recommendations have arisen in the preceding chapters and sections of this report, and from the overall conduct of the 2007 Audit. Where relevant, particular sub-catchments to which the recommendation(s) apply are identified. The Auditor commends these recommendations to the Minister, for subsequent referral to relevant parties for their consideration and appropriate action.

	Raw water quality
1	The operators and regulator(s) of the sewage treatment systems in the Catchment should continue efforts to reduce current levels of nutrient loads discharged into the Catchment.
2	The SCA should continue the process of understanding the causes of the 'high' incidences of algae in the water storages of the Kangaroo River (priority), Wingecarribee River (priority) and Lake Burragorang sub-catchments, to help ensure that specific management strategies are in place for the short, medium and long term in each sub-catchment.
3	The SCA should investigate the causes of the continued presence of pathogens in the Nattai River (Gibbergunyah Creek), and in the Wollondilly River, Mid Coxs River and Werriberri Creek (priority) sub-catchments.
4	The SCA should undertake sampling for the presence of pathogens in the Kangaroo River (priority) sub-catchment.
	Managing water resources
5	DWE should work with stakeholders to complete a Water Sharing Plan that covers the Catchment as soon as practicable.
	Land condition
6	The SCA, DECC and CMAs should undertake programs that address soil erosion and salinity in the areas with identified and observed risk, and integrate them with other programs for riparian and vegetation management where possible.
	Ecosystem health
7	The SCA should investigate the reasons and drivers for declines in both water quality and macroinvertebrate health in those regions where declines have been documented.
8	The SCA should review its water quality monitoring and macroinvertebrate sampling programs to ensure that integrated ecosystem monitoring is undertaken in all sub-catchments
9	The SCA should undertake follow-up monitoring at macroinvertebrate monitoring locations that have significantly impaired or severely impaired AusRivAS ratings.
	General
10	The frequency of the Audit should be changed to every three years, instead of two years, from 2009 to align with State of Environment (SoE) and Monitoring, Evaluation and Reporting (MER) timeframes.
11	Opportunities for the development of common or complementary indicators between the Audit SoE and MER reporting processes should be examined.
12	The SCA, DECC and CMAs should continue to work to establish a spatial information system to track and record information on all on-ground works being undertaken or funded by Government for the purposes of water quality and ecosystem health management in the Catchment.

Acronyms

ANSTO – Australian Nuclear Science and Technology Organisation
ANZECC – Australian and New Zealand Environment and Conservation Council
ARMCANZ – Agriculture and Resource Management Council of Australia and New Zealand
ASU – Area Standard Unit
ASP – Accelerated Sewerage Program
AusRivAS – Australian River Assessment System
AWT – Australian Water Technologies
AWWA – American Water Works Association
BASIX – Building Sustainability Index Scheme
BMCC – Blue Mountains City Council
BMP – Best Management Practices
BOD – Biological Oxygen Demand
BPG – Best Practice Guidelines
BWSA – Bulk Water Supply Agreement
CAP – Catchment Action Plan
CMA – Catchment Management Authority
COAG – Commonwealth of Australian Governments
CPS – Catchment Protection Scheme
CRAFT – Catchment Remote Area Fire Fighting Team
CRCAW – Cooperative Research Centre for Australian Weed Management
CRCFE – Cooperative Research Centre for Freshwater Ecology
CRCWQT – Cooperative Research Centre for Water Quality and Treatment
CRP – Current Recommended Management Practices
CSIRO – Commonwealth Scientific and Industrial Research Organisation
CSC – City of Shoalhaven Council
DA – Development Application
DEC – Department of Environment and Conservation
DECC – Department of Environment and Climate Change
DEH – Department of Environment and Heritage
DEUS – Department of Energy, Utilities and Sustainability
DIPNR – Department of Infrastructure, Planning and Natural Resources
DLWC – Department of Land and Water Conservation
DMR – Department of Mineral Resources
DNR – Department of Natural Resources
DoC – Department of Commerce
DoP – Department of Planning
DPI – New South Wales Department of Primary Industries
DUAP – Department of Urban affairs and Planning
DWE – Department of Water and Energy
EASI – Environmental Assessment of Sites and Infrastructure
EBD – Eastern Bushlands Database

EDC – Every Drop Counts
EP – Equivalent Population
EPA – Environment Protection Authority
ESD – Ecological Sustainable Development
FRI – Fisheries Research Institute
HCP – Healthy Catchments Program
H-N CMA – Hawkesbury-Nepean Catchment Management Authority
HNRMF – Hawkesbury Nepean River Management Forum
HRC – Healthy Rivers Commission
HU – Hazen Units
ICLEI – International Council for Local Environmental Initiatives
IPART – Independent Pricing and Regulatory Tribunal of NSW
IWA – International Water Association
IWCM – Integrated Water Cycle Management
LCSA – Local Community Services Association
LEP – Local Environmental Plan
LGA – Local Government Area
MER – Monitoring Evaluation and Reporting Strategy
MMP – Macroinvertebrate Monitoring Plan
MWP – Metropolitan Water Plan
NAP – National Action Plan for Salinity and Water Quality
NCC – Nature Conservation Council of NSW
NDVI – Normalised Difference Vegetation Index
NGIA – Nursery and Garden Industry Australia
NHMRC – National Health and Medical Research Council
NHT – National Heritage Trust
NLWRA – National Land and Water Resources Audit
NorBE – Neutral or Beneficial Effect
NPWS – National Parks and Wildlife Service
NRC – Natural Resources Commission
NRM – Natural Resources Management
NTU – Nephelometric Turbidity Units
PIP – Priority Industries Program
PRP – Pollution Reduction Program
PSR – pressure-state-response
Qld DNRM – Queensland Department of Natural Resources and Mines
RACC – Regional Algal Coordinating Committee
RAP – Rectification Action Plan
RDWQMF – Raw Drinking Water Quality Management Framework
REP 1 – Drinking Water Catchments Regional Environmental Plan No.1
RHS – River Health Strategy
RMAP – Riparian Management Assistance Program
RNWS – Raising National Water Standards
RO – Recycled Organics
RUSLE – Revised Universal Soil Loss Equation
SASPoM – Special Areas Strategic Plan of Management

SAWM – Smart Approved Watermark Scheme
SCA – Sydney Catchment Authority
SEPP 58 – State Environmental Planning Policy 58
SGMP – Sewer Gauging and Modelling Program
SIRIS – Sustainable Investment Research Institute
SLWCA – Strategic Land and Water Capability Assessment
SM CMA – Sydney Metropolitan Catchment Management Authority
SMP – Subsidence Management Plan
SoE – State of the Environment
SOI – Statement of Intent
SRA – Sustainable Rivers Audit
SR CMA – Southern Rivers Catchment Management Authority
STP – Sewage Treatment Plant
STS – Sewage Treatment System
VCA – Voluntary Conservation Agreement
WELS – Water Efficiency Labelling and Standards Scheme
WFP – Water Filtration Plant
WIX – Water Information Exchange
WRC – Water and Rivers Commission
WSRWI – Western Sydney Recycled Water Initiative
WSSAPoM – Wingecarribee Swamp and Special Area Plan of Management
WSUD – Water Sensitive Urban Design
WQMP – Water Quality Monitoring Plan
WQRMF – Water Quality Risk Management Framework

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Appendix A

Individuals and organisations who provided a submission or response to the Sydney Drinking Water Catchment Audit

Individuals

Noel Crowe

Francis Dutton

Organisations

Blue Mountains Conservation Society

Hawkesbury-Nepean Catchment Management Authority (H-N CMA)

Natural Resources Commission (NRC)

NSW Department of Commerce

NSW Department of Environment and Climate Change (DECC)

NSW Department of Health (DOH)

NSW Department of Primary Industries (DPI)

NSW Department of Water and Energy (DWE)

Save Water Alliance

Sydney Catchment Authority (SCA)

Southern Rivers Catchment Management Authority (SR CMA)

Sydney Water Corporation

Wingecarribee Shire Council

Moss Vale Rural Lands Protection Board

List of stakeholders provided with a draft of the report to comment on the accuracy of information and data provided to the audit:

- Sydney Catchment Authority (SCA)
- Hawkesbury-Nepean Catchment Management Authority (H-N CMA)
- Southern Rivers Catchment Management Authority (SR CMA)
- NSW Department of Environment and Climate Change (DECC)
- NSW Department of Water and Energy (DWE)
- NSW Department of Primary Industries (DPI)

Appendix B

Roles and Responsibilities of Stakeholders

Sydney Catchment Authority (SCA)

The SCA's role and responsibilies are specified by the *Sydney Water Catchment Management Act 1998*. Section 13 of this Act identifies the SCA's role to manage and protect the catchment areas and catchment infrastructure works, be a supplier of bulk water, and to regulate certain activities within or affecting the outer catchment and inner catchment areas. The principal objectives of the SCA defined in the Act are to ensure the catchment areas and infrastructure are managed and protected to promote water quality, the protection of public health and safety and the protection of the environment. The Act also enables an Operating Licence to be issued to authorise the SCA to provide, construct, operate, manage and maintain systems and services, in order to achieve its objectives.

The Act also requires the SCA to make arrangements with Sydney Water Corporation in relation to the standard of the quality of the water supplied to Sydney Water. The Bulk Water Supply Agreement (BWSA) addresses the supply of raw water to customers (primarily Sydney Water). This agreement specifies what the raw water quality to be supplied to the water filtration plants.

The SCA has a Water Management Licence, administered by DWE (formerly DNR), for its activities in relation to the abstraction and use of water from identified water sources and water management works. The licence also specifies the quantity of water that must be made available for environmental purposes.

The SCA regulates activities in the special and controlled areas likely to impact on its ability to supply high quality raw water to its customers through the Sydney Catchment Management (General) Regulation. The SCA jointly manages the Special Areas with the Department of Environment and Climate Change (DECC) under the Special Areas Strategic Plans of Management. The Plan sets the framework for a high level of protection of the natural and cultural heritage in these areas, and maintain the areas as intact buffers for the storages.

The Sydney Catchment Management (Environmental Protection) Regulation allows SCA to exercise power under the *Protection of the Environment Operations Act 1997*, in relation to non-scheduled activities. These powers may be exercised for the purposes of protecting catchment areas or protecting and enhancing the quality of water in catchment areas.

The SCA is also involved in the development assessment process in the Catchment under the Environmental Planning Act through a concurrence role of the Regional Environmental Plan N.1 (REP 1) which replaces the previous SEPP 58, assisting in the protection of Sydney's drinking water supply.

NSW Department of Environment and Climate Change (DECC)

The Department of Environment and Climate Change (DECC) was established in April 2007, and joins together the Department of Environment and Conservation (DEC), NSW Greenhouse Office, Marine Parks secretariat and particular functions from DNR and DEUS. The functions of the former DEUS, such as the Energy and Water Savings Funds and Action Plans have been transferred to the new DECC. DECC does not encompass, but shares links with, the SCA.

DECC is building on the strengths and cultures of its constituent agencies by combining knowledge, innovation, regulatory and field experience to tackle priority environmental, climate change, natural resource and cultural heritage issues for NSW. In doing so, DECC contributes towards achieving its corporate vision through:

- working towards a healthy environment cared for and enjoyed by the whole NSW community
- managing the state's natural resources, including biodiversity, soils and natural vegetation
- managing natural and cultural heritage across the state's land and waters

- acting to minimise the impacts of climate change
- promoting sustainable consumption, resource use and waste management
- regulating activities to protect the environment
- conducting biodiversity, plant, environmental and cultural heritage research to improve decision-making.

The Parks and Wildlife Group (PWG) within DECC, has a critical role in the joint management of Special Areas with SCA. The role includes the responsibility to:

- at all times comply with all applicable Acts and Regulations, agreed standard operating procedures, guidelines and all reasonable SCA directors for the purposes of enhancing or maintaining water quality and for compliance by the SCA with its statutory objectives
- provide sufficient and properly qualified and experienced staff to develop and provide the services
- deliver the CRAFT program and Annual Land Management Program for the approved Fee and the Services will be provided on that basis.

NSW Department of Primary Industries (DPI)

The NSW Department of Primary Industries (DPI) was formed in July 2004 with the amalgamation of Mineral Resources NSW, NSW Agriculture, NSW Fisheries and State Forests NSW. The DPI partners with industry and other public sector organisations to foster profitable and sustainable development of primary industries in NSW.

The Mineral Resources Division is responsible for approving, regulating and monitoring mining and associated activities in NSW. It has a role in the rehabilitation of abandoned and derelict mine sites, and is currently rehabilitating some priority derelict mine sites in the Catchment with the SCA. They also have a role in managing mine subsidence.

The Agriculture and Fisheries Division conducts agricultural research and provides practical and sustainable farm production and environmental advice to commercial farmers, graziers, horticulturists, agribusiness and other groups. This collaborative effort draws together a comprehensive range of information and knowledge which can also be disseminated through best management practices guidelines. There are extensive areas of agriculture in the Catchment. This Division is also responsible for the sustainable management of commercial and recreational fishing, the protection of aquatic threatened species, populations and ecological communities, the protection of key aquatic habitats and the conservation of aquatic biodiversity. It carries out scientific research and resource management compliance and also provides management and advisory services. In consultation with industry and the community, Fisheries develops policies and regulations on the sustainable use of the states aquatic resources. Fisheries has undertaken substantial fish sampling in the Catchment and are currently investigating the distribution of both threatened and pest aquatic specie as well as working to ameliorate the effects of instream barriers to fish passage within the Catchment.

Forest NSW is responsible for sustainably managing more than 2 million hectares of public native forests and a large area of planted forests in NSW. There are some areas of State Forest in the Catchment.

NSW Department of Planning (DoP)

The DoP is involved in the planning, policy and regulation in relation to the natural and built environment, rural and urban management (including urban growth, renewal and consolidation) and the development of housing policies.

The DoP prepared the Drinking Water Catchments Regional Environmental Plan No. 1 (REP 1) in conjunction with the SCA. This REP 1 will provide catchment management strategies to improve the planning, management and knowledge base for water quality protection in the catchments.

NSW Department of Water and Energy (DWE)

The Department of Water and Energy (DWE), which commenced operating in April 2007, delivers the Government's policy and reform agenda for the water and energy sectors in NSW. The Department provides policy, legislative, regulatory and management advice in relation to water and energy matters to three Ministers: the Minister for Climate Change, Environment and Water; the Minster for Energy; and the

Minister for Water Utilities.

The Department works with the water management, energy and urban water industries, government agencies, industry, business and consumer groups and other stakeholders towards achieving the following results:

- Secure and sustainable allocation of water between communities, industry, farmers and the environment.
- Reliable and sustainable urban water and energy supplies and well managed, efficient and affordable services.

Key services provided by the Department contributing to these results include:

- Preparing statutory plans to guide water sharing between users and the environment
- Administering water licences and approvals, assessing resource availability, allocating available water to licensees, monitoring compliance and where necessary taking appropriate enforcement action
- Developing and implementing water trading rules supporting effective market operation
- Monitoring and evaluating water resource quantity and quality, and associated ecosystems
- Liaising with other States and the Commonwealth to ensure NSW interests are protected in interstate water sharing arrangements
- Urban water planning and policy in support of the Metropolitan Water Plan
- Leadership and guidance in best-practice management, operation and maintenance for non-metropolitan urban water utilities, oversight and monitoring of utility performance, along with financial support towards backlog water and sewerage infrastructure and emergency drought assistance
- Promoting and maintaining appropriate and effective competition in energy supply markets, including the further development of national market frameworks in partnership with other States
- Energy supply and demand forecasting
- Electricity and gas network and high pressure pipeline regulation and performance monitoring
- Promotion of renewable energy and energy saving schemes
- Implementation of consumer protection frameworks and support programs for residential energy and urban water customers

NSW Department of Health (DOH)

The primary aim of NSW Health is to ensure the public is provided with the best possible health care, and thus has a role in ensuring safe drinking water. The DOH monitors the quality of drinking water via information provided by the agencies it regulates, and develops standards and guidelines for the treatment of waste water.

It manages the testing program established to verify *Cryptosporidium* and *Giardia* testing results supplied by Sydney Water, the SCA and independent laboratories. The Chief Health Officer of the DOH has the power to restrict or prevent the use of water considered unfit for human consumption.

NSW Department of Natural Resources (DNR)

The DNR aimed to achieve coordinated and sustainable management of the State's natural resources through an integrated catchment management framework. The DNR developed policies for natural resource management and maintained databases on the condition of the State's land, soil, water and vegetation. The DNR was leading the development of a Water Sharing Plan for the Sydney Region, including the Catchment area. The DNR also administered water management licences issued under the Water Act 1912, such as for surface water or groundwater extractions.

From 27 April 2007 a new Department of Water and Energy (DWE) was created to incorporate functions of the former Department of Natural Resources (DNR) and the Department of Energy, Utilities and Sustainability (DEUS). The Department of Environment and Conservation also changed its name to the Department of Environment and Climate Change (DECC) and undertook some functions previously managed by DNR.

NSW Department of Energy, Utilities and Sustainability (DEUS)

The DEUS promoted the sustainable supply and use of energy and urban water in NSW. The DEUS provided an oversight of the local water utilities in rural and regional areas. The DEUS collaborated with other government agencies, energy industry and the water utilities, consumer interest groups and other stakeholders.

Catchment Management Authorities (CMAs)

Thirteen Catchment Management Authorities (CMAs) have been established across the State by the New South Wales Government to ensure that regional communities have a significant say in how natural resources are managed in their catchments. There are 3 CMAs within the Catchment, namely the Sydney Metro, Hawkesbury Nepean and Southern Rivers.

The CMAs are locally driven organisations with a board that reports directly to the NSW Minister for Natural Resources. The CMAs are established under the *Catchment Management Authorities Act 2003* (CMA Act) to coordinate natural resource management (NRM) in each catchment. The CMAs are responsible for involving regional communities in management of the NRM issues facing their region, and are the primary means for the delivery of funding from the NSW and Commonwealth Governments to help land managers improve and restore the natural resources of the State.

In the past CMAs were responsible for the development of Catchment Blueprints which were aimed at natural resource management at a sub-catchment level. These Catchment Blueprints form the basis of the Catchment Action Plans that have recently been prepared by CMAs.

The CMAs work in partnership with the community, local government, State Government agencies, industry and individuals.

Natural Resources Commission of New South Wales (NRC)

The Natural Resources Commission (NRC) was established by the *Natural Resources Commission Act 2003* with a broad function of providing the Government with independent advice on a range of natural resource management issues. The NRC reports jointly to the Premier and the Minister for Natural Resources. The NRC's core functions are to:

- recommend state-wide standards and targets for natural resource management
- review and recommend the approval of Catchment Action Plans prepared by 13 Catchment Management Authorities across NSW
- audit Catchment Management Authorities implementation of these plans and their effectiveness in achieving state-wide standards and targets.

Other roles on the NRC include preparing to audit Water Sharing Plans under the *Water Management Act 2000*.

Local Councils

Local councils have many roles and responsibilities in the Catchment, including as:

- a regulator under the Protection of the Environment Operations Act 1997
- a land use planner using the Environmental Planning and Assessment Act 1979
- as an operator responsible for the management of infrastructure such as urban stormwater systems and sewerage services.

Independent Pricing and Regulatory Tribunal of NSW (IPART)

IPART has a range of roles, including setting maximum water prices and administering licences that authorise water utilities, including the Operating Licences issued to Sydney Water Corporation and the SCA. IPART completed the end of term review of SCA’s Operating Licence in 2005 and a new Operating Licence will be issued to SCA on 1 January 2006.

NSW Rural Fire Service (RFS)

The RFS is responsible for the coordination and planning of bushfire fighting and hazard reduction operations throughout NSW. At the local government scale, there are Bushfire Management Committees included in the above role, including representatives from DECC and the SCA. The SCA has worked with the RFS on improving fire management practices.

NSW Rural Lands Protection Boards (RLPB)

The RLPB is involved in the control of pest animal species and livestock diseases. It also has an advisory role to landholders. The SCA and the DECC have worked with the RLPB to ensure the coordination of pest control strategies in the Catchment.

NSW Rural Assistance Authority

This authority administers assistance measures to rural producers and small businesses. Conservation funding exists, for example, to encourage improved and sustainable land management. Projects include woody weed control and livestock effluent control. The authority also manages the Water Reform Structural Adjustment Program which aims to improve irrigation practices, increase water use efficiency on farms, and minimise negative impacts from irrigation upon the NSW environment.

NSW Heritage Council

The main role of the NSW Heritage Council is to implement the *Heritage Act 1977*. This includes management design and implementation for heritage listings and an advisory role on matters affecting heritage sites. Heritage Council listings include both built and key natural environments. The Wingecarribee Swamp in the Catchment is a state listed natural site. There are many built sites of state and local heritage significance in the Catchment, including Avon, Cataract and Cordeaux Dams.

Dams Safety Committee

The statutory function of the Dam Safety Committee is to ensure all prescribed dams in NSW are safe and maintained. The Committee must also ensure that mining operations near dams do not affect the integrity of the dam or create significant water loss from a storage.

Universities

Universities are often involved in providing expertise and research support for the SCA. For example, the University of NSW, Macquarie and Sydney Universities have all been involved in research on pathogens. The UWS has assisted in creating carbon and nutrient budgets, and Wollongong University has assisted with sediment budgets.

Industry

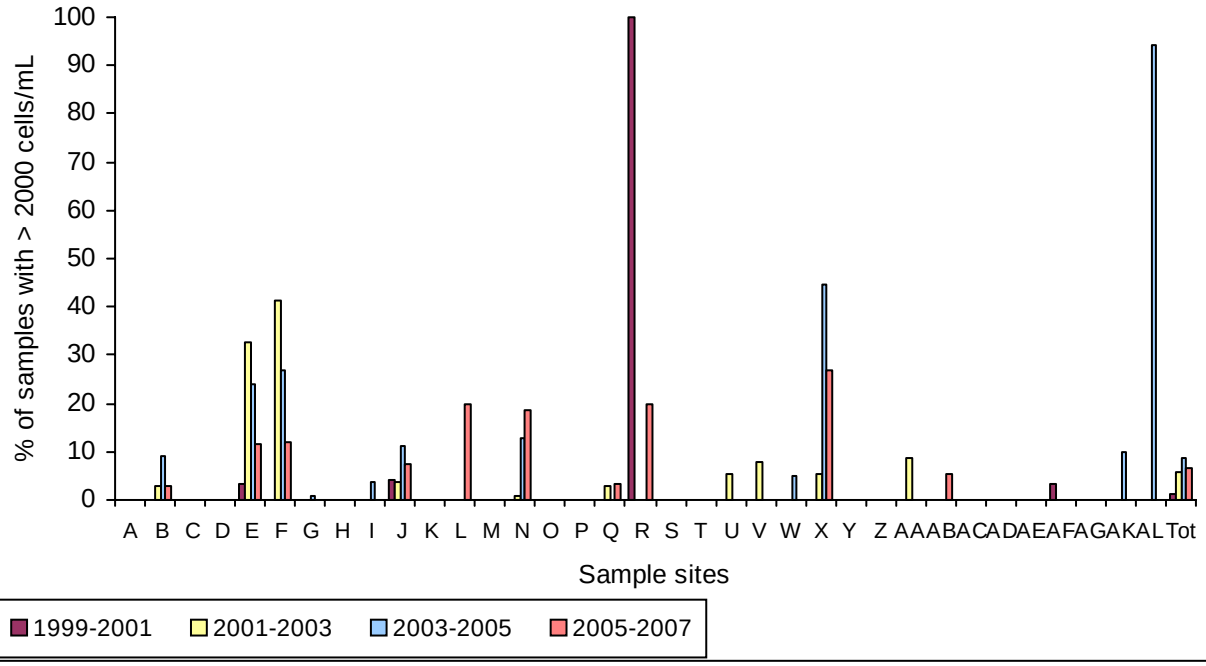
Industry in the Catchment is diverse and includes: mining and extractive industry, forestry and horticulture, livestock and commercial industries, and telecommunication and energy-based industry. The environmental performance of all industry is regulated by either council, the SCA or the EPA under the *Protection of the Environment Operations Act 1997*. New industry is subject to development assessment processes under the *EP&A Act*, including SEPP 58 for developments with a high potential threat to water quality.

Residents

Individuals must seek council approval to conduct water supply work, draw water from a council water supply, conduct sewerage or storm-water works, or connect a private drain or sewer to a public drain or sewer. Residents can have a role in community groups which are active in decision making. All residents have a basic responsibility to prevent pollution.

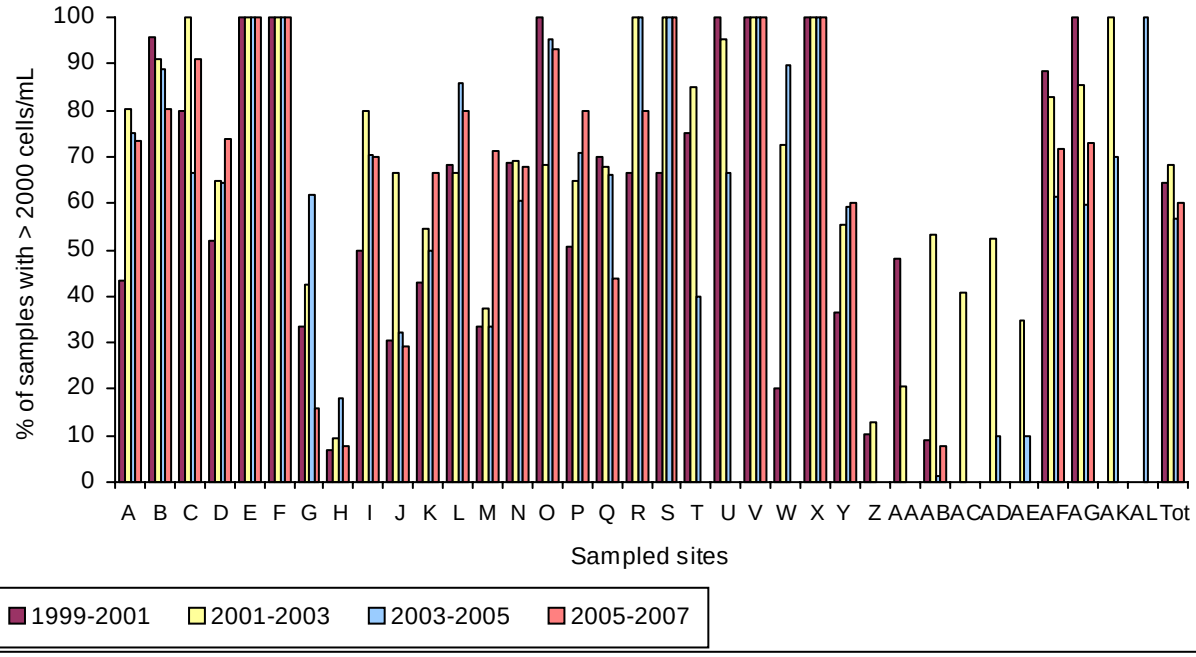
Appendix C

Figure 1: The percentage of samples with > 2000 cells/mL of toxic cyanobacteria for the 2001, 2003, 2005 and 2007 Audit periods



Source: SCA 2007

Figure 2: The percentage of samples with > 2000 cells/mL of total cyanobacteria for the 2001, 2003, 2005 and 2007 Audit periods



Source: SCA 2007

Table 1: Percentage of toxic cyanobacteria in the Sydney Drinking Water Catchment for the 2001, 2003, 2005 and 2007 Audit period

			1999 - 2001				2001 - 2003				2003 - 2005				2005 - 2007			
Code	SCA Code	Station Name	No. of Samples	H	M	L	No. of Samples	H	M	L	No. of Samples	H	M	L	No. of Samples	H	M	L
A	DAV7	Lake Avon at the Upper Avon Valve	3	0	0	0	43	0	0	0	44	0	0	0	60	0	0	0
B	DBP1	Bendeela Pondage	81	0	0	6	134	0	3	19	108	0	9	27	97	0	3	32
C	DCA1	Lake Cataract at Dam Wall	1	0	0	0	8	0	0	0	27	0	0	0	11	0	0	0
D	DCO1	Lake Cordeaux at Dam Wall	1	0	0	0	6	0	0	0	28	0	0	0	23	0	0	0
E	DFF	Fitzroy Falls composite	59	0	3	20	138	0.7	32	48	79	0	24	39	60	0	12	48
F	DFF6	Lake Fitzroy Falls at Midlake	15	0	0	27	34	3	38	24	26	0	27	27	25	0	12	48
G	DGC1	Lake Greaves at Dam Wall	3	0	0	0	54	0	0	0	107	0	1	0	108	0	0	0
H	DLC1	Lake Lower Cascade at 50m upstream	1	0	0	0	55	0	0	0	106	0	0	0	90	0	0	0
I	DNE2	Lake Nepean at 300m upstream of Dam Wall	2	0	0	50	11	0	0	0	27	0	4	11	10	0	0	10
J	DPAE	Bendeela picnic area	48	0	4	10	85	0	4	9	81	4	7	9	96	3	4	8
K	DTA1	Lake Yarrunga at 100m from Dam Wall	1	0	0	0	7	0	0	14	4	0	0	0	9	0	0	11
L	DTA3	Lake Yarrunga at Kangaroo and Yarrunga Junction	5	0	0	20	9	0	0	11	7	0	0	0	10	0	20	0
M	DTA5	Lake Yarrunga at Shoalhaven River	1	0	0	0	4	0	0	0	3	0	0	0	14	0	0	14
N	DTA8	Lake Yarrunga at Kangaroo River, Bendeela PS	36	0	0	25	97	0	1	13	109	1	12	14	118	8	11	19
O	DTA10	Lake Yarrunga at Kangaroo arm, Reed Island	6	0	0	0	18	0	0	6	21	0	0	24	15	0	0	33
P	DTC1	Lake top Cascade at 100m upstream of Dam Wall	2	0	0	0	58	0	0	0	106	0	0	0	109	0	0	1
Q	DWA2	Lake Burragorang at 500m upstream of Dam Wall	13	0	0	15	36	0	3	3	53	0	0	0	89	1	2	11
R	DWA9	Lake Burragorang at 14km upstream of Dam Wall	1	100	0	0	9	0	0	22	1	0	0	0	15	0	20	13
S	DWA12	Lake Burragorang at 9km upstream of Coxs River	0	NS	NS	NS	13	0	0	8	1	0	0	0	7	0	0	14

Source: SCA 2007

Notes: NS: Not sampled, High – > 15,000 cells/mL; Medium – 2,000 – 15,000 cells/mL; Low – 500 – 2000 cells/mL. Incidences in the high and medium categories were highlighted in red. See Appendix C Table 10 for details of all locations, DWA15 is being monitored in place of DWA19 and DWA21 due to low water level.

Table 1: Percentage of toxic cyanobacteria in the Sydney Drinking Water Catchment for the 2001, 2003, 2005 and 2007 Audit period (Continued)

			1999 - 2001				2001 - 2003				2003 - 2005				2005 - 2007			
Code	**SCA Code**	**Station Name**	**No. of Samples**	**H**	**M**	**L**	**No. of Samples**	**H**	**M**	**L**	**No. of Samples**	**H**	**M**	**L**	**No. of Samples**	**H**	**M**	**L**
AM	**DWA15**	Lake Burragorang 4km upstream Butchers Creek	0	NS	NS	NS	0	NS	NS	NS	0	NS	NS	NS	28	0	4	96
T	**DWA19**	Lake Burragorang at Kembula River arm	0	NS	NS	NS	24	0	0	4	5	0	0	0	0	NS	NS	NS
U	**DWA21**	Lake Burragorang at Coxs arm 37 km upstream of Dam Wall	1	0	0	0	18	0	6	11	6	0	0	0	0	NS	NS	NS
V	**DWA27**	Lake Burragorang at Wollondilly arm 23 km upstream of Dam Wall	1	0	0	0	13	0	8	0	1	0	0	0	1	0	0	100
W	**DWA39**	Lake Burragorang at Wollondilly arm 40 km upstream of Dam Wall	5	0	0	0	34	0	0	0	39	0	5	5	0	NS	NS	NS
X	**DWI1**	Wingecarribee Lake at outlet	89	0	0	22	116	0	5	38	162	7	38	28	150	1	26	45
Y	**DWO1**	Lake Woronora at Dam Wall	0	NS	NS	NS	14	0	0	0	27	0	0	0	15	0	0	0
Z	**HBP**	HBP1 and HBP2 taps	0	NS	NS	NS	44	0	0	11	71	0	0	0	0	NS	NS	NS
AA	**HFF4**	NPWS picnic shelter tap at Fitzroy Falls	0	NS	NS	NS	46	0	9	24	72	0	0	0	0	NS	NS	NS
AB	**HOP6**	Oberon pipeline, Leura	0	NS	NS	NS	42	0	0	0	80	0	0	5	92	0	5	9
AC	**HPR1**	Upper Canal at Prospect WFP	0	NS	NS	NS	2	0	0	0	20	0	0	0	9	0	0	11
AD	**HUC1**	Upper Canal at Broughtons Pass	1	0	0	0	16	0	0	0	60	0	0	0	4	0	0	0
AE	**HUC3**	Upper Canal at Kenny Hill	0	NS	NS	NS	2	0	0	0	30	0	0	0	4	0	0	0
AF	**RPR1**	Lake Prospect at Midlake	32	0	3	13	78	0	0	0	114	0	0	3	95	0	0	8
AG	**RPR3**	Lake Prospect near RWPS	17	0	0	6	74	0	0	3	111	0	0	6	14	0	0	8
AM	**DWI**	Lake Wingecarribee composite	0	NS	NS	NS	0	NS	NS	NS	81	1	27	31	0	NS	NS	NS
AL	**DWI3**	Lake Wingecarribee at Mid Lake	9	0	0	0	0	NS	NS	NS	17	12	82	6	0	NS	NS	NS
AK	**DNE7**	Lake Nepean	0	NS	NS	NS	0	NS	NS	NS	10	0	10	20	0	NS	NS	NS
EH	**E303**	Wingecarribee River at Sheepwash Bridge	0	NS	NS	NS	0	NS	NS	NS	0	NS	NS	NS	90	0	18	82
		Total	**434**	**0.2**	**1**	**15**	**1342**	**0.2**	**6**	**14**	**1834**	**1**	**9**	**10**	**1568**	**1**	**6**	**20**

Source: SCA 2007

Notes: NS: Not sampled, High – > 15,000 cells/mL; Medium – 2,000 – 15,000 cells/mL; Low – 500 – 2000 cells/mL. Incidences in the high and medium categories were highlighted in red. See Appendix C Table 10 for details of all locations, DWA15 is being monitored in place of DWA19 and DWA21 due to low water level.

Table 2: Percentage of total cyanobacteria in the Sydney Drinking Water Catchment for the 2001, 2003, 2005 and 2007 Audit period

			1999 - 2001				2001 - 2003				2003 - 2005				2005 - 2007			
Code	SCA Code	Station Name	No. of Samples	H	M	L	No. of Samples	H	M	L	No. of Samples	H	M	L	No. of Samples	H	M	L
A	DAV7	Lake Avon at the Upper Avon Valve	23	0	44	35	56	14	66	18	44	0	75	23	60	0	73	25
B	DBP1	Bendeela Pondage	219	70	26	3	121	68	23	6	108	51	38	10	97	35	45	10
C	DCA1	Lake Cataract at Dam Wall	25	0	80	12	20	25	75	0	27	11	56	26	11	0	91	9
D	DCO1	Lake Cordeaux at Dam Wall	29	7	45	38	17	24	41	18	28	32	32	32	23	26	48	22
E	DFF	Fitzroy Falls composite	89	97	3	0	98	91	9	0	79	80	20	0	60	92	8	0
F	DFF6	Lake Fitzroy Falls at Midlake	29	100	0	0	26	92	8	0	26	69	31	0	25	96	4	0
G	DGC1	Lake Greaves at Dam Wall	84	0	33	60	94	1	42	40	107	7	55	19	108	2	14	41
H	DLC1	Lake Lower Cascade at 50m upstream	60	0	7	48	73	0	10	34	106	1	17	31	90	0	8	12
I	DNE2	Lake Nepean at 300m upstream of Dam Wall	32	16	34	19	20	10	70	15	27	26	44	26	10	10	60	20
J	DPAE	Bendeela picnic area	142	7	23	31	78	50	17	10	81	15	17	15	96	15	15	18
K	DTA1	Lake Yarrunga at 100m from Dam Wall	7	14	29	0	11	45	9	27	4	0	50	50	9	11	56	33
L	DTA3	Lake Yarrunga at Kangaroo and Yarrunga Junction	19	26	42	26	12	42	25	8	7	0	86	14	10	0	80	20
M	DTA5	Lake Yarrunga at Shoalhaven River	3	33	0	67	8	13	25	50	3	0	33	67	14	50	21	29
N	DTA8	Lake Yarrunga at Kangaroo River, Bendeela PS	141	19	50	18	101	54	15	14	109	28	33	15	118	31	36	14
O	DTA10	Lake Yarrunga at Kangaroo arm, Reed Island	22	23	77	0	19	47	21	26	21	29	67	5	15	27	67	7
P	DTC1	Lake top Cascade at 100m upstream of Dam Wall	87	1	49	44	94	7	57	21	106	13	58	15	109	18	61	15
Q	DWA2	Lake Burragorang at 500m upstream of Dam Wall	53	21	49	15	50	36	32	18	53	45	21	17	89	12	31	30
R	DWA9	Lake Burragorang at 14km upstream of Dam Wall	3	33	33	0	11	73	27	0	1	100	0	0	15	20	60	13
S	DWA12	Lake Burragorang at 9km upstream of Coxs River	3	67	0	33	12	67	33	0	1	100	0	0	7	43	57	0

Source: SCA 2007

Notes: NS: Not sampled, High – > 15,000 cells/mL; Medium – 2,000 – 15,000 cells/mL; Low – 500 – 2000 cells/mL. Incidences in 75–100% of samples are highlighted red, incidences in 50–75%of samples are highlighted orange. See Appendix C Table 10 for details of all locations, DWA15 is being monitored in place of DWA19 and DWA21 due to low water level.

Table 2: Percentage of total cyanobacteria in the Sydney Drinking Water Catchment for the 2001, 2003, 2005 and 2007 Audit period (Continued)

			1999 - 2001				2001 - 2003				2003 - 2005				2005 - 2007			
Code	SCA Code	Station Name	No. of Samples	H	M	L	No. of Samples	H	M	L	No. of Samples	H	M	L	No. of Samples	H	M	L
AM	DWA15	Lake Burragorang 4km upstream Butchers Creek	0	NS	NS	NS	0	NS	NS	NS	0	NS	NS	NS	28	68	29	4
T	DWA19	Lake Burragorang at Kembula River arm	4	50	25	0	27	70	15	4	5	40	0	20	0	NS	NS	NS
U	DWA21	Lake Burragorang at Coxs arm 37 km upstream of Dam Wall	2	50	50	0	22	86	9	0	6	50	17	0	0	NS	NS	NS
V	DWA27	Lake Burragorang at Wollondilly arm 23 km upstream of Dam Wall	1	0	100	0	13	77	23	0	1	100	0	0	1	100	0	0
W	DWA39	Lake Burragorang at Wollondilly arm 40 km upstream of Dam Wall	5	0	20	60	33	30	42	24	39	46	44	10	0	NS	NS	NS
X	DWI1	Wingecarribee Lake at outlet	119	92	8	0	116	98	2	0	162	94	6	0	150	97	3	0
Y	DWO1	Lake Woronora at Dam Wall	22	0	36	23	29	0	55	28	27	7	52	22	15	7	53	40
Z	HBP	HBP1 and HBP2 taps	29	0	10	38	71	0	13	30	71	0	0	4	0	NS	NS	NS
AA	HFF4	NPWS picnic shelter tap at Fitzroy Falls	54	6	43	20	68	0	21	25	72	0	0	0	0	NS	NS	NS
AB	HOP6	Oberon pipeline, Leura	45	4	4	22	73	14	40	30	80	0	1	15	92	0	8	15
AC	HPR1	Upper Canal at Prospect WFP	0	NS	NS	NS	22	0	41	32	20	0	0	30	9	0	0	33
AD	HUC1	Upper Canal at Broughtons Pass	24	0	0	33	46	4	48	30	60	0	10	17	4	0	0	25
AE	HUC3	Upper Canal at Kenny Hill	0	NS	NS	NS	23	0	35	48	30	0	10	27	4	0	0	25
AF	RPR1	Lake Prospect at Midlake	87	64	24	8	100	63	20	12	114	33	28	11	95	44	27	6
AG	RPR3	Lake Prospect near RWPS	27	96	4	0	97	66	20	9	111	35	24	13	114	47	25	6
AM	DWI	Lake Wingecarribee composite	0	NS	NS	NS	0	NS	NS	NS	81	93	7	0	0	NS	NS	NS
AL	DWI3	Lake Wingecarribee at Mid Lake	0	NS	NS	NS	0	NS	NS	NS	17	100	0	0	0	NS	NS	NS
AK	DNE7	Lake Nepean	0	NS	NS	NS	0	NS	NS	NS	10	30	40	30	0	NS	NS	NS
EH	E303	Wingecarribee River at Sheepwash Bridge	0	NS	NS	NS	0	NS	NS	NS	0	NS	NS	NS	90	94	6	0
		Total	**1498**	**37**	**28**	**19**	**1661**	**41**	**27**	**17**	**1834**	**33**	**26**	**13**	**1568**	**36**	**27**	**14**

Source: SCA 2007

Notes: NS: Not sampled, High – > 15,000 cells/mL; Medium – 2,000 – 15,000 cells/mL; Low – 500 – 2000 cells/mL. Incidences in 75–100% of samples are highlighted red, incidences in 50–75%of samples are highlighted orange. See Appendix C Table 10 for details of all locations, DWA15 is being monitored in place of DWA19 and DWA21 due to low water level.

Table 3: Percentage of DAPI positive incidences of oocysts of *Cryptosporidium* in high, medium and low categories, from the 2001 and 2003 Audit periods.

Code	SCA Code	Site	Number of samples	Cryptosporidium 1999 - 2001			Number of samples	Cryptosporidium 2001 - 2003		
				High	Med	Low		High	Med	Low
Q	DWA2	Lake Burragorang at 500m upstream	1197	0	0	0	631	0	0	0.5
X	DWI1	Wingecarribee Lake at outlet	92	0	0	0	121	0	0	1.7
AC	HPR1	Upper Canal at Prospect WFP	15	0	0	6.7	11	0	0	9.1
AD	HUC1	Upper Canal at Broughtons Pass	615	0	0	0.5	100	0	0	0
AF	RPR1	Lake Prospect at Midlake	138	0	0	0	208	0	0	0
AG	RPR3	Lake Prospect near RWPS	139	0	0	1.4	202	0	0	2.0
AH	COMP1 COMP3	Prospect WFP	670	0	0	0	604	0	0	2.7
AI	COMP5	Illawarra System	264	0	0	0.4	92	0	0	0
AJ	COMP6	Blue Mountains System	265	0	0	1.1	96	0	0	2.1
CA	E083	Coxs River at Kelpie Point	40	0	0	0	31	0	0	0
CB	E130	Kowmung River at Cedar Ford	39	0	0	2.6	28	0	0	0
CC	E157	Kedumba River at Maxwells Crossing	35	0	0	2.9	30	0	0	6.7
CD	E203	Gibbergunyah Creek at Mittagong STP	41	2.4	4.9	9.8	27	0	0	14.8
CE	E206	Nattai River at Crags	0	NS	NS	NS	0	NS	NS	NS
CF	E210	Nattai River at Smallwoods Crossing	30	0	0	0	22	0	0	0
CG	E243	Little River at Fire Road	29	0	0	0	24	0	0	0
CI	E409	Wollondilly River at Murray's Flat	0	NS	NS	NS	0	NS	NS	NS
CL	E488	Wollondilly River at Jooriland	42	0	0	2.4	31	0	0	0
CM	E531	Werriberri Creek at Werombi	114	0	1	0.9	94	0	1.1	2.1
		All samples	**3765**	**0.03**	**0.08**	**0.5**	**2352**	**0**	**0.04**	**1.5**

Source: SCA 2007

Notes: NS: Not sampled

High - >1,000 oocysts per 100 L; Medium – 100-1,000 oocysts per 100 L; Low – <100 oocysts per 100 L

Incidences in 5 – 10% of samples are highlighted in orange and incidences in > 10% of samples are highlighted in red

See Appendix C Table 10 for details of all locations

Table 3: Percentage of DAPI positive incidences of oocysts of *Cryptosporidium* in high, medium and low categories, from the 2005 and 2007 Audit periods.

Code	SCA Code	Site	Number of samples	Cryptosporidium 2003 - 2005			Number of samples	Cryptosporidium 2005 - 2007		
				High	Med	Low		High	Med	Low
Q	DWA2	Lake Burragorang at 500m upstream	654	0	0	0.2	597	0	0	0
X	DWI1	Wingecarribee Lake at outlet	110	0	0	0.9	101	0	0	2.0
AC	HPR1	Upper Canal at Prospect WFP	54	0	0	3.7	22	0	0	4.5
AD	HUC1	Upper Canal at Broughtons Pass	106	0	0	0				
AF	RPR1	Lake Prospect at Midlake	219	0	0	0.5	197	0	0	0
AG	RPR3	Lake Prospect near RWPS	217	0	0	1.8	198	0	0	1.5
AH	COMP1 COMP3	Prospect WFP	2	0	0	50	517	0	0	1.0
AI	COMP5	Illawarra System	91	0	0	0	3	0	0	0
AJ	COMP6	Blue Mountains System	94	0	0	0	NS	NS	NS	NS
CA	E083	Coxs River at Kelpie Point	31	0	0	0	38	0	0	0
CB	E130	Kowmung River at Cedar Ford	33	0	0	3	33	0	0	0
CC	E157	Kedumba River at Maxwells Crossing	37	0	0	2.7	28	0	0	0
CD	E203	Gibbergunyah Creek at Mittagong STP	26	0	0	46.2	30	0	3.3	40.0
CE	E206	Nattai River at Crags	1	0	0	0	NS	NS	NS	NS
CF	E210	Nattai River at Smallwoods Crossing	19	0	0	0	19	0	0	0
CG	E243	Little River at Fire Road	26	0	0	0	23	0	0	0
CI	E409	Wollondilly River at Murray's Flat	1	0	0	0	NS	NS	NS	NS
CL	E488	Wollondilly River at Jooriland	29	0	0	0	44	0	0	6.8
CM	E531	Werriberri Creek at Werombi	106	0	0	0.9	103	0	0	1.0
		All samples	**1856**	**0**	**0**	**1.4**	**1959**	**0**	**0.1**	**1.5**

Source: SCA 2007

Notes: NS: Not sampled

High - >1,000 oocysts per 100 L; Medium – 100-1,000 oocysts per 100 L; Low – <100 oocysts per 100 L

Incidences in 5 – 10% of samples are highlighted in orange and incidences in > 10% of samples are highlighted in red

See Appendix C Table 10 for details of all locations

Table 4: Percentage of DAPI positive incidences of cysts of *Giardia* in high, medium and low categories, from the 2001 and 2003 Audit periods.

Code	SCA Code	Site	Number of samples	Giardia 1999 - 2001			Number of samples	Giardia 2001 - 2003		
				High	Med	Low		High	Med	Low
Q	DWA2	Lake Burragorang at 500m upstream	1197	0	0	0	631	0	0	0
X	DWI1	Wingecarribee Lake at outlet	92	0	0	0	121	0	0	0.8
AC	HPR1	Upper Canal at Prospect WFP	15	0	0	0	11	0	0	0
AD	HUC1	Upper Canal at Broughtons Pass	615	0	0	0	100	0	0	0
AF	RPR1	Lake Prospect at Midlake	138	0	0	0.7	208	0	0	0.5
AG	RPR3	Lake Prospect near RWPS	139	0	0	2.2	202	0	0	0.5
AH	COMP1 COMP3	Prospect WFP	670	0	0	0.1	604	0	0	0.2
AI	COMP5	Illawarra System	264	0	0	0	92	0	0	0
AJ	COMP6	Blue Mountains System	265	0	0	0.4	96	0	0	0
CA	E083	Coxs River at Kelpie Point	40	0	2.5	0	31	0	0	0
CB	E130	Kowmung River at Cedar Ford	39	0	0	2.6	28	0	0	7.1
CC	E157	Kedumba River at Maxwells Crossing	35	0	0	0	30	0	0	6.7
CD	E203	Gibbergunyah Creek at Mittagong STP	41	9.8	29.3	12.2	27	18.5	37.0	18.5
CE	E206	Nattai River at Crags	0	NS	NS	NS	0	NS	NS	NS
CF	E210	Nattai River at Smallwoods Crossing	30	0	0	3.3	22	0	0	0
CG	E243	Little River at Fire Road	29	0	0	0	24	0	0	0
CI	E409	Wollondilly River at Murray's Flat	0	NS	NS	NS	0	NS	NS	NS
CL	E488	Wollondilly River at Jooriland	42	0	0	0	31	0	0	3.2
CM	E531	Werriberri Creek at Werombi	114	0	0.9	1.8	94	0	0	0
		All samples	**3765**	**0.1**	**0.4**	**0.4**	**2352**	**0.2**	**0.4**	**0.6**

Source: SCA 2007

Notes: NS: Not sampled

High - >1,000 oocysts per 100 L; Medium – 100-1,000 oocysts per 100 L; Low – <100 oocysts per 100 L

Incidences in 5 – 10% of samples are highlighted in orange and incidences in > 10% of samples are highlighted in red

See Appendix C Table 10 for details of all locations

Table 4: Percentage of DAPI positive incidences of cysts of *Giardia* in high, medium and low categories, from the 2005 and 2007 Audit periods.

Code	SCA Code	Site	Number of samples	Giardia 2003 - 2005			Number of samples	Giardia 2005 - 2007		
				High	Med	Low		High	Med	Low
Q	DWA2	Lake Burragorang at 500m upstream	654	0	0	0.3	597	0	0	0.2
X	DWI1	Wingecarribee Lake at outlet	110	0	0	0	101	0	0	2.0
AC	HPR1	Upper Canal at Prospect WFP	54	0	0	0	22	0	0	4.5
AD	HUC1	Upper Canal at Broughtons Pass	106	0	0	0				
AF	RPR1	Lake Prospect at Midlake	219	0	0	0	197	0	0	0
AG	RPR3	Lake Prospect near RWPS	217	0	0	0	198	0	0	1.0
AH	COMP1 COMP3	Prospect WFP	2	0	0	0	517	0	0	0.4
AI	COMP5	Illawarra System	91	0	0	0	3	0	0	0
AJ	COMP6	Blue Mountains System	94	0	0	0	NS	NS	NS	NS
CA	E083	Coxs River at Kelpie Point	31	0	0	3.2	38	0	0	7.9
CB	E130	Kowmung River at Cedar Ford	33	0	0	3.0	33	0	0	3.0
CC	E157	Kedumba River at Maxwells Crossing	37	0	0	5.4	28	0	0	0
CD	E203	Gibbergunyah Creek at Mittagong STP	26	19.2	53.8	23.1	30	0	36.7	36.7
CE	E206	Nattai River at Crags	1	0	0	0	NS	NS	NS	NS
CF	E210	Nattai River at Smallwoods Crossing	19	0	0	0	19	0	0	0
CG	E243	Little River at Fire Road	26	0	0	0	23	0	0	0
CI	E409	Wollondilly River at Murray's Flat	1	0	0	100	NS	NS	NS	NS
CL	E488	Wollondilly River at Jooriland	29	0	0	6.9	44	0	0	4.5
CM	E531	Werriberri Creek at Werombi	106	0	0	0	103	0	0	5.8
		All samples	**1856**	**0.3**	**0.8**	**0.8**	**1959**	**0**	**0.6**	**1.7**

Source: SCA 2007

Notes: NS: Not sampled

High - >1,000 oocysts per 100 L; Medium – 100-1,000 oocysts per 100 L; Low – <100 oocysts per 100 L

Incidences in 5 – 10% of samples are highlighted in orange and incidences in > 10% of samples are highlighted in red

See Appendix C Table 10 for details of all locations

Table 5: Volume (ML) of water licensed to be extracted for each sub-catchment in the Sydney Drinking Water Catchment and the use of the water extracted

	Back and Round Mountain Creeks	Braidwood Creek	Bungonia Creek	Endrick River	Jerrabattagula Creek	Kangaroo River	Kowmung Creek	Lake Burragorang	Little River	Lower Coxs River	Mid Coxs River	Mid Shoalhaven River	Mongarlowe River	Mulwaree River	Nattai River	Nerrimunga River	O'Hares Creek	Reedy Creek	Upper Coxs River	Upper Nepean River	Upper Shoalhaven River	Upper Wollondilly	Werriberri Creek	Wingecarribee River	Wollondilly River	Woronora River	Total
Domestic	0	2	11	0	3	8	0	1	0	1	5	0	3	3	3	2	0	0	1	3	0	10	7	9	14	0	85
Experimental Research	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3
Farming	0	0	0	0	0	12	0	5	0	0	0	0	0	5	0	0	0	5	0	10	0	0	10	0	5	0	5247
Industrial	0	0	2	0	0	6	0	0	0	0	78	0	46	5	76	0	0	1	73	2	0	7	91	177	84	0	668
Industrial - Sand and Gravel	0	0	5	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	5	0	0	0	0	0	84	0	94
Irrigation	1330	120	936	15	374	975	151	81	31	107	863	61	302	1315	33	277	253	268	119	1009	140	1344	2362	1776	4266	71	18545
Mining	0	0	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73	0	0	0	0	0	0	0	159
Pisciculture	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	2	0	0	0	0	18	0	0	23
Power Stations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23000	0	0	0	0	0	0	0	0
Recreation - High Security	0	8	0	0	0	0	0	0	0	50	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	63
Recreation - Low Security	0	0	5	0	0	8	0	0	0	0	0	0	0	83	0	0	0	0	0	2	0	3	0	0	0	0	101
Stock	0	6	42	0	10	34	0	6	0	0	8	0	5	14	14	3	3	0	6	25	0	57	52	53	65	0	390
Town Water Supply	0	360	0	0	0	3650	0	0	0	0	70	0	0	0	0	0	0	0	0	250	0	15300	0	2920	269	0	22819
Total	1330	496	1087	15	387	4693	151	93	31	158	1044	61	359	1427	126	282	256	274	23279	1301	140	16721	2511	4968	4796	71	66026

Source: DWE 2007

Table 6: Percentage of samples collected in exceedence at lake and reservoir locations for 2007 Audit period

Code	SCA Code	Station Name	Turbidity (<10NTU)	Conductivity (<30 µS/cm)	pH (6.5–8.5)	Total Al (<0.055 mg/L)	Total Fe (<0.3 mg/L)	Total P (<10 µg/L)	Filtered P (<5 µg/L)	Total N (<350 µg/L)	Oxidised N (<10 µg/L)	Ammonia (<10 µg/L)	Dissolved Oxygen (85–110%)	Chlorophyll-a (<5 µg/L)
A	DAV7	Lake Avon at the Upper Avon Valve	2	100	10.4	0.9	6.4	8.1	1.8	0.9	40.5	38.7	33.9	58.6
C	DCA1	Lake Cataract at Dam Wall	6.4	100	46.3	28.8	45.9	9.9	2.6	28.8	70.7	91.1	56.9	29.7
D	DCO1	Lake Cordeaux at Dam Wall	6.1	100	12.5	4.1	44.6	9.9	1.6	37	41.7	79.2	79.2	61.4
F	DFF6	Lake Fitzroy Falls at Midlake	17.3	100	0	100	86.8	15	11.7	70	60	43.3	10.8	98.8
G	DGC1	Lake Greaves at Dam Wall	15.6	4.5	66.3	100	94.9	6.3	3.9	3.1	67.1	63.2	52.6	38.4
H	DLC1	Lake Lower Cascade at 50m upstream	5.5	100	0	0	10.3	5.3	10.7	0	96	56	36.4	5.8
I	DNE2	Lake Nepean at 300m upstream of Dam Wall	1.9	100	18.1	36	5	22.7	1.8	96.4	99.1	68.2	55.9	21.7
K	DTA1	Lake Yarrunga at 100m from Dam Wall	20	100	6.2	90.9	99	22.5	9.2	76.8	99.3	73.9	72.6	38.8
L	DTA3	Lake Yarrunga at Kangaroo River and Yarrunga junction	25.7	100	11	78.1	85.9	25	9.4	79.7	96.9	71.9	83.3	55.6
M	DTA5	Lake Yarrunga at Shoalhaven River	29.8	100	7.2	87	94.2	17.4	5.8	72.5	100	81.2	67.3	53
N	DTA8	Lake Yarrunga at Kangaroo River, Bendeela PS	34.3	100	2.9	96.3	100	38.1	14.3	81	78.6	69	52.5	87.3
O	DTA10	Lake Yarrunga at Kangaroo arm, Reed Island	28.9	100	10.5	95.8	97.9	41.7	4.2	79.2	91.7	66.7	64	85.4
P	DTC1	Lake Top Cascade at 100m upstream of Dam Wall	4.9	100	5.6	2.2	1.1	9.9	2.2	19.8	63.7	37.4	40	37.2
Q	DWA2	Lake Burragorang at 500m upstream of Dam Wall	7.5	100	0.4	14.1	2.8	8.5	3.8	23.5	87.1	31.3	81.3	14.1
R	DWA9	Lake Burragorang at 14km upstream of Dam Wall	15.3	100	0.4	28.9	5.9	8.4	3.5	28	89	36.7	76	6.4
S	DWA12	Lake Burragorang at 9km upstream of Coxs River	20.7	100	0	44.4	11.5	5.9	4.8	26.4	82	30.9	65.1	16.6
T	DWA19	Lake Burragorang at Kedumba River arm	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
U	DWA21	Lake Burragorang at Coxs Arm 37km upstream of Dam Wall	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V	DWA27	Lake Burragorang at Wollondilly Arm 23 km upstream of Dam Wall	19.3	100	0.3	52.7	13.2	7.9	2	29.8	86	33.7	71.4	1.9
W	DWA39*	Lake Burragorang at Wollondilly Arm 40 km from Dam Wall	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
AN	DWA311	Lake Burragorang at Wollondilly Arm 40 km from Dam Wall	27.9	100	0	92	17.7	19.2	2.7	41.8	93.2	36.3	85.3	24.6
X	DWI1	Wingecarribee Lake at outlet	33.8	100	0	98.7	79.7	33.3	11.1	80.8	82.8	72.7	30	98.3
Y	DWO1	Lake Woronora at Dam Wall	8.8	99.4	31.9	28.6	0	5.7	0	8.6	97.1	65.7	22.2	1.7
AF	RPR1	Lake Prospect at Midlake	0.6	100	4.4	17.8	1.5	5.2	4.2	4.7	6.8	27.2	16.8	0
AG	RPR3	Lake Prospect near RWPS	0.8	100	5.5	58.3	0	5.6	0	5.6	11.1	19.4	0.8	0

Source: SCA 2007

Notes: pH and dissolved oxygen percentage indicates outside guideline range. ANZECC and ARMCANZ 2000 guideline values in parenthesises.

Red cells indicate 75–100%, orange 50–75% and yellow 25–50% exceedence of guidelines. DWA19 and DWA21 were not monitored within the Audit period.

*DWA39 was too dry to be sampled in the 2005-07 Audit period, hence a new site, DWA311 was chosen to replace it.

Table 7: Percentage of samples collected in exceedence at catchment locations for 2007 Audit period

Code	SCA Code	Station Name	Turbidity (<15NTU)	Conductivity (<350 µS/cm)	pH (6.5-8.5)	Total Al (<0.055 mg/L)	Total Fe (<0.3 mg/L)	Total P (<20 µg/L)	Filtered P (<15 µg/L)	Total N (<250 µg/L)	Oxidised N (<15 µg/L)	Ammonia (<13 µg/L)	Dissolved Oxygen (85-110%)	Chlorophyll-a (<5 µg/L)
CA	E083	Coxs River at Kelpie Point	28.5	1.1	0	68.6	46.6	27	0	79.7	56.7	27.9	15.4	8.6
CB	EI30	Kowmung River at Cedar Ford	30.3	0	3.6	64.1	34.8	33.7	0	66.3	72.5	18.8	11.1	3.1
CC	EI57	Kedumba River at Maxwells Crossing	48.2	0	3.7	67.5	68.8	14.1	1.3	81.3	98.7	10.3	40.7	6.3
CD	E203	Gibbergunyah Creek at Mittagong STP	25	62.9	8	96.3	44.4	85.7	51.5	100	33.8	100	64	15.4
CE	E206	Nattai River at The Crags	52.2	34.1	0	77.8	69.1	79.7	26.4	100	95.8	45.8	18.5	13.9
CF	E210	Nattai River at Smallwoods Crossing	25	15.8	0	80	100	20	0	90	85	65	40	5
CG	E243	Little River at Fireroad	0	0	8.7	39.1	52.2	4.3	0	13	56.5	39.1	26.1	4.3
EH	E303	Wingecarribee River at Sheepwash Bridge	0	0	0	100	100	75	0	100	20	0	0	100
CH	E332	Wingecarribee River at Berrima	75.9	0	0	97.5	90	75	12.5	100	92.5	95	33.3	96.6
CI	E409	Wollondilly River at Murrays Flat	71.4	55	8	82.5	80.6	83.7	63.5	99	85.6	75	72	74.2
CJ	E450	Wollondilly River at Golden Valley	47.1	58.8	0	60	77.5	52.5	20	97.5	60	52.5	55.6	57.1
CK	E457	Mulwarree River at Towers Weir	75.4	59	30	97.4	97.4	94.9	51.3	100	82.1	79.5	80	83.3
CL	E488	Wollondilly River at Jooriland (Fowlers Flat)	86.7	0	0	99.2	98.4	82.7	1.5	99.3	89	35.4	16.1	90.5
CM	E531	Werriberri Creek at Werombi	67.4	4.2	8.1	94.4	99.2	39.5	7.4	92.7	93.7	77.2	92	21.9
EA	E6006	Sandy Creek inflow	0	0	78.6	100	56.3	0	0	6.3	0	0	18.8	0
CN	E601	Nepean River at Inflow to Lake Nepean	4.3	0	4.3	87	100	26.1	0	95.8	100	56.5	17.4	56.5
CO	E602	Burke River at inflow to Lake Nepean	12	0	14.8	64.1	83.8	8.5	0	27.1	39.5	8.6	23.1	2.9
EB	E604	Flying Fox Creek No.3	0	0	13.3	20	0	0	0	66.7	100	20	46.7	6.7
EC	E608	Goondarin Creek inflow	0	0	0	58.8	23.5	0	0	11.8	100	11.8	70.6	0
ED	E609	Cataract River inflow	0	0	25	56.3	100	0	0	25	87.5	50	87.5	0
EE	E6131	Waratah River at Flatrock Crossing	0	0	0	16.7	33.3	8.3	0	25	8.3	16.7	30.8	0
EF	E677	Woronora River inflow	0	0	42.9	50	37.5	0	0	0	0	37.5	12.5	0
EG	E680	Cordeaux River at causeway	0	0	5.9	17.6	70.6	0	0	29.4	82.4	11.8	17.6	11.8
CW	E697	Nepean River	4.2	0	4.2	83.3	100	25	0	95.8	100	58.3	16.7	54.2
CP	E706	Kangaroo River at Hampden Bridge	31	0	2.3	99	100	50.5	10.8	97.5	100	22.8	7.7	13.1
CQ	E822	Mongarlowe River at Mongarlowe	27.1	0	10.7	75	67.9	0	0	10.7	10.7	25	40.8	0
MN	E8311	Corang River at Meengora	0	0	68.4	100	57.9	0	0	21.1	5.3	26.3	57.9	0
CR	E847	Shoalhaven River at Fossickers Flat	88.8	0	0	100	93	82.5	3.4	96.5	93.1	31	7.1	27.8
CS	E851	Shoalhaven River at downstream Tallowa Dam	4	0	0	100	100	16	0	100	100	80	8	3.8
CT	E860	Shoalhaven River at Mount View	38.6	30.9	3.4	76.2	81	38	5.8	76.9	37.5	25	18.5	22.9
CU	E861	Shoalhaven River at Hillview	32.7	0	4.7	90.2	67	30.1	5.2	74.3	49.1	22.4	29.2	9.1
MR	E890	Boro Creek at Marlowe	0	0	65	100	100	10	10	60	15	35	95	10
CV	E891	Gillamatong Creek at Braidwood	22.2	81.2	0	55.1	85.7	59.3	20.8	98.1	66.7	31.3	78.3	15.4
CY	GO515	Woronora River at the Needles	20.5	0	9.8	70.7	69.3	9.2	2.6	64.5	69.7	21.1	45.8	0

Source: SCA 2007. **Notes:** pH and dissolved oxygen percentage indicates outside guideline range. ANZECC and ARMCANZ 2000 guideline values in parenthesises. Red cells indicate 75–100%, orange 50–75% and yellow 25 - 50% exceedence of guidelines.

Table 8: Change from previous Audit Report for water quality parameter groups.

Code	SCA Code	Physical		Toxicants		Nutrients		Chlorophyll-a & Dissolved Oxygen	
		2003-05	2005-07	2003-05	2005-07	2003-05	2005-07	2003-05	2005-07
CA	E083	|	-	-	-	-	-	|	|
CB	E130	|	-	|	-	|	-	+	|
CC	E157	-	|	|	-	|	|	|	-
CD	E203	+	|	|	|	|	|	|	+
CE	E206	+	-	-	-	|	|	|	|
CF	E210	-	|	-	|	|	|	|	|
CG	E243	|	|	+	-	-	+	|	-
CH	E332	|	-	|	|	|	|	|	|
CI	E409	|	+	|	-	|	|	+	|
CJ	E450	|	+	|	-	|	|	-	|
CL	E488	+	-	-	|	|	|	-	-
CM	E531	|	|	+	-	+	-	+	-
CO	E602	-	+	|	|	-	|	|	|
CW	E697		|		-		|		|
CP	E706	|	-	+		-	-	|	|
CQ	E822	|	|	|	-	|	|	-	|
CR	E847	-	-	-	|	-	-	|	-
CS	E851	+	|	|	|	|	|	|	|
CT	E860	|	-	+	-	|	-	|	|
CU	E861	-	|	|	-	|	|	|	-
CV	E891	|	|	+	-	+	-	|	|
CY	GO515		|		-		-		-
A	DAV7	-	|	|	|	-	+	|	|
C	DCA1	-	|	+	-	|	|	|	|
D	DCO1	-	|	+	-	|	|	|	-
F	DFF6	-	|	+	-	|	+	+	-
G	DGC1	-	+	+	-	-	+	-	|
H	DLC1	-	|	|	|	|	|	-	+
I	DNE2	-	|	|	|	|	|	|	|
K	DTA1	-	|	+	-	|	|	|	|
L	DTA3	-	|	|	|	|	|	|	|
M	DTA5	-	|	+	-	|	|	|	|
N	DTA8	-	|	+	-	|	|	|	-
O	DTA10	-	|	+	-	|	|	|	-
P	DTC1	-	|	|	|	|	+	-	+
Q	DWA2	-	|	|	|	-	|	|	-
R	DWA9	-	|	|	-	-	|	+	-
S	DWA12	-	|	|	-	-	|	|	|
T	DWA19	-	ND	+	ND	-	ND	|	ND
U	DWA21	-	ND	+	ND	-	ND	-	ND
V	DWA27	-	|	|	-	-	|	|	|
W	DWA39	-	ND	+	ND	-	ND	-	ND
AN	DWA311*	ND		ND		ND		ND	
X	DWI1	-	|	+	-	|	|	+	-
Y	DWO1	-	|	+	-	|	|	+	|
AF	RPR1	-	|	|	|	|	-	|	|
AG	RPR3	-	|	|	-	|	|	|	|

Note: Red cells indicate 75–100%, orange 50–75% and yellow 25–50% exceedence of guidelines

- = increased percentage exceedence from previous audit period, + = decreased percentage exceedence from previous audit period and | = no change from previous audit period. *DWA39 was too dry to be sampled in the 2005-07 Audit period, hence a new site, DWA311 was chosen to replace it.

Table 9: Code, SCA Code and macroinvertebrate Ausrivas band for the 2003, 2005 and 2007 Audit periods.

Sub-Catchment	Code	SCA Code	Edge						Riffle						Combined					
			2001	2002	2003	2004	2005	2006	2001	2002	2003	2004	2005	2006	2001	2002	2003	2004	2005	2006
Grose/Blue Mountains	NR	MMP39	A	B	A	A	B	B						B						B
Grose/Blue Mountains	NS	MMP40	A	C	B	A	A	B	A						A					
Grose/Blue Mountains	PL	MMP121					B													
Grose/Blue Mountains	QS	MMP177						A						B						B
Upper Coxs	OV	A16	A	X	A	A	A	A	A	B	A	A			A	B	A	A		
Upper Coxs	NP	MMP37	A	A	A	A	A	X	X	B	A	A	A	A	A	B	A	A	A	A
Upper Coxs	NQ	MMP38														C				
Upper Coxs	PB	MMP105				A						A								
Upper Coxs	PJ	MMP118					B													
Upper Coxs	QZ	MMP195						A												
Mid Coxs	MC	E086	X	A	A	A	A	A	X	A	A	A	X	A	X	A	A	A	A	A
Mid Coxs	OC	MMP55	X	A	A	A	A	X	A	B	A	A	B	A	A	B	A	A	B	A
Mid Coxs	OD	MMP56														B				
Mid Coxs	RV	MMP78			B															
Mid Coxs	PK	MMP120					A													
Mid Coxs	QV	MMP184						B												
Lower Coxs	ME	E157	A	A	A	A	X	A	A	X	A	X	A	A	A	A	A	A	A	A
Lower Coxs	NT	MMP41	C	C																
Lower Coxs	OR	MMP76			A	B	A	A				A	A	A				B	A	A
Lower Coxs	NO	MMP36		B																
Lower Coxs	RU	MMP77															A			
Lower Coxs	OY	MMP102				A						A								
Lower Coxs	PM	MMP122					C						B						C	
Lower Coxs	PN	MMP123						C												
Lower Coxs	QU	MMP183						A												
Kowmung	MD	E130		A	A	A	X	A		A	A	A	A	A		A	A	A	A	A
Kowmung	NE	MMP14		A	B	X	X	X	X	A	A	B	A	A	A	A	B	NRA	A	A
Kowmung	QE	MMP15	A	OEM																
Kowmung	SD	MMP91				B						A								
Kowmung	PO	MMP124					X													
Kowmung	PP	MMP125						B						A						B
Lake Burragorang	MU	MMP02		B	B	B	A	NRA					B						B	NRA
Lake Burragorang	OW	MMP01					B													
Lake Burragorang	RT	MMP75					B													
Werriberri Creek	MV	MMP03		A	A	B	A	A			A	A	A	B			NRA	B	A	B
Werriberri Creek	OE	MMP57	A	A	A	C	B	A												
Werriberri Creek	NW	MMP45		B																
Werriberri Creek	OZ	MMP103				A		C												
Werriberri Creek	PQ	MMP127					B													

Table 9: Code, SCA Code and macroinvertebrate Ausrivas band for the 2003, 2005 and 2007 Audit periods.

Sub-Catchment	Code	SCA Code	Edge						Riffle						Combined					
			2001	2002	2003	2004	2005	2006	2001	2002	2003	2004	2005	2006	2001	2002	2003	2004	2005	2006
Little River	MW	MMP04		B	A	B	B	B												
Little River	MX	MMP05		B	A	A	A	A		A	A		X	B		B	A		A	B
Little River	OF	MMP58		B	B															
Little River	SC	MMP89				B														
Little River	PR	MMP129					B													
Nattai	MF	E206	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Nattai	MG	E210		A	A	A	B	B			A	B	A	B			A	B	B	B
Nattai	RX	MMP80			C															
Nattai	SB	MMP87				B														
Nattai	PW	MMP135					A													
Nattai	RF	MMP26						B												
Upper Nepean	NJ	MMP20		A	B	A		X				A						A		
Upper Nepean	OH	N935			A	B	A	A			B	B					B	B		
Upper Nepean	MK	E6133		B																
Upper Nepean	SL	BWN1			B															
Upper Nepean	OX	MMP100				A														
Upper Nepean	PG	MMP113				B														
Upper Nepean	PI	MMP115				A														
Upper Nepean	PX	MMP136					X													
Upper Nepean	PY	MMP137						A												
Woronora	MT	GO515	B	B	A	C	C	B	A	A	B			B	B	B	B			B
Woronora	OJ	R21	A	A	B	B	X	A	C						C					
Woronora	OB	MMP53		B																
Woronora	SK	WON01			A															
Woronora	PZ	MMP139					B													
Woronora	RD	MMP209						B												
Upper Wollondilly	NK	MMP27	X	A	A	X	A	B												
Upper Wollondilly	OO	Uwol1	A	A	A	B	A	B												
Upper Wollondilly	NY	MMP50		A		B														
Upper Wollondilly	RY	MMP83			B															
Upper Wollondilly	PU	MMP133					A													
Upper Wollondilly	PV	MMP134						X												
Wollondilly	MJ	A6	A	B	B	C	B	B												
Wollondilly	MH	E488		A	A	OEM	B	A		B						B				
Wollondilly	NL	E409		B																
Wollondilly	SA	MMP85			B															
Wollondilly	PF	MMP112				C						C								
Wollondilly	PT	MMP130					X						A						A	
Wollondilly	RC	MMP208						B												

Table 9: Code, SCA Code and macroinvertebrate Ausrivas band for the 2003, 2005 and 2007 Audit periods.

Sub-Catchment	Code	SCA Code	Edge						Riffle						Combined					
			2001	2002	2003	2004	2005	2006	2001	2002	2003	2004	2005	2006	2001	2002	2003	2004	2005	2006
Wingecarribee	ON	U10	C	B	B	B	B	B	B		C	B		C	C		C	B		C
Wingecarribee	OP	Winge2	A	A	A	A	A	X	A	A	B	A	A	A	A	A	B	A	A	A
Wingecarribee	MB	MMP30		A																
Wingecarribee	RZ	MMP84			A															
Wingecarribee	QA	MMP140					C													
Wingecarribee	RB	MMP203						A												
Kangaroo	ML	E706	A	A	A	A	A	X	A	A	A	A	A	X	A	A	A	A	A	X
Kangaroo	NV	MMP43	B	A	B	A	B	B	A	A	A	A	A	A	B	A	B	A	B	B
Kangaroo	NU	MMP42														B				
Kangaroo	RN	MMP68															A			
Kangaroo	SE	MMP92				A														
Kangaroo	QC	MMP144					X													
Kangaroo	QT	MMP180						A						A						A
Bungonia	OT	A8	B		B	B	A	B												
Bungonia	MP	E847	B	A	B	B	B	B		B	A	B	B	A		B	B	B	B	B
Bungonia	NX	MMP48		A																
Bungonia	RK	MMP65			A															
Bungonia	SI	MMP98				B														
Bungonia	QD	MMP148					C													
Bungonia	RE	MMP210						A						A						A
Mulwarree	MA	A5	A	A	A		B	A												
Mulwarree	MI	E457	B	C	A	B	B	C												
Mulwarree	RW	MMP79			A															
Mulwarree	PH	MMP114				A														
Mulwarree	QB	MMP142					A													
Mulwarree	QW	MMP188						A												
Nerrimunga	MO	E8361	B	A	B	A	B	B												
Nerrimunga	NZ	MMP51	A	A	C	B	A	B												
Nerrimunga	OA	MMP52		A																
Nerrimunga	QF	MMP150					B													
Nerrimunga	RQ	MMP71			OEM			C												
Mid Shoalhaven	MN	E8311	OEM	A	X	B	A	B	B						NRA					
Mid Shoalhaven	MQ	E861	A	A	A	B		A	A	A	B	A			A	A	B	B		
Mid Shoalhaven	QP	MMP170					A						A						A	
Mid Shoalhaven	RG	MMP35						B												
Mid Shoalhaven	RO	MMP69			X															
Mid Shoalhaven	SS	MMP99				A														
Mid Shoalhaven	QI	MMP159					A						A						A	

Table 9: Code, SCA Code and macroinvertebrate Ausrivas band for the 2003, 2005 and 2007 Audit periods.

Sub-Catchment	Code	SCA Code	Edge						Riffle						Combined					
			2001	2002	2003	2004	2005	2006	2001	2002	2003	2004	2005	2006	2001	2002	2003	2004	2005	2006
Endrick	OU	MMP11	A	OEM	A	A	A	A												
Endrick	ND	MMP12	OEM	A	A	A	B	A	A		B	A		A	NRA		B	A		A
Endrick	RL	MMP66			B															
Endrick	PS	MMP13						C												
Boro	MR	E890	A	B	A	B	B	B												
Boro	OS	MMP33	A		A	A	A	B												
Boro	NN	MMP34		A																
Boro	RI	MMP63						C												
Boro	PD	MMP107				B														
Boro	QG	MMP154					B													
Reedy	OK	R7	A	A	B	B	A	A			C		B				C		B	
Reedy	OM	Reed1	A	A	A	B	B	B			A	B	B				A	B	B	
Reedy	NM	MMP32		B																
Reedy	RR	MMP72			B															
Reedy	PE	MMP108				A														
Reedy	QH	MMP157					A													
Reedy	QY	MMP194						A												
Mongarlowe	OG	Mong1	A	A	A	A	A	B	A	A	B	A	A	A	A	A	B	A	A	B
Mongarlowe	OI	R13	X	A	X	A	A	A	X	A	A	X		A	X	A	A	A		A
Mongarlowe	MM	E822		A																
Mongarlowe	RP	MMP70			A															
Mongarlowe	PC	MMP106				A														
Mongarlowe	QJ	MMP160					A													
Mongarlowe	QL	MMP162						A												
Braidwood	OQ	E860	OEM	X	A	A	B	A	B	A	B	A			NRA	A	B	A		
Braidwood	MS	E891	B	B	B	B	B	B												
Braidwood	NI	MMP19		A																
Braidwood	RJ	MMP64			B															
Braidwood	RH	MMP62				B														
Braidwood	QM	MMP163					B													
Braidwood	QR	MMP174						C												
Back & Round	NF	MMP16	B	A	A	B	A	A	A	A	B	B		A	B	A	B	B		A
Back & Round	NG	MMP17	A	A	A	A	A	A	A	A	A	B		A	A	A	A	B		A
Back & Round	NH	MMP18		A																
Back & Round	SH	MMP95				B														
Back & Round	QK	MMP161					X													
Back & Round	QQ	MMP171						A												

Table 9: Code, SCA Code and macroinvertebrate Ausrivas band for the 2003, 2005 and 2007 Audit periods.

Sub-Catchment	Code	SCA Code	Edge						Riffle						Combined					
			2001	2002	2003	2004	2005	2006	2001	2002	2003	2004	2005	2006	2001	2002	2003	2004	2005	2006
Jerrabattagulla	NA	MMP08	X	A	OEM	A	A	OEM												
Jerrabattagulla	NB	MMP09	A	A	B	X	A	A												
Jerrabattagulla	NC	MMP10		A												A				
Jerrabattagulla	RM	MMP67			A															
Jerrabattagulla	SG	MMP94				A						A								
Jerrabattagulla	QO	MMP168					X													
Jerrabattagulla	QN	MMP167						A												
Upper Shoalhaven	MY	MMP06	X	A	A	X	X	A	B	B	A	B		A	B	B	A	NRA		A
Upper Shoalhaven	OL	R8	B	A	A	A	X	A	A	A	B			A	B	A	B			A
Upper Shoalhaven	MZ	MMP07		B			A						A			B			A	
Upper Shoalhaven	RS	MMP73			B															
Upper Shoalhaven	SF	MMP93				B														
Upper Shoalhaven	RA	MMP199						A												

Source: Ecowise 2007.

Note: Lavender (X) = Richer assemblage than AusRivAs reference condition; Green (A) = Similar to AusRivAs reference location; Yellow (B) = Significantly impaired; Red (C) = Severely impaired. OEM = outside experience of model, no assessment can be made of the site; NRA = No Reliable Assessment could be made of the site

Table 10: DECC code (water quality and macroinvertebrate), SCA code, site description, latitude, longitude, category and sub-catchment

WQ Code	Macro Code	SCA Code	Site Description	Latitude	Longitude	Category	Sub-Catchment
	DA	23001	Black Bobs Creek at St Maur Wines	-34.60276	150.27293	M	Wingecarribee
	DB	23002	Ryans Creek at Belle View	-33.63292	150.11964	M	Mid Coxs
	DC	23006	Nattai River at Boswell Park	-34.44351	150.42938	M	Nattai
	DD	23020	Loddon Creek at Falls	-34.28736	150.89532	M	Upper Nepean
	DE	23026	Blackheath Creek at Avondale II	-33.64308	150.18192	M	Mid Coxs
	DF	23030	Nattai Creek	-34.4308	150.40102	M	Nattai
	DG	23035	Tonalli River downstream at Cemetery Track	-34.09407	150.23298	M	Lake Burragorang
	DH	23053	Wollondilly River at Grovedale	-34.72908	149.56685	M	Upper Wollondilly
	DI	24007	Kedumba River at Oval	-33.7244	150.30515	M	Lower Coxs
	DJ	24008	Fenwicks Creek at Williams Creek	-34.6179	149.6652	M	Upper Wollondilly
	DK	24017	Farmers Creek at Tweed Road	-33.48097	150.12993	M	Upper Coxs
	DL	24018	Fenwicks Creek at Fenwicks Creek	-34.65325	149.66738	M	Upper Wollondilly
	DM	24028	Tarlo River at Oki	-34.61496	149.8073	M	Wollondilly
	DN	24029	Tarlo River at Rhyanna Road	-34.59682	149.76092	M	Wollondilly
	DO	25002	Kellys Creek at Gurnang State Forest	-33.97788	149.86053	M	Kowmung
	DP	25004	Chimney Creek at Trickett's Arch crossing	-33.98297	149.91413	M	Kowmung
	DQ	25013	Tuglow River at Tuglow Forest Road	-33.9398	149.89787	M	Kowmung
		A1	Witts Creek	-35.61	149.62	R	Back & Round
		A10	Sooly Creek	-34.68	149.69	R	Upper Wollondilly
		A11	Coxs River	-33.62	150.16	R	Mid Coxs
		A12	Kings Creek	-35.18	149.72	R	Boro
		A13	Brogers Creek	-34.74	150.59	R	Kangaroo
		A14	Jerrabattagulla Creek	-35.68	149.59	R	Jerrabattagulla
		A15	Nadgigomar Creek	-35.03	149.93	R	Nerrimunga
	OV	A16	Coxs River at Lidsdale	-33.38059	150.07798	MR	Upper Coxs
		A2	Upper Shoalhaven River	-35.57	149.63	R	Back & Round
		A3	Reedy Creek	-35.31	149.76	R	Reedy
		A4	Upper Mongarlowe River	-35.45	149.94	R	Mongarlowe
	MA	A5	Mulwaree River at Lake Bathurst	-35.01734	149.65313	MR	Mulwarree
	MB	A6	Upper Tarlo River at Tarlo	-34.60536	149.80126	MR	Wollondilly
		A7	Woolshed Creek	-34.37	149.82	R	Wollondilly
	OT	A8	Bungonia Creek at Bungonia	-34.853028	149.94336	MR	Bungonia
		A9	Heffernans Creek	-34.66	149.49	R	Upper Wollondilly
	SL	BWN1	Doudles Creek at Diamond Fields Road	-34.5125	150.52444	M	Upper Nepean
AH		COMP1,COMP3	Prospect WFP			P	Prospect
AI		COMP5	Illawarra System			P	
AJ		COMP6	Blue Mountains System			P	

Table 10: DECC code (water quality and macroinvertebrate), SCA code, site description, latitude, longitude, category and sub-catchment

WQ Code	Macro Code	SCA Code	Site Description	Latitude	Longitude	Category	Sub-Catchment
		CR1	Coxs River upstream of Lake Lyell	-33.486168	150.076972	Delta Fish	Upper Coxs
		CR1	Coxs River upstream of Lake Lyell	-33.486168	150.076972	Delta Fish	Upper Coxs
		CR1	Coxs River upstream of Lake Lyell	-33.486168	150.076972	Delta Fish	Upper Coxs
A		DAV7	Lake Avon at the Upper Avon Valve	-34.45576383	150.7164813	WQA	Upper Nepean
B		DBP1	Bendeela Pondage	-34.72629609	150.4783012	A	Kangaroo
C		DCA1	Lake Cataract at Dam Wall	-34.27178165	150.807385	WQA	Upper Nepean
D		DCO1	Lake Cordeaux at Dam Wall	-34.34017371	150.7461518	WQA	Upper Nepean
E		DFF	Fitzroy Falls composite	-34.64455409	150.4981783	A	Kangaroo
F		DFF6	Lake Fitzroy Falls at Midlake	-34.64455409	150.4981783	WQA	Kangaroo
G		DGC1	Lake Greaves at Dam Wall	-33.65549518	150.307785	WQA	Grose
H		DLC1	Lake Lower Cascade at 50m upstream	-33.68534323	150.3043738	WQA	Grose
I		DNE2	Lake Nepean at 300m upstream of Dam Wall	-34.33772242	150.6066004	WQA	Upper Nepean
AK		DNE7	Lake Nepean			WQ	Upper Nepean
J		DPAE	Bendeela picnic area	-34.74050664	150.4680408	A	Kangaroo
K		DTA1	Lake Yarrunga at 100m from Dam Wall	-34.76815486	150.3174508	WQA	Kangaroo
O		DTA10	Lake Yarrunga at Kangaroo arm, Reed Island	-34.74761906	150.4259182	WQA	Kangaroo
L		DTA3	Lake Yarrunga at Kangaroo and Yarrunga Junction	-34.74399407	150.3752163	WQA	Kangaroo
M		DTA5	Lake Yarrunga at Shoalhaven River	-34.81777456	150.20641	WQA	Bungonia
N		DTA8	Lake Yarrunga at Kangaroo River, Bendeela Pumping Station	-34.73693917	150.467287	WQA	Kangaroo
P		DTC1	Lake top Cascade at 100m upstream of Dam Wall	-33.69419994	150.3004084	WQA	Grose
S		DWA12	Lake Burragorang at 9km upstream of Coxs River	-33.91122702	150.3775965	WQA	Lake Burragorang
AM		DWA15	Lake Burragorang at 4km upstream Butchers Creek	-33.900726	150.339863	A	Lake Burragorang
T		DWA19	Lake Burragorang at Kembula River arm	-33.85636736	150.3388934	WQA	Lower Coxs
Q		DWA2	Lake Burragorang at 500m upstream of Dam Wall	-33.8888162	150.5871209	WQAP	Lake Burragorang
U		DWA21	Lake Burragorang at Coxs arm 37 km upstream of Dam Wall	-33.85258428	150.3108194	WQA	Lower Coxs
V		DWA27	Lake Burragorang at Wollondilly arm 23 km upstream of Dam Wall	-33.99535189	150.4177451	WQA	Lake Burragorang
AN		DWA311	Lake Burragorang at Wollondilly River upstream of Nattai River	-34.092016	150.394924	WQ	Lake Burragorang
W		DWA39	Lake Burragorang at Wollondilly arm 40 km upstream of Dam Wall	-34.13491802	150.3454745	WQA	Lake Burragorang
R		DWA9	Lake Burragorang at 14km upstream of Dam Wall	-33.96465397	150.4697875	WQA	Lake Burragorang
AM		DWI	Lake Wingecarribee composite	-34.54118111	150.4833341	WQ	Wingecarribee
X		DWI1	Wingecarribee Lake at outlet	-34.54118111	150.4833341	AP	Wingecarribee
AL		DWI3	Lake Wingecarribee at Midlake			A	Wingecarribee
Y		DWO1	Lake Woronora at Dam Wall	-34.10995364	150.932814	WQA	Woronora
CA		E083	Coxs River at Kelpie Point	-33.87306938	150.2496957	WQP	Mid Coxs
	MC	E086	Coxs River at Kelpie Point	-33.87166	150.2538	M	Mid Coxs
CB	MD	E130	Kowmung River at Cedar Ford	-33.94577	150.24502	WQPM	Kowmung
CC	ME	E157	Kedumba River at Kedumba crossing	-33.80299	150.36355	WQPM	Lower Coxs
CD		E203	Gibbergunyah Creek at Mittagong STP	-34.44416698	150.4367589	WQP	Nattai

Table 10: DECC code (water quality and macroinvertebrate), SCA code, site description, latitude, longitude, category and sub-catchment

WQ Code	Macro Code	SCA Code	Site Description	Latitude	Longitude	Category	Sub-Catchment
CE	MF	E206	Nattai River at The Crags	-34.39076	150.42502	WQPM	Nattai
CF	MG	E210	Nattai River at Smallwoods Crossing	-34.14333	150.42466	WQPM	Nattai
CG		E243	Little River at Fireroad	-34.19050717	150.4639912	WQP	Little River
EH		E303	Wingecarribee River at Sheepwash Bridge	-34.538146	150.480759	WQA	Wingecarribee
CH		E332	Wingecarribee River at Berrima	-34.49622028	150.341527	WQ	Wingecarribee
CI	MH	E409	Wollondilly River at Murrays Flat	-34.72142	149.79604	WQPM	Wollondilly
CJ		E450	Wollondilly River at Golden Valley	-34.55155165	150.0804688	WQ	Wollondilly
CK	MI	E457	Mulwaree River at The Towers	-34.78062	149.70775	WQM	Mulwarree
CL	MJ	E488	Wollondilly River at Jooriland	-34.22634	150.25412	WQPM	Wollondilly
CM		E531	Werriberri Creek at Werombi	-33.98144591	150.5578818	WQP	Werriberri Creek
EA		E6006	Sandy Creek inflow	-34.39634815	150.7557944	WQ	Upper Nepean
CN		E601	Nepean River at Inflow to Lake Nepean	-34.38468654	150.5701507	WQ	Upper Nepean
CO		E602	Burke River at inflow to Lake Nepean	-34.41401368	150.5943221	WQ	Upper Nepean
EB		E604	Flying Fox Creek No.3	-34.46096881	150.7399157	WQ	Upper Nepean
EC		E608	Goondarin Creek inflow	-34.39221742	150.826598	WQ	Upper Nepean
ED		E609	Cataract River inflow	-34.36476021	150.8544887	WQ	Upper Nepean
EE		E6131	Waratah Rivulet at Flat Rock Crossing	-34.19760975	150.9332262	WQ	Woronora
	MK	E6133	Goondarin Creek at top of Cordeaux Dam	-34.38961	150.82682	M	Upper Nepean
EF		E677	Woronora River inflow	-34.15030231	150.9141536	WQ	Woronora
EG		E680	Cordeaux River at causeway	-34.42281913	150.7735826	WQ	Upper Nepean
CW		E697	Nepean River	-34.4764	150.5292	WQ	Upper Nepean
CP	ML	E706	Kangaroo River at Hampton Bridge	-34.728	150.52136	WQM	Kangaroo
CQ	MM	E822	Mongarlow River at Mongarlowe	-35.42163	149.93554	WQM	Mongarlowe
	MN	E8311	Corang River at Meangora	-35.14543	150.04317	WQM	Mid Shoalhaven
	MO	E8361	Nerrimunga Creek at Minshall Trig	-35.00894	149.93277	M	Nerrimunga
CR	MP	E847	Shoalhaven River at Fossikers Flat	-34.8175	150.20076	WQM	Bungonia
CS		E851	Shoalhaven River at downstream Tallowa Dam	-34.77869282	150.3150118	WQ	Kangaroo
CT	OQ	E860	Shoalhaven River at Mount View	-35.44934	149.7207	WQM	Braidwood
CU	MQ	E861	Shoalhaven River at Hillview	-35.18208	149.953	WQM	Mid Shoalhaven
	MR	E890	Boro Creek at Marlowe	-35.23021	149.84681	WQM	Boro
CV	MS	E891	Gillamatong Creek at Braidwood	-35.42535	149.7366	WQM	Braidwood
CY	MT	GO515	Woronora River at the Needles	-34.04677	151.00619	WQM	Woronora
	DR	HAWK10	Megalong Creek at Narrow Neck	-33.7297	150.2462	M	Mid Coxs
	DT	HAWK864	Coxs River at Lithgow	-33.5505	150.1227	M	Mid Coxs
Z		HBP	HBP1 and HBP2 taps	-34.7423765	150.4712599	A	Kangaroo
AA		HFF4	NPWS picnic shelter tap at Fitzroy Falls	-34.64884017	150.4817412	A	Kangaroo
AB		HOP6	Oberon pipeline, Leura	-33.70815475	150.3347928	A	Lower Coxs
AC		HPR1	Upper Canal at Prospect WFP	-33.8235	150.8696	AP	Prospect

Table 10: DECC code (water quality and macroinvertebrate), SCA code, site description, latitude, longitude, category and sub-catchment

WQ Code	Macro Code	SCA Code	Site Description	Latitude	Longitude	Category	Sub-Catchment
AD		HUC1	Upper Canal at Broughtons Pass	-34.2273	150.7423	A	Upper Nepean
AE		HUC3	Upper Canal at Kenny Hill	-34.0497	150.7805	A	Prospect
	OW	MMP01	Tonalli River upstream Yerrandrie	-34.13193207	150.1833653	M	Lake Burragorang
	MU	MMP02	Tonalli River upstream of Basin Creek	-34.10353	150.26675	M	Lake Burragorang
	MV	MMP03	Werriberri Creek at Serenity Park	-33.97936	150.55922	M	Werriberri Creek
	MW	MMP04	Blue Gum Creek along fire trail W41	-34.2152	150.48938	M	Little River
	MX	MMP05	Little River at fire trail W41	-34.18919	150.46594	M	Little River
	MY	MMP06	Shoalhaven River at Yarra Glen	-35.84466	149.64001	M	Upper Shoalhaven
	MZ	MMP07	Jinden Creek at Jinden Ridge Road	-35.88195	149.56465	M	Upper Shoalhaven
	NA	MMP08	Boggy Creek upstream of Shoalhaven River	-35.78929	149.63869	M	Jerrabattagulla
	NB	MMP09	Jerrabattgulla Creek at Warragandra	-35.6814	149.593	M	Jerrabattagulla
	NC	MMP10	Shoalhaven River at Berlang	-35.72485	149.64837	M	Jerrabattagulla
	OX	MMP100	Wongawilli Creek at Avon to Cordeaux Road	-34.3411	150.7267	M	Upper Nepean
	OY	MMP102	Reedy Creek at Kedumba Valley Road	-33.8263	150.37167	M	Lower Coxs
	OZ	MMP103	Back Creek at Burragorang Road	-34.07705	150.53537	M	Werriberri Creek
	PA	MMP104	Piper's Flat Creek at Wallerawang	-33.40491	150.06386	M	Upper Coxs
	PB	MMP105	Coxs River at Sandy Hook	-33.68928	150.15709	M	Upper Coxs
	PC	MMP106	Warrambucca Creek at Northangera Road	-35.46824	149.92973	M	Mongarlowe
	PD	MMP107	Pipeclay Creek at Mayfield	-35.20861	149.79746	M	Boro
	PE	MMP108	Mulloon Creek at Mulloon Road	-35.26394	149.60322	M	Reedy
	OU	MMP11	Titringo Creek at High Forest	-35.09347	150.07766	M	Endrick
	PF	MMP112	Bannaby Creek at Adavale Road	-34.43278	149.98376	M	Wollondilly
	PG	MMP113	Lizard Creek at Fire Road 8	-34.30794	150.79164	M	Upper Nepean
	PH	MMP114	Mulwaree River at Tarago	-35.07008	149.65766	M	Mulwarree
	PI	MMP115	Bellambi Creek at Fire Road 7D	-34.32807	150.84378	M	Upper Nepean
	PJ	MMP118	Kerosene Creek at McKanes Bridge	-33.53227	150.24188	M	Upper Coxs
	ND	MMP12	Endrick River at Nerriga	-35.08635	150.11734	M	Endrick
	PK	MMP120	Ganbenang Creek at Ganbenang Road	-33.63652	150.1359	M	Mid Coxs
	PL	MMP121	Greaves Creek at Grand Canyon	-33.65712	150.3231	M	Grose
	PM	MMP122	Jamison Creek at Dalrymple Avenue	-33.71561	150.3748	M	Lower Coxs
	PN	MMP123	Spring Creek at Kedumba Valley Road	-33.82587	150.3707	M	Lower Coxs
	PO	MMP124	Jaunter Creek at Jaunter Road	-33.98822	149.89926	M	Kowmung
	PP	MMP125	Hollanders River at Ben Lomond Fire Trail	-33.9142	149.98592	M	Kowmung
	PQ	MMP127	Werriberri Creek at Hermitage Road	-34.10793	150.55009	M	Werriberri Creek
	PR	MMP129	Moore Creek at Bolins Road Fire Trail	-34.31378	150.5116	M	Little River
	PS	MMP13	Bindi Brook Creek at Nerriga	-35.12917	150.08333	M	Endrick
	PT	MMP130	Long Swamp Creek upstream Paddy's River	-34.59348	150.11683	M	Wollondilly
	PU	MMP133	Dixons Creek on Goulburn-Crookwell Road	-34.68515	149.58405	M	Upper Wollondilly
	PV	MMP134	Whiteheads Creek on Goulburn-Crookwell Road	-34.68005	149.57126	M	Upper Wollondilly

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WQ Code	Macro Code	SCA Code	Site Description	Latitude	Longitude	Category	Sub-Catchment
	PW	MMP135	Nattai River at Colleys Flat	-34.43106	150.40186	M	Nattai
	PX	MMP136	Lizard creek down stream Fire Road	-34.30036	150.7932	M	Upper Nepean
	PY	MMP137	Nepean River at Belmore Crossing	-34.31096	150.54817	M	Upper Nepean
	PZ	MMP139	Heathcote Creek at Battery Causeway	-34.09529	150.97952	M	Woronora
	NE	MMP14	Kowmung River at Kowmung Fire Trail	-33.95586	149.97779	M	Kowmung
	QA	MMP140	Whites Creek off Willow Drive	-34.54618	150.36319	M	Wingecarribee
	QB	MMP142	Gundary Creek at Homelee	-34.81098	149.74348	M	Mulwarree
	QC	MMP144	Barrengarry River at Oakleigh	-34.72236	150.52879	M	Kangaroo
	QD	MMP148	Marulan Creek at South Marulan Road	-34.74178	149.99039	M	Bungonia
	QE	MMP15	Tuglow River at Tuglow Forest Road	-33.94019	149.8935	M	Kowmung
	QF	MMP150	Jacqua Creek at Bungonia-Windellema Road	-34.92777	149.94012	M	Nerrimunga
	QG	MMP154	Millendale Creek at Mayfield Road	-35.13904	149.7432	M	Boro
	QH	MMP157	Reedy Creek at Goulburn Road	-35.21708	149.66523	M	Reedy
	QI	MMP159	Corang River at Braidwood-Nerriga Road	-35.20445	150.05156	M	Mid Shoalhaven
	NF	MMP16	Witts Creek at Krawaree Road Crossing	-35.60659	149.61447	M	Back & Round
	QJ	MMP160	Northangera Creek at Woodleigh Fire Trail	-35.49094	149.92353	M	Mongarlowe
	QK	MMP161	Parlour Creek at Harolds Cross Road	-35.57534	149.58817	M	Back & Round
	QL	MMP162	Feagans Creek at Myrtle Road	-35.43035	149.96843	M	Mongarlowe
	QM	MMP163	Little Bombay Creek at Mulloon Fire Trail	-35.40881	149.63604	M	Braidwood
	QN	MMP167	Wyanbene Caves Creek at Wyanbene Road	-35.76014	149.65486	M	Jerrabattagulla
	QO	MMP168	Jerrabattgulla Creek at Hereford Hall Road	-35.80817	149.55977	M	Jerrabattagulla
	NG	MMP17	Shoalhaven River at Farringdon Crossing	-35.50914	149.67196	M	Back & Round
	QP	MMP170	Shaolhave River at Oallen Ford Road	-35.14987	149.95816	M	Mid Shoalhaven
	QQ	MMP171	Back Creek at Captains Flat Road	-35.50575	149.69823	M	Back & Round
	QR	MMP174	Bombay Creek at Little Bombay (Hoskinstown Road)	-35.41745	149.69444	M	Braidwood
	QS	MMP177	Linden Creek at Hillcrest Avenue	-33.68104	150.52681	M	Grose
	NH	MMP18	Back Creek at Wallace Gap Road	-35.69028	149.6375	M	Back & Round
	QT	MMP180	Gerringong Creek at Gerringong Creek Road	-34.68746	150.61499	M	Kangaroo
	QU	MMP183	Waterfall Creek at Kedumba Valley Road	-33.80113	150.36632	M	Lower Coxs
	QV	MMP184	Blackheath Creek at Goannamanna	-33.61808	150.23378	M	Mid Coxs
	QW	MMP188	Mulwarree River at Brewon	-34.8565	149.65378	M	Mulwarree
	NI	MMP19	Bombay Creek at Bombay Fire Trail	-35.44365	149.63054	M	Braidwood
	QX	MMP192	Budjong Creek at Sandy Point	-35.06143	149.864	M	Nerrimunga
	QY	MMP194	Manar Creek at The Dip	-35.2886	149.69828	M	Reedy
	QZ	MMP195	Marrangaroo Creek at Great Western Highway	-33.43731	150.11307	M	Upper Coxs
	RA	MMP199	Little Snowball Creek at Krawaree Road	-35.9314	149.56833	M	Upper Shoalhaven
	NJ	MMP20	Nepean River at Maguires Crossing	-34.47627	150.5343	M	Upper Nepean
	RB	MMP203	Kelly's Creek at Wildes Meadows Road bridge	-34.59932	150.48785	M	Wingecarribee
	RC	MMP208	Turallo Creek at Grants Flat	-34.53104	149.74265	M	Wollondilly

Table 10: DECC code (water quality and macroinvertebrate), SCA code, site description, latitude, longitude, category and sub-catchment

WQ Code	Macro Code	SCA Code	Site Description	Latitude	Longitude	Category	Sub-Catchment
	RD	MMP209	Heathcote Creek upstream confluence with Woronora River	-34.06309	150.99651	M	Woronora
	RE	MMP210	Shoalhaven River at Blue Track	-34.82937	150.04338	M	Bungonia
	RF	MMP26	Nattai River upstream Colleys Flat	-34.20111	150.36306	M	Nattai
	NK	MMP27	Wollondilly River at Goonagulla	-34.66412	149.52425	M	Upper Wollondilly
	NL	MMP30	Black Bobs Creek at Bunny Galore	-34.47919	150.19288	M	Wingecarribee
	NM	MMP32	Durran Durra Creek at Euradux	-35.34241	149.8167	M	Reedy
	OS	MMP33	Kings Creek upstream Boro Creek	-35.1815	149.72366	M	Boro
	NN	MMP34	Boro Creek at Lower Boro	-35.19277	149.78967	M	Boro
	RG	MMP35	Ningenimble Creek at Oallen Road	-35.16561	149.99028	M	Mid Shoalhaven
	NO	MMP36	Cedar Creek at Hayes Crossing	-33.82823	150.31449	M	Lower Coxs
	NP	MMP37	Coxs River at McKanes Bridge	-33.54952	150.12444	M	Upper Coxs
	NQ	MMP38	Farmers Creek at Great Western Highway	-35.79039	149.63903	M	Upper Coxs
	NR	MMP39	Woodford Creek at Woodford Dam	-33.6974	150.48568	M	Grose
	NS	MMP40	Yosemite Creek upstream of Minnihaha Falls	-33.68591	150.32642	M	Grose
	NT	MMP41	Kedumba River at Scenic Railway	-33.4351	150.1815	M	Lower Coxs
	NU	MMP42	Brogers Creek at Priddles Lane Crossing	-34.71099	150.68207	M	Kangaroo
	NV	MMP43	Kangaroo River at Upper Kangaroo	-34.68472	150.6006	M	Kangaroo
	NW	MMP45	Werriberri Creek at top of Warragamba	-33.9294	150.54865	M	Werriberri Creek
	NX	MMP48	Jerrara Creek at Jerrara Road	-34.81325	149.95138	M	Bungonia
	NY	MMP50	Wollondilly River at Gundowringa	-34.54403	149.57862	M	Upper Wollondilly
	NZ	MMP51	Jacqua Creek at Lumley Road	-34.93714	149.84472	M	Nerrimunga
	OA	MMP52	Nadgigomar Creek at Oallen Ford	-35.08992	149.89097	M	Nerrimunga
	OB	MMP53	Woronora River at Eckersley Ford	-34.10057	150.97309	M	Woronora
	OC	MMP55	Little River at Six Foot Track	-33.76537	150.13575	M	Mid Coxs
	OD	MMP56	Jenolan River at Camping Area	-33.81735	150.03585	M	Mid Coxs
	OE	MMP57	Werriberri Creek at The Oaks	-34.08907	150.56116	M	Werriberri Creek
	OF	MMP58	Little River at Buxton	-34.26191	150.35834	M	Little River
	RH	MMP62	Jembaicumbene Creek at Bendoura	-35.50167	149.71583	M	Braidwood
	RI	MMP63	Millendale Creek at Glendor	-35.18426	149.78983	M	Boro
	RJ	MMP64	Little Bombay Creek at Little Bombay	-35.41167	149.67389	M	Braidwood
	RK	MMP65	Stoney Creek at Marulan	-34.75888	149.96889	M	Bungonia
	RL	MMP66	Nadgengutta Creek at Nerriga Road	-35.13833	150.06722	M	Mid Shoalhaven
	RM	MMP67	Stoney Creek at Oranmeir	-35.69028	149.6375	M	Jerrabattagulla
	RN	MMP68	Barrengarry Creek at Sunnyvale	-34.70278	150.53139	M	Kangaroo
	RO	MMP69	Oallen Creek at Oallan Ford	-35.14722	149.95611	M	Mid Shoalhaven
	RP	MMP70	Feagans Creek at Charlies Forest Road	-34.23903	150.91819	M	Mongarlowe
	RQ	MMP71	Windellama Creek at Windellama	-35.00172	149.88942	M	Nerrimunga
	RR	MMP72	St Omer Creek at Euradux	-35.36466	149.81757	M	Reedy
	RS	MMP73	Jinden Creek at Krawaree Road Crossing	-35.88444	149.59306	M	Upper Shoalhaven

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WQ Code	Macro Code	SCA Code	Site Description	Latitude	Longitude	Category	Sub-Catchment
	RT	MMP75	Basin Creek south of Yerranderie	-34.12615	150.2355	M	Lake Burragorang
	OR	MMP76	Leura Falls Creek at Fire Trail W74	-33.749722	150.32944	M	Lower Coxs
	RU	MMP77	Jamison Creek at Jamison Valley	-33.76447	150.35186	M	Lower Coxs
	RV	MMP78	Megalong Creek at Old Ford Reserve	-33.73217	150.235	M	Mid Coxs
	RW	MMP79	Crisps Creek at Bungendor	-35.08361	149.63389	M	Mulwarree
	RX	MMP80	Gibbergunyah Creek downstream Mittagong STP	-34.44333	150.43694	M	Nattai
	RY	MMP83	Pejar Creek at Woodhouselee	-34.57248	149.62978	M	Upper Wollondilly
	RZ	MMP84	Medway Rivulet at Old Hume Hayway	-34.5296	150.30602	M	Wingecarribee
	SA	MMP85	Narambulla Creek at Carrick	-34.68036	149.89818	M	Wollondilly
	SB	MMP87	Sheepwash Creek at Drapers Road	-34.41733	150.47144	M	Nattai
	SC	MMP89	Moore Creek at Buxton	-34.27259	150.51606	M	Little River
	SD	MMP91	Budthingeroo Creek at Mumbedah Fire Trail	-33.89216	150.03585	M	Kowmung
	SE	MMP92	Sawyers Creek at Glen Murray Road	-34.73914	150.56512	M	Kangaroo
	SF	MMP93	Currembene Creek upstream Little Snowball Creek	-35.93504	149.58967	M	Upper Shoalhaven
	SG	MMP94	Bush Paddock Creek at Jerrabattagulla Road	-35.69861	149.58485	M	Jerrabattagulla
	SH	MMP95	Mount Creek at Mount Elrington	-35.52979	149.64419	M	Back & Round
	SI	MMP98	Barbers Creek at Tallong	-34.71746	150.0587	M	Bungonia
	SJ	MMP99	Jerricknorra Creek at Braidwood Road	-35.2352	150.0067	M	Mid Shoalhaven
	OG	Mong1	Mongarlowe River at Charleyong	-35.25125	149.92159	M	Mongarlowe
EI		N92	Neapean River at Maldon Weir	-34.2468	150.668	WQM	Upper Nepean
	OH	N935	Nepean River at Pheasents Nest	-34.24647	150.66693	M	Upper Nepean
		R1	Nepean River	-34.46	150.53	R	Upper Nepean
		R10	Heathcoate Creek	-34.06	151	R	Woronora
		R12	Nattai River	-34.14	150.42	R	Nattai
	OI	R13	Mongarlowe River at Monga	-35.54319	149.92988	MR	Mongarlowe
		R16	Little River	-33.77	150.12	R	Mid Coxs
		R17	Wollondilly River	-34.31	150.07	R	Wollondilly
		R18	Guineacor Creek	-34.33	149.98	R	Wollondilly
	OJ	R21	Waratah Rivulet at Flat Rock Crossing	-34.19604	150.93453	MR	Woronora
		R22	Kowmung River	-33.96	149.98	R	Kowmung
		R4	Endrick River	-35.09	150.12	R	Endrick
		R6	Reedy Creek	-35.28	149.7	R	Reedy
	OK	R7	Mulloon Creek at Tawarri	-35.33418	149.58566	MR	Reedy
	OL	R8	Currumbene Creek at Krawaree Road Crossing	-35.89098	149.59496	M	Upper Shoalhaven
	OM	Reed1	Reddy Creek at Mayfield Road	-35.30935	149.759	M	Reedy
AF		RPR1	Lake Prospect at Midlake	-33.82869775	150.9020014	WQAP	Prospect
AG		RPR3	Lake Prospect near RWPS	-33.8217813	150.8892929	WQAP	Prospect
	DS	SHOA01	Kangaroo River upstream Gerrigong Creek	-34.6858	150.6008	M	Kangaroo
	DU	SHOA104	Jinden Creek at Tallanganda State Forest	-35.882	149.5646	M	Upper Shoalhaven

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WQ Code	Macro Code	SCA Code	Site Description	Latitude	Longitude	Category	Sub-Catchment
	DV	SHOA1211	Mongarlowe River upstream Charleyong Bridge	-35.2504	149.92	M	Mongarlowe
	ON	U10	Wingecarribee River at Berrima	-34.49112	150.33213	MR	Wingecarribee
		U11	Wollondilly River	-34.74	149.75	R	Wollondilly
		U12	Mulwaree River	-34.75	149.73	R	Mulwarree
		U2	Mittagong Creek	-34.48	150.42	R	Wingecarribee
		U3	Katoomba Creek	-33.72	150.3	R	Lower Coxs
		U4	Gibbergunyah Creek	-34.45	150.42	R	Nattai
		U5	Nattai River	-34.45	150.46	R	Nattai
		U6	Farmers Creek	-33.47	150.13	R	Upper Coxs
		U7	Gillamatong Creek	-35.44	149.78	R	Braidwood
		U8	Paddys River	-35.9	149.59	R	Wollondilly
		U9	Forbs Creek	-34.05	151.01	R	Woronora
	OO	Uwol1	Wollondilly River at Baw Baw Bridge	-34.74883	149.65896	M	Upper Wollondilly
	OP	Winge2	Wingecarribee River at Greenstead	-34.4167	150.19289	M	Wingecarribee
	SK	WON01	Woronora River at Gurra Causeway	-34.10656	150.94793	M	Woronora

Notes: A – Algae, M – Macroinvertebrate, P – Pathogen, WQ – Water Quality, R - Riparian