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NSW GOVERNMENT Department of Primary Industries

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RECREATIONAL FISHING NEW SOUTH WALES

RISK ASSESSMENT RECREATIONAL FISHING IN SYDNEY WATER SUPPLY DAMS

Final Report

January 2019

RISK ASSESSMENT RECREATIONAL FISHING IN SYDNEY WATER SUPPLY DAMS

Final Report

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Version (s)

Revision	***Date***	***Author (s)***	***Notes***
1	31-8-18	Danny Simpson, Michael Sierp	Preliminary draft
2	8-10-18	Danny Simpson, Michael Sierp	Draft for Review
3	24-10-18	Danny Simpson, Michael Sierp	Draft for Review
3b	5-11-2018	Danny Simpson, Michael Sierp	Amended Draft for Review
Final	16-1-2019	Danny Simpson, Michael Sierp	Inclusion of Peer Review Comments

Distribution

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3b	5-11-18	D. Baker, J Brayn	Amended Draft for Review
Final	16-1-19	J Harnwell	Final report

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Executive Summary

The Risk Assessment- Recreational Fishing In Sydney Water Supply Dams project (the project) is an initiative of the NSW Minister for Primary Industries who requested that DPI Fisheries research the possibility of a risk assessment on one or more of Sydney's water supply reservoirs in order to provide detailed information on possible risks to public health associated with allowing recreational fishing in these areas.

The project focuses on three reservoirs: **Prospect Reservoir** and **Cataract Reservoir** within the GSWSS and **Woodford Dam** which is no longer part of the supply system. These storages were selected based on their differing features and role within the GSWSS and are considered broadly representative of the other storages in the system. By assessing risk at these representative storages, a comprehensive understanding of the possible risks of allowing recreational fishing access to each of the storages within the GSWSS is established.

The Risk Assessment process used in this project is a *Qualitative Risk Assessmen*t which is suitable for assessing the broad risks of recreational fishing access to reservoirs in the GSWSS. It follows the standards of The Australian/New Zealand Standard for Risk Assessment (AS/NZS/ISO31000:2018) and is adapted to integrate with the process shown within the Australian Drinking Water Guidelines (2017).

A range of stakeholders were identified early in the project as being critical to the provision of background information and the identification of the threats to be carried forward to the formal risk assessment process. A key component of the process was a Stakeholder Workshop to identify and assess the range of risks that may be apparent in allowing recreational fishing access to reservoirs

Key stakeholder participants included:

- Government Agencies – DPI Fisheries, WaterNSW, Sydney Water, Health NSW, NPWS
- Recreational Fishing Groups – RFNSW, Recreational Fishing Alliance, Australian Fishing Trade Association.

Given the technical nature of the project, an independent water quality risk specialist be engaged to:

1. review the Risk Assessment Methodology used in the project;
2. review the background information to ensure that it was adequate to inform the Risk Assessment process;
3. participate in the Risk Assessment Workshop; and
4. review this report.

Dr. Dan Deere of Water Futures was recommended by WaterNSW as the preferred reviewer and was subsequently engaged by DPI Fisheries for this purpose.

The Risk Assessment identified 7 possible Risk Sources and 19 possible Risk Events from allowing recreational fishing access in GSWSS reservoirs. The range of risk events related not only to impacts on water quality but also disruptions to the operation of the system and safety aspects for users.

One Severe risk and 1 High risk were identified for each of Prospect and Cataract Reservoirs while none were identified for Woodford Reservoir.

Table ES.1: Risk Assessment Results for Prospect Reservoir

Risk No.	Risk Source	Event	Potential Consequences	L	C	R	Rationale 50 cars, single access point & 100 people
C1	**A1, A6, A9,**	**Recreational fishing access causes bushfires in the catchment**	• Life and property is lost • Bushfire prevention requires the investment of more resources • Rainfall after bushfire leads to increased sediment and nutrient transport to reservoirs which can increase turbidity and cause algal blooms • Increased treatment costs	**3**	**5**	**S**	• Principle is based on increased access increases risk • Increasing residence time on the site therefore also increases risk • Current Bushfire prevention/response plans do not incorporate increased public access beyond defined areas for recreational fishing
R3	**A1, A6**	**Deliberate contamination of the reservoir**	• Increased visitation provides greater opportunities for terrorism	**1**	**4**	**H**	• Deliberate attempts may to have significant impact if successful but unlikely to be related to allowing recreational fishing access • Incidence (and therefore likelihood) of deliberate attempts to contaminate water supply is very low – historical records

Table ES.2 Risk Assessment Results for Cataract Reservoir

C1	**A1, A6, A9,**	**Recreational fishing access causes bushfires in the catchment**	• Life and property are lost • Bushfire prevention requires the investment of more resources • Rainfall after bushfire leads to increased sediment and nutrient transport to reservoirs which can increase turbidity and cause algal blooms • Increased treatment costs	**3**	**5**	**S**	• Principle is based on increased access increases risk • Increasing residence time on the site therefore also increases risk • Current Bushfire prevention/response plans do not incorporate increased public access beyond defined areas

R3	**A1, A6**	**Deliberate contamination of the reservoir**	• Increased visitation may provide greater opportunities for terrorism	**1**	**5**	**H**	• Deliberate attempts may to have significant impact if successful but unlikely to be related to allowing recreational fishing access • Incidence (and therefore likelihood) of deliberate attempts to contaminate water supply is very low – historical records

An additional important phase of the Risk Assessment was to identify suitable treatment options for those High and Severe risks that were identified during the initial Risk Assessment phase so that mitigations may be developed for reducing risks to acceptable levels. A conventional approach to risk management is presented in Table 10.1.

Table 0.3: Risk Management

SEVERE	Do not go ahead with action unless significant treatments result in mitigation of risk to acceptable level
HIGH	Do not go ahead with action unless treatments result in mitigation of risk to acceptable level
MEDIUM	Risks rated at this level should be considered for further treatment, but action may still go ahead under defined conditions
LOW	Risks considered to be adequately managed and not requiring further treatment

Each of the risks associated with recreational fishing access to the GSWSS that were assessed as Severe or High were further examined to determine the possible management treatments that may be employed to reduce risks to medium or low levels.

The outcome of this reassessment showed that all risks were able to be sufficiently mitigated to an acceptable 'Medium' level thus supporting progress of the proposal to facilitate recreational fishing access in GSWSS reservoirs (see Tables ES 3 & 4).

Table ES.3: Treatments and Mitigated Risk Assessment for Prospect Reservoir

Risk No.	Risk Source	Event	Unmitigated Risk Ranking			Treatment Assumed Usage: 50 cars, single access point & 100 people	Treatment Impacts	Mitigated Risk Ranking		
			L	C	R			L	C	R
C1	**A1, A6, A9,**	**Recreational fishing access causes bushfires in the catchment**	**3**	**5**	**S**	• No access on days of Total Fire Ban Days • No smoking • Daylight access • Controlled access point • No fires • Improved communications with fire authorities • Treatments likely to result in more effective response and containment thereby reducing impacts and consequences • Upgraded bushfire management planning to attend broader public access • Education and public awareness to increase surveillance activities • Access plans developed • Include NPWS and Rural Fire Service in planning for recreational access	• the proposed treatments aim to reduce both the likelihood and consequence of the risk event. preventing and controlling access reduces the likelihood of fires being started by recreational fishers. by not allowing access on these days and by upgrading response plans, less people will be impacted by fires compared to allowing uncontrolled access.	**2**	**4**	**M**
R3	**A1, A6**	**Deliberate contamination of the reservoir**	**1**	**5**	**H**	• Public education and awareness • Increased compliance and penalties • Access plans developed • Improved detection monitoring • Upgraded response plans	• the proposed treatments will reduce the consequences of deliberate contamination by encouraging community surveillance and custodianship. This will enable a better response to possible incidents thus allowing management	**1**	**4**	**M**

							intervention to be quickly implemented to reduce impacts.				

Table ES.4: Treatments and Mitigated Risk rankings for Cataract Reservoir

Risk No.	Risk Source	Event	Unmitigated Risk Ranking			Treatment Assumed usage: 40 kayaks and cars, single access point	Treatment Impact	Mitigated Risk Ranking		
			L	C	R			L	C	R
C1	**A1, A6, A9,**	**Recreational fishing access causes bushfires in the catchment**	**3**	**5**	S	• No access on days of Total Fire Ban Days • No smoking • Daylight access • Controlled access point • No fires • Improved communications with fire authorities • Treatments likely to result in more effective response and containment thereby reducing impacts • Upgraded bushfire management planning to attend broader public access • Education and public awareness to increase surveillance activities • Access plans developed which incorporate management protocols for recreational access to public lands such as National Parks and Wilderness Areas	• the proposed treatments aim to reduce both the likelihood and consequence of the risk event. preventing and controlling access reduces the likelihood of fires being started by recreational fishers. By not allowing access on these days and by upgrading response plans, less people will be impacted by fires compared to allowing uncontrolled access.	**2**	**4**	**M**

						• Include NPWS and Rural Fire Service in planning for recreational access				
R3	**A1, A6**	**Deliberate contamination of the reservoir**	**1**	**5**	H	• Public education and awareness • Increased compliance and penalties • Access plans developed • Improved detection monitoring • Upgraded response plans	• the proposed treatments will reduce the consequences of deliberate contamination by encouraging community surveillance and custodianship. This will enable a better response to possible incidents thus allowing management intervention to be quickly implemented to reduce impacts.	**1**	**4**	**M**

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1 Introduction

1.1 Aim and Scope of this Project

This project aims to identify and describe the possible impacts of recreational fishing in water supply reservoirs in the Greater Sydney Water Supply System (GSWSS). Specifically, it attempts to raise the information that relates to the use of reservoirs in the GSWSS for recreational fishing, the impacts that recreational fishing activity may have on the management of these reservoirs and the potential risk to public health by allowing recreational fishing to occur.

This Risk Assessment focuses on three reservoirs: **Prospect Reservoir** and **Cataract Reservoir** within the GSWSS and **Woodford Dam** which is no longer part of the supply system. These storages were selected based on their differing features and role within the GSWSS and are considered broadly representative of the other storages in the system. By assessing risk at these representative storages, a comprehensive understanding of the possible risks of allowing recreational fishing access to each of the storages within the GSWSS is established.

It should be noted that the risk assessment does not address the issue of any environmental impacts associated with recreational fish stocking or enhancement of fish stocks; these issues are addressed in the *NSW Freshwater Fish Stocking Fisheries Management Strategy (DPI, 2005).*

1.2 Delivery Methodology

The Risk Assessment process used in this project is a *Qualitative Risk Assessmen*t which is suitable for assessing the broad risks of recreational fishing access to reservoirs in the GSWSS. It follows the standards of The Australian/New Zealand Standard for Risk Assessment (AS/NZS/ISO31000:2018) and is adapted to integrate with the process shown within the Australian Drinking Water Guidelines (2017). A full description of the Risk Assessment methodology is provided in Section 8 of this document.

Significant contemporary information was gathered through the engagement of key stakeholders, WaterNSW, DPI Water and DPI Fisheries.

A consolidated Overview report was distributed to all stakeholders for comment prior to the Risk Assessment Workshop. A meeting was held with WaterNSW to discuss the document to ensure that it accurately reflected the specific nature of the GSWSS.

Prior to the Risk Assessment Workshop, participants were provided with further information relating to the Risk Assessment methodology that would be applied in the workshop, along with the updated Overview report.

The Risk Assessment was conducted over two days; the first day included a site inspection of Prospect and Woodford Reservoirs and the second day, the workshop.

The Workshop addressed the most important risks relating to recreational fishing access to the three reservoirs in the GSWSS including impacts on water quality and bushfire. Risks that were not

addressed in the workshop were subsequently assessed and are presented in this draft report for stakeholder review and comment ahead of finalising in conjunction with the independent review findings.

Note: This report presents information that was collected by the author(s) to inform this project and was gathered predominantly from the ProQuest worldwide scientific journal database and other on-line sources. Similar studies and reports relevant to the risk assessment project were included and are referenced accordingly. It is not claimed that the reports used for this overview comprise every source of information that is available to inform this topic, rather it aims to present that information which is considered sufficient for the purposes of the project.

1.3 Independent Review

Given the technical nature of the project, the Steering Committee agreed to a request from WaterNSW that an independent water quality risk specialist be engaged to:

5. review the Risk Assessment Methodology used in the project;
6. review the background information to ensure that it was adequate to inform the Risk Assessment process;
7. participate in the Risk Assessment Workshop; and
8. review this report.

Dr. Dan Deere of Water Futures was recommended by WaterNSW as the preferred reviewer and was subsequently engaged by DPI Fisheries for this purpose. His review comments are the subject of a separate report.

2 Recreational Fishing in NSW

2.1 Fishing in Reservoirs and Impoundments

Recreational fishing in reservoirs and other water supplies is very commonly practiced in most countries across the world and in many cases is seen as an activity that complements the achievement of water quality outcomes for potable supplies. Internationally renowned biologist and conservationist Professor David Bellamy summed up how recreational fishers care for the waters in which they fish when he said:

"Good anglers are the eyes and ears of waterside wildlife. Without their lobby our rivers would still be used as sewers."

In Australia, there are several hundred man-made storages that supply water for domestic and irrigation use that allow recreational fishing and actively promote these storages for recreational use. The configuration and management of these storages may vary from the management approach employed within the GSWSS.

In Queensland, anglers can access 63 water storages for fishing by purchasing a Stocked Impoundment Permit (SIP) (https://www.qld.gov.au/recreation/activities/boating-fishing/rec-fishing/dams). A number of these storages, including Somerset Dam and Wivenhoe Dam, are the primary water source for greater Brisbane. Recreational access to both locations is heavily promoted by SEQ Water and extensive facilities to support this access are provided (http://www.seqwater.com.au/water-supply/dam-operations/wivenhoe-dam).

In a recent survey it was found that Somerset Dam is in the top 5 fished locations in Queensland. (http://www.sweetwaterfishing.com.au/Somerset.htm). Gregg & Rolfe (2013), estimated that in 2011, over 272,000 days were spent fishing in the 31 impoundments that were part of the SIP which generated annual economic value of $95.3 million, mainly in regional areas. Individual reservoirs could generate economic value of up to $10.42 million / year by attracting visitors to regional areas (Gregg & Rolfe, 2013).

Most recently, the South Australian Government announced the opening of all SA Water reservoirs to recreational fishing and is in the process of finalising management arrangements for these sites. The reservoirs selected for investigation are a combination of "offline" reservoirs which do not contribute to domestic water supply and direct and secondary reservoirs which service water filtration plants.

Recreational fishing in water supply impoundments is widely accepted in Victoria where many water supplies are also the venue for significant recreational fishing activity. Many of these reservoirs are an important source of domestic water supply, particularly in rural areas. Lake Eppalock in central Victoria is the main source of raw water for the City of Bendigo (population 100,000) and is also an extremely popular recreation area that provides access for fishing, water skiing, houseboating and sailing and has many residences located on its shore.

In NSW, numerous water storages allow access for recreational fishing (see Appendix 1) and form an important and traditional component of the recreational freshwater fishery in NSW. Thirty-nine of

these storages are used for domestic water supply to regional communities across the state. In each case, recreational fishing access is carefully managed to ensure that water quality objectives are achieved and maintained while also providing for high quality fishing experiences. An additional number of storages associated with the Snowy Mountains Hydro-electric Scheme and power generation in the Hunter valley also facilitate angler access. Many of these storages now provide world class fishing for trout and native species which have been stocked by DPI Fisheries. All anglers contribute to the stocking and management of the reservoirs through the NSW Recreational Fishing Fee which generates $16 million annually for recreational fishing development.

Fishing in these reservoirs is supported by the NSW Freshwater Fish Stocking Fisheries Management Strategy (FMS) (DPI, 2005) which provides the framework for the stocking of up to 7 million fish per year into these impoundments. The FMS involved the development of an environmental impact statement (EIS), public consultation (in November/December 2003) and approval by the Minister for Planning under the Environmental Planning and Assessment Act 1979. Key elements of the FMS are:

- comprehensive assessment arrangements to minimise or eliminate impacts of stocking on the environment, including interactions between stocked species and threatened species;
- improvements to hatchery production and fish quality through a quality assurance program;
- an accreditation scheme for hatcheries involved in the activity;
- improved understanding and use of genetic material in fish breeding programs;
- improved broodstock collection techniques, husbandry and management;
- greater involvement in the activity by Aboriginal people and other stakeholders;
- better information management, verification and reporting procedures;
- improved performance monitoring and compliance; and
- improved education and public awareness.

The popularity and value of freshwater fishing in Australia is perhaps best described by Ernst & Young (2011) who provide the following estimates of recreational fishing activity in the Murray-Darling Basin.

- **Direct Expenditure on recreational fishing - $1,352 million**
- **Direct value-added expenditure - $375 million**
- **Contribution to GDP - $403 million**
- **Contribution to employment- 10,950 jobs**

In the USA, 24 million freshwater anglers fished a total of 443 million days during 2001 and over 70% of those days were spent fishing in lakes and reservoirs within 40 kilometres of peoples' homes (American Fisheries Society, 2017) and in 2012, the economic value of reservoir fishing was measured at $24 billion/year (USDI et al, 2012).

3 The Greater Sydney Water Supply System

Eleven major reservoirs are included in the Greater Sydney Water Supply System which comprises five main supply systems including Warragamba, Woronora, Blue Mountains, Upper Nepean and Shoalhaven systems. Warragamba Dam within the Warragamba network is the largest of the water supply reservoirs supplying water to over 3.7 million Sydney residents (80% of population) via the Prospect Water Filtration Plant; one of nine filtration plants within the network. The Greater Sydney Water Supply System is a largely integrated system meaning that water supply is highly flexible and can be reconfigured to address any water quality and quantity issues that may arise (waternsw.com.au/supply/Greater-Sydney).

The following extract from WaterNSW (waternsw.com.au/supply/Greater-Sydney) briefly describes the role and function of Prospect Reservoir and Cataract Dam within the water supply network:

"At 35 kilometres from Sydney and with a catchment of 10km2, The Prospect Reservoir stores 33.33GL at capacity (WaterNSW, 2017). Water from Warragamba and the Upper Nepean dams by-passes Prospect Reservoir. However, the reservoir remains an integral part of Sydney's drinking water supply and is still used regularly in times of high demand for water, or when other parts of the water supply system are taken offline for maintenance (WaterNSW, 2017). Conversely, Cataract Dam, 84km from Sydney has a total operating capacity of 97.19GL and with a catchment of 130 km2 is an additional supply of water for Sydney, via Pheasants Nest Weir, Broughton Pass Weir and the Upper Canal" (Water NSW, 2017).

Table 3.1: Storage Capacity of Reservoirs in Greater Sydney Water Supply System (waternsw.com.au/supply/Greater-Sydney)

Reservoir	Storage Capacity (Megalitres)	Catchment Status
CATARACT	**97,370**	CLOSED
CORDEAUX	93,640	?
AVON	214,360	?
NEPEAN	68,100	SEMI-CLOSED
WORONORA	71,790	?
LAKE BURRAGORANG (WARRAGAMBA RESERVOIR)	2,031,000	SEMI-CLOSED
PROSPECT	**48,200**	OPEN
WINGECARRIBEE	25,880	OPEN
FITZROY FALLS	22,920	SEMI-CLOSED (OPEN TO FISHING)
LAKE YARRUNGA (TALLOWA RESERVOIR)	90,000	SEMI-CLOSED (OPEN TO FISHING)
BLUE MOUNTAINS	2,890	CLOSED
TOTAL	**2,766,150**	

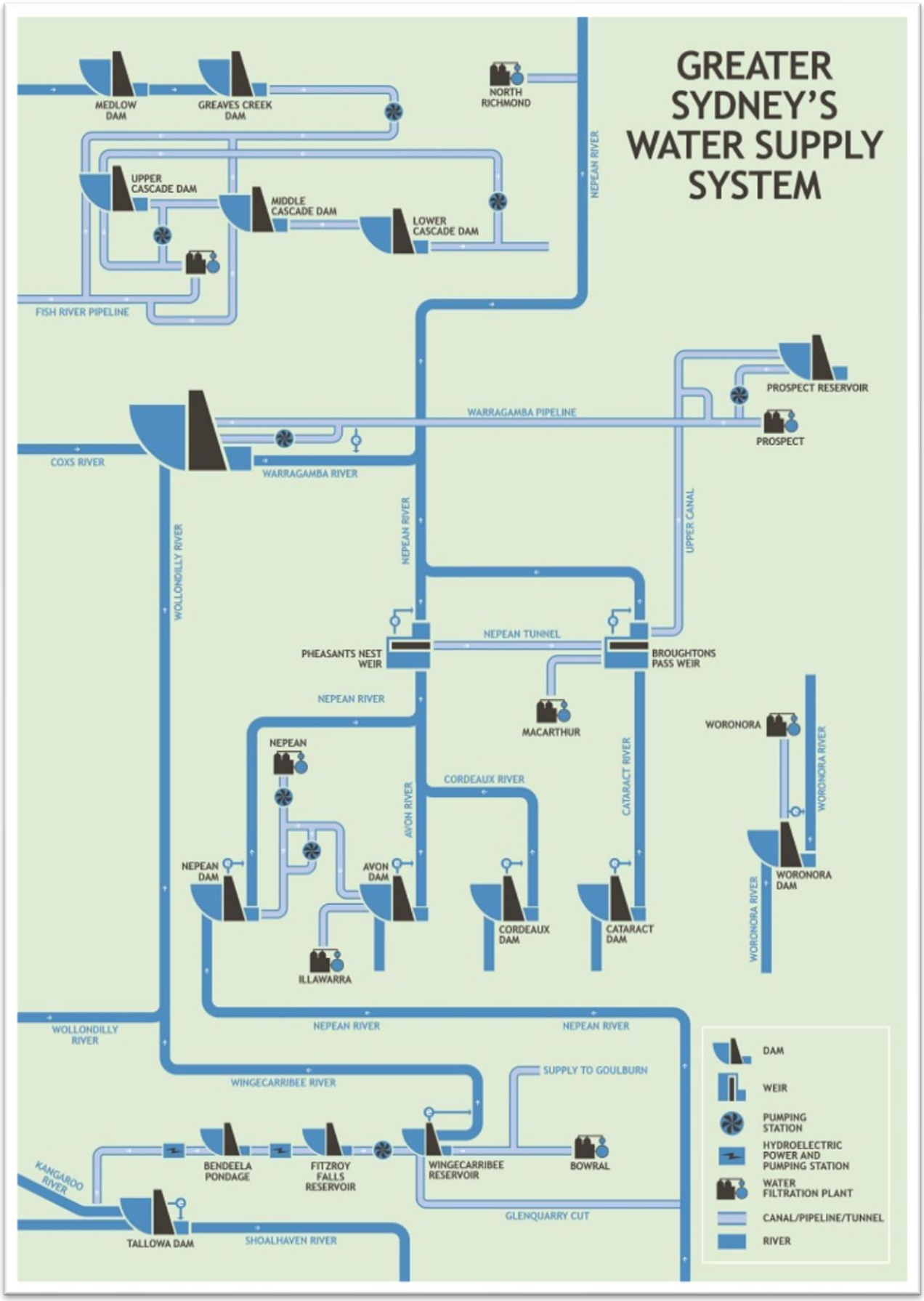

Figure 3.1: Overview of the Greater Sydney Water Supply System (Water NSW, 2017)

3.1 Water pollution in the GSWSS

Research undertaken by WaterNSW has determined the following key pollutants of water within the GSWSS (and elsewhere):

- **Pathogens**, such as *Cryptosporidium* and *Giardia*, can cause health concerns for water users and are costly to remove from drinking water.
- **Nutrient** loading of nitrogen and phosphorus compounds can lead to eutrophication and the formation of cyanobacteria (blue-green algae) blooms in water bodies.
- **Suspended solids** (fine particles from soil and other sources suspended in the water) can clog up water treatment plants, help transport nitrogen and phosphorus, and reduce the effectiveness of UV treatment and natural sunlight in the removal of pathogens.

The risk that these pollutants pose to the water supply is assessed using the Pollution Source Assessment Tool (PSAT) which informs on where in the drinking water catchments intervention may be needed (https://www.waternsw.com.au/water-quality/science/why/pollutants).

PSAT identified the five most significant pollution sources for all priority pollutants as:

- **grazing;**
- **intensive animal production;**
- **forests;**
- **urban stormwater; and**
- **other urban land-uses.**

More information on PSAT is shown in Appendix 1. The key findings report is available at https://www.waternsw.com.au/__data/assets/pdf_file/0009/127692/Key-Findings-Report-Pollution-Source-Assessment-Tool-2012-2016.pdf and is considered an important source of information for this project.

3.2 Raw Water Management

The Australian Drinking Water Guidelines (ADWG) highlight the importance of catchment management to avoid waterborne disease outbreaks. Most of the reservoirs within the Greater Sydney Water Supply System are contained within “closed” or “semi-closed” catchments, meaning that industrial, rural and urban development is minimal and public access is tightly controlled. In most closed catchments, public access is not permitted.

The restrictions on development and access in these catchments relates to the primary objective of harvesting sufficient quantities of high-quality water to meet Sydney’s supply demands. The management of reservoir catchments is considered a critical component of the total management approach employed by WaterNSW but is only one element of a multiple barrier approach to achieving the water quality standards described within the ADWG.

Miller et al (2006) present some relevant guiding principles of the ADWG as follows:

- The multiple barrier approach is universally recognised as the foundation for ensuring safe drinking water.
- No single barrier is effective against all conceivable sources of contamination, is effective 100 per cent of the time or constantly functions at maximum efficiency.
- Prevention of contamination provides greater surety than removal of contaminants by treatment.
- The most effective barrier is protection of source waters to the maximum degree practical.
- Water suppliers should adopt a preventive risk management approach, as stipulated in the ADWG, to maintain the supply of water at the highest practicable quality.
- The guideline values should never be seen as a licence to degrade the quality of a drinking water supply to that level**.**
- The greatest risk to consumers of drinking water is pathogenic micro-organisms. Protection of water sources and treatment are of paramount importance and must never be compromised.
- The drinking water system must have, and continuously maintain, robust multiple barriers appropriate to the level of contamination facing the raw water supply.
- Any sudden or extreme change in water quality, flow or environmental conditions (e.g. extreme rainfall or flooding) should arouse suspicion that drinking water might become contaminated.
- Ensuring drinking water safety and quality requires the application of a considered risk management approach

WaterNSW presents its system of managing water supply as follows:

- Our water quality framework, principles and guidelines and standards we strive to meet
- The multi-barrier approach we take
- How we track and manage pollution sources
- Our water quality monitoring program
- How we report on water quality

(Waternsw.com.au/supply/Greater-Sydney)

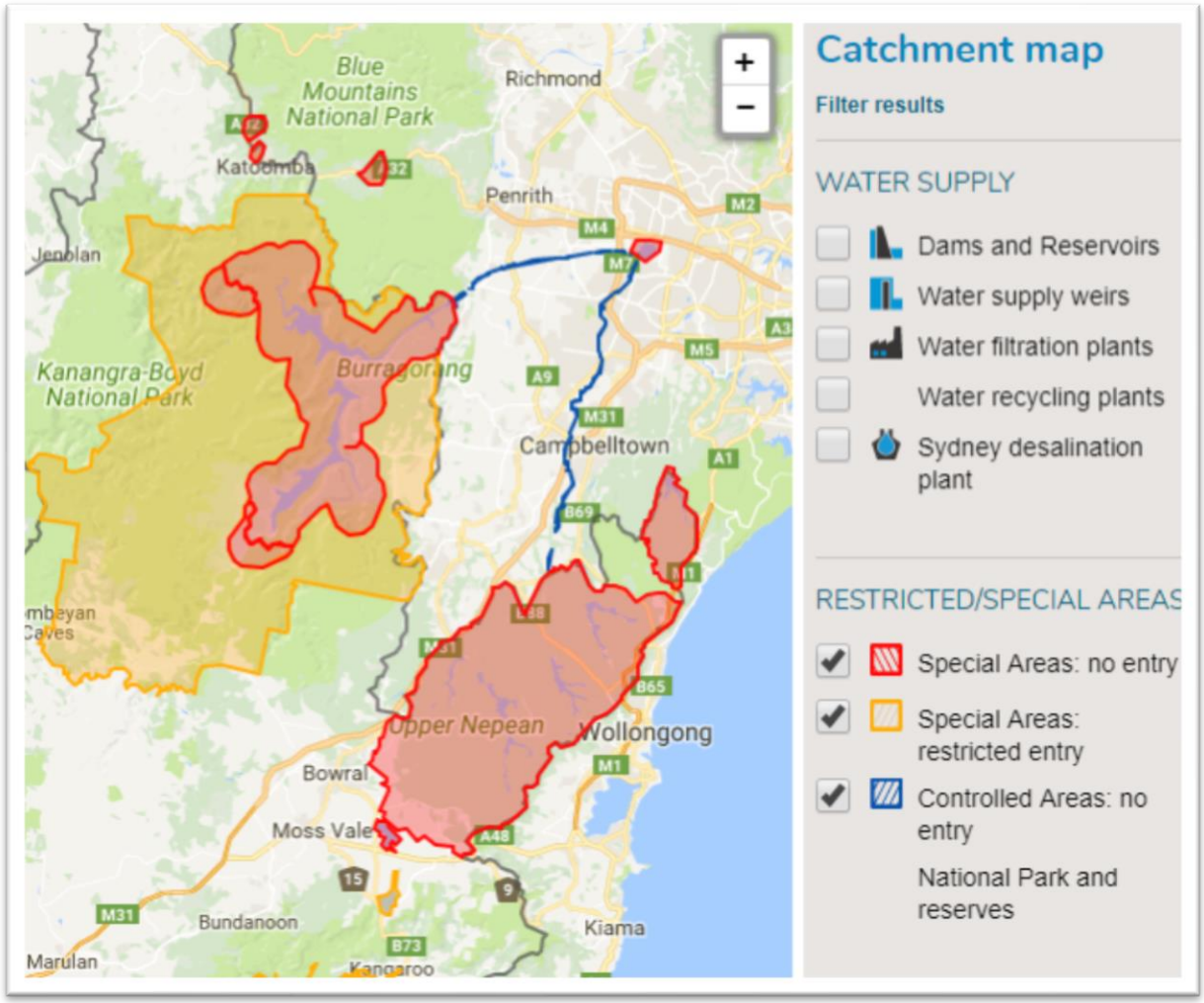

Figure 3.2: Greater Sydney Water Supply System catchment map

3.2.1 Multi Barrier Approach to Water Supply Management

The multi-barrier approach is a whole of system approach to protecting water supply, which features a series of physical, regulatory and management barriers to degradation of raw and treated water. Figure 3.3 shows that catchment water protection and reservoir management are the first steps in the multi-barrier process to managing water supply and that several critical steps aimed at achieving water quality standards are implemented after raw water leaves a reservoir.

This Risk Assessment project will primarily focus on the possible impacts of recreational fishing to the first two steps in the multi-barrier approach – the catchment of the reservoirs and the actual reservoir waterbody. Activities within these areas may have consequences for the downstream components of the multi-barrier approach i.e. Water Filtration Plants which will be considered as part of the risk assessment.

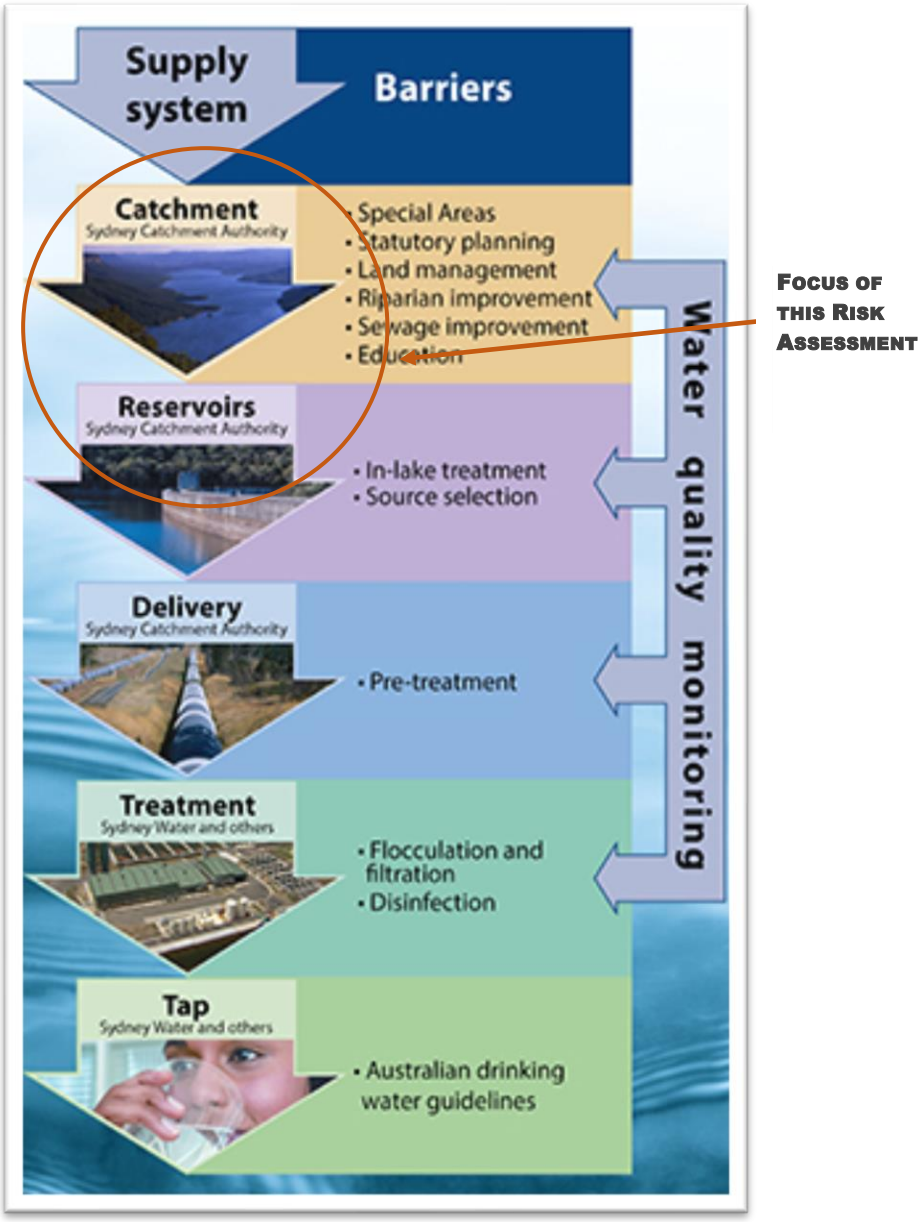

Figure 3.3: Multi-barrier approach to water supply management.

http://www.waternsw.com.au/supply/Greater-Sydney/quality/multi-barrier

3.2.2 Managing Catchments and Reservoirs

Raw water falling as rain in the catchments of storage reservoirs is protected through a suite of physical barriers and regulatory instruments. These restrict access and development in catchment areas and safeguard against contamination from pollution. Maintaining closed catchments i.e. catchments that do not allow public access or development, is considered a particularly effective means of protecting raw water before it enters the reservoir.

In-reservoir treatment is the second step in the multi-barrier approach which may involve a range of methods for improving water quality. While chemical dosing of reservoirs with copper sulphate to suppress microbial activity is practiced in Australia, it is not used in the storages of the GSWSS where

aeration is more commonly applied. Aeration of reservoirs to prevent thermal and chemical stratification aids in improving water quality by preventing the formation of anaerobic conditions in the lower strata of the water column in reservoirs. Aeration also plays an important role in lowering iron and manganese levels which can taint taste. Pre-chlorination of raw water is also used to treat these elements.

The transport of sediments to reservoirs during rain events which makes chlorination less effective, the development of cyanobacteria (blue-green algae), and the presence of higher than permitted levels of water-borne pathogens are the major water quality issues confronting management of the system (Fell, 2014).

A key advantage of the raw water supply network managed by WaterNSW is its flexibility which allows raw water from several sources to supply the network. This means that if adverse conditions occur which cause water quality degradation (e.g. bushfires, algal blooms), water supply is secure as alternative supply options are available.

3.3 Monitoring

The raw water in the dams and at entry to Sydney Water treatment facilities is periodically examined for water characteristics which are checked against Australian Drinking Water Guidelines (2013). The results of these tests are made publicly available.

There are three key components to the monitoring program for the waterbodies:

Routine and compliance monitoring - this monitoring aims to ensure that raw water supplied to WaterNSW customers meet the standards set by the Australian Drinking Water Guidelines.

Targeted or investigative monitoring including hot spot monitoring in locations such as below sewage treatment plants, sale yards or intensive animal production facilities, to assess the impact of point source pollution on stream quality

Event-based monitoring in response to rainfall and other events such as chemical spills or algal blooms. (WaterNSW, 2017)

Fell (2014) reports that over 100 sites within the GSWSS are monitored for up to 600 characteristics and which incorporates a range of approaches and techniques compliant to the Australian and New Zealand Risk Management Standard (AS-NZS 4360.2004). When certain parameters exceed water quality criteria, the GSWSS SCADA system alerts operators.

3.4 Water Treatment

There is a significant volume of literature available on the various treatment processes that are regularly employed for achieving water quality standards for potable water supply. Fell (2014) provides an overview of those processes used in the Greater Sydney Water Supply System. The treatment process consists of the following key elements:

Retention

Water from the catchment is retained in the dam for a sufficiently long time for much of the suspended matter to settle and for bio-pathogens to significantly de-activate. The capacity of dams in the Sydney catchment provides 4 – 5 years of supply, so residence times are significant during times of low to moderate inflow. However, residence times are significantly reduced during periods of high and very high inflows. Residence times can be short during extreme inflow events.

Screening

Prior to leaving the dam/reservoir site and again on entering the treatment plants, water is screened to remove macro-objects and screen-able solids.

Coagulation and Flocculation

In this step ferric chloride and a polyelectrolyte coagulant is added to the raw water and mixed. Both adsorb onto particles present encouraging them to coagulate into larger flocs.

Filtration

The flocculated stream is then sent under pressure to a filter where it passes through a bed comprised of crushed anthracite, sand and gravel.

Disinfection

The disinfection step may be preceded by pH adjustment, but primarily relies on the use of chlorine or chloramine to kill any micro-organisms still present. Both chlorine and chloramine are used for disinfection, with pH control at this stage being important. Sydney Water's distribution systems ensure that there is residual chlorine in the water when it gets to consumers. (Fell, 2014)

The Prospect Water Filtration Plant located in Sydney's western suburbs is the largest WFP of the nine that service the Greater Sydney area. It is estimated that 77% of Sydney's water is delivered by the plant (Fell, 2014). The plant is located adjacent to Prospect Reservoir which serves only as a backup storage if the supply system is upset (Fell, 2014).

Raw water enters the Prospect WFP where fine screening occurs before the coagulant Ferric chloride ($FeCl_3$) is added together with a small quantity of polyelectrolyte before being distributed (Fell, 2014).

4 Stakeholder Engagement

A range of stakeholders were identified early in the project as being critical to the provision of background information and the identification of the threats to be carried forward to the formal risk assessment process.

Key stakeholder groups identified included:

- Government Agencies – DPI Fisheries, WaterNSW, Sydney Water, Health NSW, NPWS
- Recreational Fishing Groups – RFNSW, Recreational Fishing Alliance, Australian Fishing Trade Association.

The aim of the stakeholder engagement was primarily to:

- Source published and unpublished reports and data concerning recreational fishing access in reservoirs;
- Source data and reports relating to the management and the operation of the GSWSS;
- Engage with a selection of key stakeholders in order to identify the range of values and threats associated with the reservoir; and
- Seek feedback and opinion on options to facilitate fishing access to the reservoirs.

The stakeholder engagement included face to face meetings and/or telephone conversations and email exchanges, providing data towards further feedback on perceived values and threats.

The consultation process also highlighted the need to ensure that the primary functional objectives of each of the key stakeholders was clearly acknowledged during the project.

4.1 Statement of Objectives

The Statement of Objectives (SoO) documents the key objectives for each of the key stakeholder groups involved in the project. The SoO allows stakeholders to clearly understand the values and requirements of all stakeholders as they relate to this project. These objectives may be embedded in legislation and/or policy of government and management organisations or may represent the aspirations or strategic priorities of user groups and industry sectors. For this risk assessment, the following Statement of Objectives were agreed:

Note: *Those marked with an asterisk* are reproduced verbatim from the reference sources*

DPI Fisheries

- To deliver a risk assessment on recreational fishing in Sydney water supply reservoirs as requested by the Minister for Primary Industries.

Recreational fishers

- Enable recreational fishing access to appropriate water storages to enhance the socio-economic benefits within the local communities surrounding these areas.
- Make NSW a premier recreational fishing destination and promote the health and well-being benefits of fishing for communities and families.

WaterNSW*

SOURCE WATER PROTECTION

- Protection of the Greater Sydney drinking water catchment to ensure safe water is supplied to Sydney Water, local councils and other distributors for treatment and distribution to their customers.

BULK WATER SUPPLY

- Supplying water from its storages to customers in the Greater Sydney drinking water catchment and in the state's regulated surface water systems.

  https://www.waternsw.com.au/water-quality/catchment/manage/our-role

Health NSW*

- *A secure and safe supply of drinking water is fundamental to public health. The NSW Government has endorsed the Australian Drinking Water Guidelines 2011 (published by the National Health and Medical Research Council and the Natural Resource Management Ministerial Council). The guidelines provide a solid foundation for assessing drinking water quality, by specifying health-based and aesthetic criteria as well as the philosophy of a "multiple barrier approach" from catchment to tap, so to ensure safety of the water. http://www.health.nsw.gov.au/environment/water/Pages/drinking-water.aspx

Sydney Water*

We work to ensure our drinking water:

- meets the standards set out in the Australian Drinking Water Guidelines#
- satisfies two of our key regulators - NSW Health and the Independent Pricing and Regulatory Tribunal (IPART).
- Sydney Water is responsible for barriers associated with drinking water treatment and distribution within its area of operations. It is not responsible for the catchment, dam, and bulk raw water delivery activities performed by WaterNSW, or for the activities performed by Sydney Desalination Plant Pty Ltd (SDP).
- Sydney Water will comply with the ADWG with respect to the concepts of good practice, and apply these concepts in the manner, form, and timeframes specified by NSW Health. Sydney Water aims to comply with the ADWG health-related long-term performance measures and the aesthetic related long-term term performance measures as specified by NSW Health.

  http://www.sydneywater.com.au/SW/water-the-environment/how-we-manage-sydney-s-water/safe-drinking-water/our-drinking-water-management-system/index.htm

PRINCIPLES OF THE AUSTRALIAN DRINKING WATER GUIDELINES*

The Australian Drinking Water Guidelines (ADWG) are designed to provide an authoritative reference to the Australian community and the water supply industry on what defines safe, good quality water, how it can be achieved and how it can be assured. The guidelines have been developed after consideration of the best available scientific evidence and provide a framework for good management of drinking water supplies to ensure safety at point of use. They address both the health and aesthetic quality aspects of supplying good quality drinking water.

Principles

- The greatest risks to consumers of drinking water are pathogenic micro-organisms.
- Protection of water sources and treatment are of paramount importance and must never be compromised.
- The drinking water system must have, and continuously maintain, robust multiple barriers appropriate to the level of potential contamination facing the raw water supply.
- Any sudden or extreme change in water quality, flow, or environmental conditions (e.g. extreme rainfall or flooding) should arouse suspicion that drinking water might become contaminated.
- System operators must be able to respond quickly and effectively to adverse monitoring signals. System operators must maintain a personal sense of responsibility and dedication to providing consumers with safe water and should never ignore a consumer complaint about water quality.
- Ensuring drinking water safety and quality requires the application of a considered risk management approach.

  https://www.nhmrc.gov.au/guidelines/publications/eh52/

5 Recreational Fishing Access

5.1 Fishing Characterisation

Proposals to allow recreational fishing in GSWSS reservoirs do not generally advocate for allowing largely unmanaged access and recognise that the primary function of reservoirs is to provide an adequate source of potable water to the population of Sydney and surrounding areas. For this reason, proposals for recreational fishing access must be carefully designed and when implemented must be stringently managed to ensure that any risk to the water supply is minimised or, where possible, removed.

Because recreational fishing access to potable water supplies is widely practiced, the type of fishery that can be developed and its management to minimise risk to water supplies is well understood. The aspirations of the recreational fishing community in NSW accord with the broad approach taken to reservoir fishery development in other developed countries and/or states in that they aim to achieve quality fishing experiences that harmonise with the primary functions of the reservoirs and embrace the principles of sustainable development.

Risk Sources

Fishing Type

The Risk Assessment Workshop was conducted by first defining the 'type' of recreational fishing activities that were proposed for each of the reservoirs. Initial discussion focussed on assessing the risks associated with uncontrolled access to each for the three reservoirs however, it was soon agreed that this was impractical for the purposes of the assessment. Consequently, the 'type' of access was refined and is shown in Table 8.2. below. These activities are described as **Risk Sources**.

Table 8.2: Risk Sources from recreational fishing in GSWSS reservoirs

Activities	Source Code	Category 1 Prospect Reservoir	Category 2 Cataract Reservoir	Category 3 Woodford Reservoir
Vehicle access on defined roads	**A1**	√	√	√
Car Parking	**A2**	√	√	√
Infrastructure (boat ramps, fishing platforms, toilets, paths)	**A3**	√	√	√
Pedestrian access to and along shoreline	**A6**	√	√	√
Un-powered boating	**A7**	√	√	√
Bait fishing	**A8**	√	√	√
Powered boating	**A9**			√

Fishing Level

Participants also agreed that it was necessary to define the expected level of use by recreational fishers at each of the reservoirs to provide context to the assessment. The levels of use for each of the three reservoirs are shown below in Table 8.3.

Table 8.3: Possible usage levels of reservoirs

Reservoir	Expected Maximum Weekend Usage
Prospect	50 cars, single access point & 100 people
Cataract	40 kayaks and cars, single access point
Woodford	40 kayaks and cars, single access point

5.2 Risk Register

Each of the **Risk Sources** were analysed to identify the associated **Risk Events** which are presented in provides a guide to the typical arrangements for recreational fishing in reservoir fisheries.

Table 5.1: Typical recreational fishing service requirements in impoundments.

Infrastructure

- Roads (2WD & 4WD)
- Car parking
- Fishing platforms

Walking tracks

- Signage
- Toilets
- Rubbish facilities

Access

- Shoreline access
- Boating (powered and unpowered)
- Guided access

Fisheries

- Stocking with appropriate species
- Habitat enhancement
- Bait and lure fishing
- Specific regulations
- Catch and Release
- Put and take

Regulatory arrangements

- Controlled numbers
- Recreational Fishing Licence/Reservoir permit
- Compliance
- Bushfire threat management

5.3 Possible Impacts of Recreational Fishing on Water Quality in Reservoirs

Dedicated comprehensive research studies into the effects of recreational fishers on water quality in Australian reservoirs are not forthcoming from the literature. This is confirmed by one study by Burgin (2017) who suggests that studies into this area are scant. Miller et al (2006) state that *"the qualitative*

cause and effect and conceptual relationships between recreational access and impacts on water quality are now well established. The few studies that have been undertaken that measure actual water quality impacts of recreation through empirical scientific observation have been unable to conclusively prove a quantitative link between the level and type of recreational activities and the degree of water quality impacts, mainly due to confounding influences."

Burgin (2017) reviews indirect **impacts** of recreational fishing in freshwater ecosystems:

- infrastructure effects on water quality;
- impacts from walking tracks;
- off-road vehicles and boating;
- overland dispersal of non-native plants;
- disease and pathogen transmission; and
- non-native fish species.

In this context therefore, there are **three vectors** for deleterious water quality effects regarding reservoirs that govern the above **impacts**: Access, Use and Liability. They are:

(1) The effects on water quality caused by recreational fishers entering the local sites **(Access)**

(2) The effects on water quality caused by recreational fishers using the sites, and use of the reservoirs for recreational fishing **(Use),** and

(3) Effects on recreational fishers accessing the reservoirs in the case of resultant or inadvertent poor water quality or other aspects **(Liability).**

If vector (3) is addressed, by considering (1) and (2), the parameters of interest to the risk assessment with respect to water quality can be captured by considering the following parameters:

(a) Turbidity;
(b) Heavy metal contamination;
(c) Water chemistry parameters (non-ambient);
(d) Pollution (inadvertent or deliberate);
(e) Parasites;
(f) Diseases; and
(g) Toxic algae (plankton dynamics).

In its Uncovered Finished Water Reservoirs Guidance Manual, the EPA, Office of Water, (1999) suggested that human activity measures as sources of contamination can be captured under the headings:

- Pesticides and Fertilizers
- Swimming
- Discarded Debris
- Deliberate contamination, and
- Human Activity Measures.

In the context of recreational fishing access, each these aspects should be assessed to make sure that they are not a risk, or where a high risk is identified it should have contingencies and treatments applied to reduce or eliminate the risk. Whilst individual studies have assessed these parameters and their effects on human health, no dedicated empirical or review paper was forthcoming from the literature research which examined these aspects comprehensively with regards to correlation

between recreational fishing of reservoirs and water quality. This finding strengthens the importance of the current risk assessment.

A comprehensive list of items to investigate for recreational fishing and water quality risks therefore includes:

- Turbidity;
- Heavy metal contamination;
- Water chemistry parameters (non-ambient);
- Pollution (inadvertent or deliberate);
- Parasites;
- Diseases;
- Toxic algae (plankton dynamics);
- Swimming/wading whilst fishing;
- Discarded debris; and
- Human Activity Measures.

5.3.1 Turbidity

Recreational fishing access could be assumed to not feasibly affect turbidity if recreational fishers were not allowed to swim or wade in reservoirs, however, the activity of accessing shorelines either by foot or vehicle may contribute to the transport of sediment to reservoirs during rainfall events. Turbidity can also be the inadvertent result of eutrophication and high algal abundance (Sierp, 2008); however, this would be captured at the plankton dynamics aspect regardless.

5.3.2 Heavy Metal Contamination

The issues surrounding the effects on reservoir water quality from heavy metal contamination by recreational fisher access is likely to be very minor in comparison to other activities which may occur in catchments e.g. mining in the Nepean catchment. There is no available literature relating to this topic.

5.3.3 Water Chemistry Parameters

The relationship between recreational fishing access and water chemistry parameters can be influenced by the materials that recreational fishers use to fish that that may enter the reservoir e.g.:

- Bait;
- Lures;
- Attractants;
- Berley;
- Human waste;
- Fish carcasses; and
- Garbage left behind.

Amaral, et al., (2013) empirically tested bait addition and the results indicated that the use of 5-10 kg of ground bait (berley) per angler (3-20 tons of ground bait per year) did not alter the ecological functioning of a test reservoir in the UK, however, higher angling pressures may lead to a significant increase in nutrient concentrations and consequent increases in primary production in the waterbody. Higher angling pressure can mean an increase in attractants, berley, human waste, fish carcass nutrient release and garbage if not appropriately managed.

If recreational fishers abide by fishing regulations, they could inadvertently improve water quality through reducing the numbers of pest species such as Carp (*Cyprinus carpio),* Redfin *(Perca fluviatilis) and* Goldfish (*Carassius auratus*) (Rowe, et al., 2008) which are catalysts for poor water quality (Sierp et al (2008), Novalesflamarique (1993) and Cadwallader (1978). Fish community stock assessments for the Prospect and Cataract reservoirs are not available, although it is understood Prospect has populations of Australian Bass (*Macquaria novemaculeata*) and European Carp (C*yprinus carpio*) and Cataract has been historically stocked with a number of non-endemic native species including Murray Cod (*Maccullochella peelii*), Trout Cod (*Maccullochella macquariensis*), Macquarie Perch (*Macquaria australasica*) and Silver Perch (*Bidyanus bidyanus).*

5.3.4 Pollution (inadvertent or deliberate)

The reviewed literature provides no evidence of a correlation between an increase in water pollution and increasing recreational fishing activity in reservoirs. However, it is known that high levels of recreational activity can lead to increased rubbish deposition in high use areas if it is not correctly managed.

Pollution events are possibly more likely to occur via petrochemical leakage from vehicles entering the reservoir reserves or from powered watercraft. Leakages from vehicles are likely to be contained within discrete areas such as carparks and roadways but may find their way into the waterbody. Petrochemical leakages from powered water craft are more difficult to detect and manage however powered boating access is not the subject of this risk assessment overview. Deliberate events could currently occur in reservoirs, but contingency plans are established to manage issues such as terrorism or illegal industrial waste disposal which occurs regularly in country areas of Australia.

5.3.5 Parasites

Water borne parasites common to freshwater include *Giardia lamblia and Cryptosporidium parvum. Giardia lamblia*, also called *Giardia intestinalis,* is a parasite which causes infection (giardiasis) in the bowel. The parasite is a single-celled organism that can attach itself in large numbers to the wall of the bowel and interferes with the body's natural absorption of nutrients (WA Dept. of Health, 2017). In the context of this risk assessment, swallowing polluted water from rivers, streams, springs, ponds, and lakes is the vector. WaterNSW currently screens for this parasite but its regime for Prospect Reservoir and Cataract Dam may need to be assessed against the current project. In an international project the occurrence of zoonotic *Giardia duodenalis* in examined fish species at two different aquatic environments underlines the possibility of fish to be an additional reservoir for zoonotic *G. duodenalis* assemblages that contributes to the contamination of water with this pathogen and thus the role of fish in the epidemiology of human giardiasis cannot be ruled out (Ghoneim NH, 2012).

Giardiasis was the second most frequently reported enteric condition in 2011 in NSW. There were 2,362 notifications in the year 2011, an increase of 20% compared with the annual average for the previous five years (NSW Department of Health, 2011). Monitoring for the protozoan parasites *Cryptosporidium* and *Giardia* is carried out twice per week in Prospect Reservoir according to the WaterNSW website (https://www.waternsw.com.au/water-quality/quality/monitoring accessed 21 June 2018).

Cryptosporidium parvum and *C. homonis* cause Cryptosporidiosis which is a diarrhoeal disease caused by the parasite, which infects the intestine. *Cryptosporidium* is present in the faecal matter of infected

humans and animals. Infection occurs when the parasite is ingested, transmission can occur through drinking contaminated water. WaterNSW currently screens for this parasite but its regime for Prospect Reservoir and Cataract Dam may be considered with regards the current project. There were 359 Cryptosporidiosis notifications received in NSW in 2011 (NSW Department of Health, 2011). This represented a reduction of 50% compared to the annual average for the previous five years (n=723) suggesting the disease is volatile year to year in terms of infectiousness. Cryptosporidium can be transmitted to waterbodies from human faecal matter which is not correctly contained or treated.

The Australian Drinking Water Guidelines (2011) recommends a multi-barrier approach to minimise the risks of these pathogens. Investigative testing is encouraged in response to events (e.g. heavy rainfall) that could increase the risk of contamination. WaterNSW implements additional monitoring during high risk events (WaterNSW 2016).

5.3.6 Water borne diseases

Under the NSW Public Health Act, the following enteric diseases and conditions are notifiable in NSW: Cholera, Cryptosporidiosis, Giardiasis, Hepatitis A and Haemolytic uraemic syndrome (HUS), Hepatitis E, Listeriosis, Paratyphoid, Rotavirus, shiga toxin producing *Escherichia coli* (STEC/VTEC) infections, Shigellosis, Salmonellosis, Typhoid, institutional gastroenteritis in two or more people, and foodborne disease in two or more people (NSW Department of Health, 2011). Individual cases of other enteric diseases such as Campylobacter and Norovirus infection are not notifiable in NSW but could be risks for recreational fishers (NSW Department of Health, 2011).

NSW laboratories report cases of notifiable enteric diseases to public health units (PHUs). Outbreaks of foodborne or suspected foodborne illness and institutional gastroenteritis are reportable by doctors, hospitals, child care centers and aged care facilities. Notifiable disease data are routinely entered by public health unit staff into the NSW Notifiable Conditions Information Management System (NCIMS) (NSW Department of Health, 2011).

Mosquito-borne diseases may also be risk to reservoir users. Diseases transmitted by mosquitoes in Australia include Dengue fever, Australian encephalitis, Ross River (RR) virus disease and Barmah Forest (BF) virus disease (Sydney University, 2017).

5.3.7 Toxic Algae

According to the Sydney Catchment Authority's report on Cyanobacteria risks, Prospect and Cataract were classed as mesotrophic (medium level of nutrients and intermediate level of algal production) with no recordings of any major algal blooms (cholorphyll-a exceeding 20µg/L) (Sydney Catchment Authority, 2010). However, the toxic blue green algae *Anabaena circinalis* has been detected suggesting if the management of the catchment changed resulting in significant amounts of nutrients being released then blue green algae blooms could occur.

Coincidentally, a large body of work including Australian research and many international case studies since the 1970s (Shapiro J., 1975) has proven that where applicable, restructuring fish communities in reservoirs and dams can provide a more cost effective, safer and more efficient method of controlling water quality with respect to blue green algae blooms and their toxins than the use of the commonly applied measures in Australia (Sierp et al 2008). This is dependent upon a range of factors however and can only be determined on a case by case basis.

The effects of toxic blue green algae are monitored as regular business by WaterNSW according to the monitoring regime mentioned above under the Water Chemistry parameter section. Hence this aspect would already be alerted by the monitoring that is currently in place under the assumption that the monitoring is already adequately performed by Water NSW monthly (WaterNSW, 2017).

5.3.8 Swimming/Wading whilst fishing

In a 1998 study in Portland, Oregon, it was found that bacteria and viruses that cause disease in humans may be passed in the faeces, shedded skin and mucous membranes of infected persons swimming in a reservoir (EPA, Office of Water, 1999). A single infected person can pass a significant number of pathogenic faecal organisms in a single faecal event up to 10^9 protozoa and 10^{14} virus (EPA, Office of Water, 1999). The problem is aggravated by the inability to conduct primary disinfection in the reservoirs and by hydraulic short-circuiting that could result in the contamination rapidly reaching the reservoir outlet. Based on these factors, the authorities in Portland Oregon were advised to develop an emergency protocol for the immediate shutdown and disinfection of any reservoir in which swimming is observed (EPA, Office of Water, 1999). Another empirical research program in Riverside Country Southern California, showed predictable considerable spatial and temporal variability in pathogen concentrations within the reservoir, with elevated levels of Cryptosporidium, Rotavirus, and Poliovirus in the epilimnion during periods of high recreational use due to Accidental Fecal Releases (AFRs) from recreational swimming, water skiing and jet skiing (Anderson, 1998).

Liability can be addressed by adopting an appropriate range of management practices that are currently applied to fishing in numerous Australian reservoirs on the assumption that safe access would be granted to the water bodies, swimming would not be permitted, entry to the water would only be allowed whilst wearing waders or not at all and that the reservoirs would be closed in the case of poor water quality.

5.3.9 Discarded Debris

This aspect is addressed by considering the frequency of reservoir users, number and availability of waste collection receptacles and social aspects of reservoir use.

5.3.10 Human Activity Measures

Human activity measures and the effects on water quality are a function of use and numbers of individual users. There is a correlation between water quality and the parameters mentioned above.

In the United States, Section 314 of the Clean Waters Act known as The Clean Waters Program specifically targets the special needs of degraded lakes and reservoirs that are used for both water supply and recreation. The program is funded via a directive from the United States EPA which requires that states to use at least 5% of the Section 319 Nonpoint Program funding for Clean Lakes Program Activities.

The goal of the Clean Lakes Program is better water quality, more fish, more fishing, and greater public use of lakes and reservoirs. The program was specifically designed to help states and local communities address special problems facing public lakes and reservoirs such as degraded in-lake and shoreline habitat; degraded fisheries; nuisance exotic species; eutrophication; in-lake nutrient recycling; and biological contamination.

The Clean Lakes Program is a partnership based on more holistic view of lake and reservoir management and includes those stakeholders interested in lake water quality and other uses of lakes and reservoirs. The most recently completed and assessed lake restoration project in Iowa resulted in quadrupling lake and park use and improving the fish community and fishing by several orders of magnitude.

6 Reservoir Selection

To assist in the selection of reservoirs for assessment, reservoirs were classified according to their role within the GSWSS. The reservoirs were sorted into three main Categories – Category 1: Direct Supply Reservoirs which supply water directly to Water Filtration Plants and Category 2: Secondary Supply Reservoirs which do not have a direct connection to a WFP. The third category includes reservoirs that are no longer part of the GSWSS and are known as Off-line reservoirs.

The categorised GSWSS reservoirs and their key attributes are summarised in Table 6.1 below. One reservoir from each of these categories was selected by the Steering Committee for examination in this Risk Assessment project. Reservoirs were selected on the basis that they best represent the category and were able to provide a template for assessing the risk of recreational fishing access to that category of reservoirs. The reservoirs selected from each category are

Category 1: Prospect Reservoir

"Located about 35 kilometres west of Sydney, Prospect Reservoir was completed in 1888 as part of the Upper Nepean Scheme to supply Sydney with water collected from the weirs on the Illawarra Plateau south of the city.

Between 1902-1935 four dams were added to expand the Upper Nepean Scheme and boost supplies to Prospect Reservoir. Even after Warragamba Dam was completed in 1960, Prospect Reservoir continued to play an important role in storing Sydney's water.

Today, water from Warragamba and the Upper Nepean dam's bypasses Prospect Reservoir. However, the reservoir remains an integral part of Sydney's drinking water supply and is still used regularly in times of high demand for water and when other parts of the water supply system are taken offline for maintenance."

https://www.waternsw.com.au/supply/Greater-Sydney/dams/prospect-dam

Category 2: Cataract Dam

"Located about 84 kilometres south of Sydney, Cataract was the first of the four dams constructed to collect water from the Illawarra Plateau. Created by damming the Cataract River, construction started in 1902 and was completed in 1907.

Together with Cordeaux Dam, Cataract's main role today is to supply water to Camden, Campbelltown and Wollondilly council areas via the Macarthur water filtration plant.

Together, the Nepean, Avon, Cataract and Cordeaux dams also provide an additional supply of water for Sydney, via Pheasants Nest Weir, Broughtons Pass Weir and the Upper Canal."
https://www.waternsw.com.au/supply/visit/cataract-dam

Category 3: Woodford Reservoir

"Woodford Creek Dam is a concrete arch dam which was built on the junction of Woodford Creek and Bulls Creek and completed in 1928. It is no longer used as a water supply. In late 2009 Woodford Dam surrounds were opened up to walkers and mountain bikers. Access to the dam wall and lake is still prohibited." *https://en.wikipedia.org/wiki/Blue_Mountains_Dams*

Table 6.1: Great Sydney Water Supply System Reservoir Categories

(source: https://www.waternsw.com.au/supply/Greater-Sydney/dams**)**

Reservoir	Storage Capacity (Megalitres)	Distribution	Service Point	Direct Supply to WFP	Current fishing access
Category 1: Direct Supply reservoirs					
Avon	214,360	Avon River	Pheasants Nest Weir	Y	N
		Pipe	Illawarra WFP & Nepean WFP		
Nepean	68,100	Nepean River	Pheasants Nest Weir	Y	N
		Pipe	Nepean WFP		
Woronora	71,790	Woronora River		Y	N
		Pipe	Woronora WFP		
Lake Burragorang (Warragamba Reservoir)	2,031,000	Warragamba River		Y	N
		Warragamba Pipeline	Prospect WFP		
Prospect	48,200	Pipe	Prospect WFP	Y	N
Wingecarribee	25,880	Wingecarribee River,	Wollondilly River	Y	N
		Glenquarry cut	Nepean River		
		Pipe	Bowral WFP		
Lower cascade Dam		Pipe	Blue Mountains	?	N
Category 2: Secondary Supply Reservoirs					
Cataract	97,370	Cataract river	Broughton's Pass Weir	N	N
Cordeaux	93,640	Cordeaux river	Pheasants Nest Weir	N	N
Fitzroy Falls	22,920	Pipe	Wingecarribee Reservoir,	N	Partial
Lake Yarrunga (Tallowa Reservoir)	90,000	Natural Carrier	Shoalhaven River	N	Partial
		Pipe	Bendeela Pondage	N	
Bendeela Pondage		Pipe	Fitzroy Falls reservoir	N	N
Blue Mountains	2890				
Medlow Dam		Natural Carrier	Greaves Creek Dam	N	N
Greaves Creek Dam	.	Pipe	Upper Cascade dam	N	N
Upper Cascade dam		Pipe	Middle Cascade Dam	N	N
Middle Cascade Dam		Pipe	Lower cascade Dam	N	N
Category 3 Offline Reservoirs					
Woodford Dam		Not part of supply system		N	N

7 Risk Assessment Methodology

7.1 The Australian/New Zealand Standard for Risk Assessment

The Risk Assessment Methodology follows an adapted version of The Australian/New Zealand Standard for Risk Assessment (AS/NZS/ISO31000:2018) and was combined integrated with the recommended RA process provided within the Australian Drinking Water Guidelines (2013) (see section 3.1). The general process of undertaking this risk assessment is as follows;

1 identify key stakeholders,

2 formulate a Statement of Objectives,

3 document the nature of possible fishing activities that may be proposed for each reservoir,

4 describe of GSWSS, its function and water quality information,

5 formulate a risk register for recreational fishing access to reservoirs,

6 assess risk for each of the risk events and document rationale,

7 identify suitable treatment options for High and Extreme Risks and;

8 reassess high and extreme risks to reduce them to acceptable levels.

IMPORTANT: The Risk Assessment methodology used this project assesses the relative risk of facilitating recreational fishing access to GSWSS reservoirs.

Table 7.1 summarises the key terms and definitions that are used by the standard and which will apply in the Risk Assessment (AS/NZS/ISO31000:2018).

Table 7.1: Terms and definitions used for Risk Assessments (AS/NZS/ISO31000:2018)

Term	**Definition**
Risk	EFFECT OF UNCERTAINTY ON OBJECTIVES An effect is a deviation from the expected. It can be positive, negative or both, and can address, create or result in opportunities and threats. Objectives can have different aspects and categories and can be applied at different levels. Risk is usually expressed in terms of risk sources , potential events, their consequences and their likelihood.
Risk Management	COORDINATED ACTIVITIES TO DIRECT AND CONTROL AN ORGANIZATION WITH REGARD TO RISK.
Stakeholder	PERSON OR ORGANIZATION THAT CAN AFFECT, BE AFFECTED BY, OR PERCEIVE THEMSELVES TO BE AFFECTED BY A DECISION OR ACTIVITY The term “interested party” can be used as an alternative to “stakeholder”.
Risk Source	ELEMENT WHICH ALONE OR IN COMBINATION HAS THE POTENTIAL TO GIVE RISE TO RISK
Event	OCCURRENCE OR CHANGE OF A PARTICULAR SET OF CIRCUMSTANCES An event can have one or more occurrences, and can have several causes and several consequences. An event can also be something that is expected which does not happen, or something that is not expected which does happen. An event can be a risk source.
Consequence	OUTCOME OF AN EVENT AFFECTING OBJECTIVES A consequence can be certain or uncertain and can have positive or negative direct or indirect effects on objectives. Consequences can be expressed qualitatively or quantitatively. Any consequence can escalate through cascading and cumulative effects.
Likelihood	CHANCE OF SOMETHING HAPPENING **Likelihood** is used to refer to the chance of something happening, whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically (such as a probability or a frequency over a given time period). The English term “likelihood” does not have a direct equivalent in some languages; instead, the equivalent of the term “probability” is often used. However, in English, “probability” is often narrowly interpreted as a mathematical term. Therefore, in risk management terminology, “likelihood” is used with the intent that it should have the same broad interpretation as the term “probability” has in many languages other than English.
Control	MEASURE THAT MAINTAINS AND/OR MODIFIES RISK **Controls** include, but are not limited to, any process, policy, device, practice, or other conditions and/or actions which maintain and/or modify risk. **Controls** may not always exert the intended or assumed modifying effect.

7.2 Qualitative Risk Assessment

Generally, risk assessments are either **qualitative** or **quantitative** depending upon the data and resources available (see Table 7.2). A Qualitative Risk Assessment methodology was used in this project.

This Qualitative Risk Assessment process considered both the general and where possible, the specific events relating to recreational fishing access to Cataract, Prospect and Woodford Reservoirs. These events were assessed and validated to provide an important assessment tool for further application to other reservoirs within the GSWSS. Any specific events that were identified for the demonstration reservoirs were assessed in detail.

Table 7.2: Comparison of Qualitative and Quantitative Risk Assessments

Qualitative Risk Assessment	**Quantitative Risk Assessments**
Because they predominantly deal with broad risks, and are therefore simple, Qualitative Risk Assessments are able to consider all **risks** in a project	Quantitative Risk Assessments only consider the **risks** from a Qualitative Risk Assessment which require further analysis.
Qualitative Risk Assessments utilise **stakeholder** inputs to judge the **likelihood** and **consequence**.	Quantitative Risk Assessments use mathematical and simulation tools to calculate the **likelihood** and **consequence**.
Risks are assigned a numeric ranking of **likelihood** and **consequence.**	Quantitative Risk Assessments estimate the **likelihood** of meeting targets and contingency needed to achieve desired levels of performance.
Qualitative Risk Assessments are usually applied in most of the projects as they are cost effective.	Quantitative Risk Assessments may not be applied to many simple or moderately complex projects as they are expensive

7.3 Alternative Terminology

The definitions and terminology used by The Australian/New Zealand Standard for Risk Assessment (AS/NZS/ISO31000:2018) are commonly substituted with alternative terms. Table 7.3 provides a guide to the alternative terminology that was used in the Risk Assessment.

Table 7.3: Common alternative terminology used in Risk Assessments

Term	**Alternatives**
Risk Assessment	Risk Analysis
Risk Management	Mitigation
Risk Source	Activity
Event	Threat, Hazard

Consequence	Impact
Likelihood	Probability
Control	Treatment, Action

7.4 Risk Assessment Matrix

Assessing the level of a risk involves determining the consequence and likelihood of that risk occurring. The assessment of risk also takes into consideration any controls that are currently in place to minimise negative risk or enhance positive opportunities.

Risks are ranked according to the **likelihood** of the threat occurring and the **consequence** of the impact. These rankings are then incorporated into the **Risk Assessment Matrix** (Table 7.4) to give a **Risk Ranking.**

Table 7.4: Risk Assessment Matrix

LIKELIHOOD	CONSEQUENCE				
	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Critical
5. Near certain	Low	Medium	High	Severe	Severe
4. Highly likely	Low	Medium	Medium	High	Severe
3. Likely	Low	Low	Medium	High	Severe
2. Unlikely	Low	Low	Low	Medium	High
1. Highly unlikely	Low	Low	Low	Medium	High

7.4.1 Likelihood

Likelihood as the probability or chance of a risk event occurring. There are five categories of likelihood that are used in the Risk Assessment as shown in Table 7.5.

Table 7.5 Likelihood categories used in Risk Assessment

Likelihood Rating	Descriptor	Definition
5	**Near certain**	Is expected to occur in most circumstances
4	**Likely**	Will probably occur in most circumstances
3	**Possible**	Might occur or should occur at some time
2	**Unlikely**	Could occur at some time but is not expected
1	**Rare**	May occur only in exceptional circumstances

7.4.2 Consequence

Consequence is described in The Australian/New Zealand Standard for Risk Assessment (AS/NZS/ISO31000:2018) as an outcome of a risk event affecting objectives. The categories of **consequence** are shown Table 7.6.

Table 7.6 Consequence categories used in Risk Assessment

Consequence Severity Level	Descriptor	Consequence to the current aquatic fauna assemblages
5	**Critical**	Major impact, complete failure of systems
4	**Major**	Major impact, systems significantly compromised and abnormal operation if at all, high level of monitoring required
3	**Moderate**	Minor impact, modification to normal operation but manageable, operation costs increased, increased monitoring
2	**Minor**	Minor impact, some manageable operation disruption
1	**Insignificant**	Insignificant impact, little disruption to normal operation

7.5 Rationale

An important element of the risk assessment process is to document the rationale used to determine the level assigned for each risk event. The rationale should describe the key reasons and influences for the risk levels that were agreed by the participants in the workshop.

8 Risk Assessment

8.1 Overview

A Risk Assessment workshop was held in Sydney on 8 August 2018 and involved delegates from key stakeholder organisations. The following people were invited to attend site inspections of the three reservoirs on 7 August 2018, followed by the workshop on 8 August. Invitees and workshop participants are shown in Table 8.1.

Site inspections were conducted at Prospect Reservoir and Woodford Reservoir but due to logistical constraints, Cataract Reservoir was not inspected. Fortunately, most of the participants in the project had previously visited Cataract Reservoir and were familiar with the site.

Table 8.1: Risk Assessment Site Inspection and Workshop invitee list

Project Steering Committee		**Site Inspection**	**Workshop**
Jim Harnwell	Senior Fisheries Manager DPI Fisheries, Project Manager.		✓
Peter Turnell	Group Director Recreational and Indigenous Fisheries, NSW DPI		✓
Cam Westaway	Senior Fisheries Manager Inland, DPI Fisheries		✓
Danielle Baker	Director Water Analytics, DPI Water	✓	✓
Karl Mathers	RFNSW	✓	
Independent Technical Reviewer			
Dr Dan Deere	Water Futures		✓
Water NSW			
Graham Begg	Manager Water Information Solutions, NSW Water	✓	✓
Dr Andrew Ball	NSW Water		✓
David Tomlinson	Water System Operations Manager Greater Sydney, NSW Water		✓
Kirk Newport	NSW Water	✓	✓
Government Key Stakeholders			
Ben Blayney	Water Manager, Sydney Water		
Jonathon Sanders	Area Manager, NPWS (Prospect Nature Reserve)	No Response	
Katrina Wall	NSW Health		✓
Recreational Fishing Community			
Chris Cleaver	RFNSW, Tackle Industry	✓	✓
Peter Gibson	RFA		✓
Project Consultants			
Danny Simpson	Project Manager, Pulse Environmental Consulting	✓	✓
Dr Michael Sierp	Technical, Aquatic Biosecurity Pty Ltd	✓	✓

8.2 Risk Register

8.2.1 Risk Sources

Fishing Type

The Risk Assessment Workshop was conducted by first defining the 'type' of recreational fishing activities that were proposed for each of the reservoirs. Initial discussion focussed on assessing the risks associated with uncontrolled access to each for the three reservoirs however, it was soon agreed that this was impractical for the purposes of the assessment. Consequently, the 'type' of access was refined and is shown in Table 8.2. below. These activities are described as **Risk Sources**.

Table 8.2: Risk Sources from recreational fishing in GSWSS reservoirs

Activities	Source Code	Category 1 Prospect Reservoir	Category 2 Cataract Reservoir	Category 3 Woodford Reservoir
Vehicle access on defined roads	**A1**	√	√	√
Car Parking	**A2**	√	√	√
Infrastructure (boat ramps, fishing platforms, toilets, paths)	**A3**	√	√	√
Pedestrian access to and along shoreline	**A6**	√	√	√
Un-powered boating	**A7**	√	√	√
Bait fishing	**A8**	√	√	√
Powered boating	**A9**			√

Fishing Level

Participants also agreed that it was necessary to define the expected level of use by recreational fishers at each of the reservoirs to provide context to the assessment. The levels of use for each of the three reservoirs are shown below in Table 8.3.

Table 8.3: Possible usage levels of reservoirs

Reservoir	Expected Maximum Weekend Usage
Prospect	50 cars, single access point & 100 people
Cataract	40 kayaks and cars, single access point
Woodford	40 kayaks and cars, single access point

8.3 Risk Register

Each of the **Risk Sources** were analysed to identify the associated **Risk Events** which are presented in Table 8.4. This **Risk Register** provided the basis for the Risk Assessment process and describes the management issues that were considered for allowing recreational fishing access to reservoirs within the GSWSS. It was formulated by drawing on experience, research and liaison with stakeholders.

Table 8.4: Risk register for recreational fishing access to GSWSS reservoirs

Value/Aspect	Risk No.	Risk Source	Event	Potential Consequences
Catchment	**C1**	**A1, A6, A9,**	**Recreational fishing access causes bushfires in the catchment**	• Life and property are lost • Bushfire prevention requires the investment of more resources • Rainfall after bushfire leads to increased sediment and nutrient transport to reservoirs which can increase turbidity and cause algal blooms • Increased treatment costs
	C2	**A1, A2, A6,**	**Vehicle and pedestrian access causes erosion on unsealed roads and tracks**	• Greater sediment transport to the reservoir increases turbidity • Greater sediment transport to the reservoir increases nutrient concentrations which may cause algal blooms
	C3	**A1, A6**	**Roads, tracks, fences and other assets area damaged**	• Increased costs of management • Interruptions to operations
	C5	**A1, A6**	**Weeds infest the catchment area and waterbody**	• Increased costs of management to control weeds • Weeds are transported to and within the reservoir on shoes and vehicle tyres • Declared weeds enter the area
	C6	**A1, A6**	**Vegetation is damaged**	• Increased costs of management • Loss of habitat
	C7	**A1, A6**	**Human defecation in uncontrolled areas of the catchment**	• Increased incidence of harmful viruses, bacteria and protozoans enter the water supply

	C8	**A1, A6**	**Rare fauna and flora species are disturbed or damaged**	• Loss of species or populations • Loss of habitat
	C9	**A1, A2**	**Petrochemical leakage from vehicles**	• Petrochemical contamination has impacts on natural and amenity values • Chemical contamination may result in degradation to water quality and threaten human health
	C10	**A6**	**Illegal recreational activities in the catchment (swimming, dog access etc.)**	• Increased incidence of harmful viruses, bacteria and protozoa enter the water supply • Damage to assets • Increased compliance • Introduction of pests
	C11	**A6**	**Rubbish is disposed incorrectly by recreational fishers**	• Increased costs of management • Damage to fauna
Operations, Assets and Liability	**O1**	**A1, A6**	**Recreational fishing interacts with other catchment uses (e.g. mining)**	• Disturbance to operations • Damages claims
	O2	**A1, A6, A3, A7, A9**	**Recreational fishers are injured**	• Injuries to users by falling, venomous invertebrates, drowning and thermal stress • Liability claims against operators • Increased costs of management • Health impacts through having contact with the water in the reservoir including chemicals, toxins and pathogens • Illness caused by consuming fish
	O3	**A1, A2, A3, A6, A7, A9**	**Recreational fishing interferes with operational requirements**	• Disruption of operations • Increased costs of operations (e.g. treatment, maintenance)

				• Increased visitor numbers require additional staff to manage compliance
	O4	**A1, A2, A3, A6**	**Recreational fishing requires significant capital investment**	• Capital cost implications for operators • Recurrent costs implications for operators
	O5	**A1, A6**	**Water infrastructure is damaged**	• Possible operational failure • Increased costs of management
Reservoirs	**C7**	**A1, A6**	**Human defecation in uncontrolled areas of the catchment**	• Increased incidence of harmful viruses, bacteria and protozoans enter the water supply
	R1	**A8**	**Baits used by fishers contaminate the water supply**	• Increased incidence of harmful viruses, bacteria and protozoa affecting the water supply
	R2	**A6**	**Illegal recreational activities in the reservoir (swimming, dog access etc.)**	• Increased incidence of harmful viruses, bacteria and protozoa affecting the water supply • Drowning • Increased compliance effort and cost
	R3	**A1, A6**	**Deliberate contamination of the reservoir**	• Increased visitation provides greater opportunities for terrorism • Introduction of noxious and pest species e.g. European carp

9 Risk Assessment Results

The results of the Risk Assessment undertaken during the Risk Assessment workshop are presented in Table 9.1,Table 9.2 and Table 9.3 . Time constraints restricted the assessment of all risks for all reservoirs during the workshop therefore, only the perceived 'important' risks were assessed. Additionally, where the process allowed, an assessment of the less important risks was undertaken. The participants in the workshop agreed that adopting this process would provide a useful template for assessing all risks at all reservoirs. This was undertaken after the workshop.

Table 9.1: Risk Assessment Results for Prospect Reservoir

Risk No.	Risk Source	Event	Potential Consequences	L	C	R	Rationale 50 cars, single access point & 100 people
C1	**A1, A6, A9,**	**Recreational fishing access causes bushfires in the catchment**	• Life and property is lost • Bushfire prevention requires the investment of more resources • Rainfall after bushfire leads to increased sediment and nutrient transport to reservoirs which can increase turbidity and cause algal blooms • Increased treatment costs	**3**	**5**	**S**	• Principle is based on increased access increases risk • Increasing residence time on the site therefore also increases risk • Current Bushfire prevention/response plans do not incorporate increased public access beyond defined areas for recreational fishing
C2	**A1, A2, A6,**	**Vehicle and pedestrian access causes erosion on unsealed roads and tracks**	• Greater sediment transport to the reservoir increases turbidity • Greater sediment transport to the reservoir increases nutrient concentrations which may cause algal blooms	**3**	**3**	**M**	• Increased visitation and vehicle use will cause erosion and degradation of existing roads
C3	**A1, A6**	**Roads, tracks, fences and other assets area damaged (deliberate or inadvertent)**	• Increased costs of management • Interruptions to operations	**2**	**1**	**L**	• Hydrometric assets and security assets included • Prospect is bitumen road only currently. Existing means of access only • Change to security required • Assets behind the fence require consideration
C5	**A1, A6**	**Weeds infest the catchment area and waterbody**	• Increased costs of management to control weeds • Weeds are transported to and within the reservoir on shoes and vehicle tyres • Declared weeds enter the area	**2**	**1**	**L**	• Seeds and weed fragments can be transported on the tyres of vehicles or on the shoes of fishers
C6	**A1, A6**	**Vegetation is damaged**	• Increased costs of management • Loss of habitat	**2**	**1**	**L**	• Vegetation damage is likely only to be associated with areas of higher use e.g.: along paths

							• Anglers may damage vegetation to seek better shoreline access
C7	**A1, A6**	**Human defecation in uncontrolled areas of the catchment**	• Increased incidence of harmful viruses, bacteria and protozoans enter the water supply	**2**	**4**	**M**	• Water in Prospect not often used as a continuous supply source • Kayakers might leave the kayak for toileting • Financial impacts from the pathogen management • Prospect already has designated toilet facilities • Flexibility in water supply system allows Prospect to be removed from system in the event of contamination
C8	**A1, A6**	**Rare fauna and flora species are disturbed or damaged**	• Loss of species or populations • Loss of habitat	**1**	**1**	**L**	• Unlikely that recreational access will cause significant disturbance • There may be disruption to breeding of birds • Some damage to rare vegetation may occur if not managed correctly
C9	**A1, A2**	**Petrochemical leakage from vehicles (Cars and motorbikes)**	• Petrochemical contamination has impacts on natural and amenity values • Chemical contamination may result in degradation to water quality and threaten human health	**1**	**3**	**L**	• Currently, Prospect is open to vehicles approx. 20-50 cars day • Roads drain away from Reservoir
C10	**A6**	**Illegal recreational activities in the catchment (swimming, dog access etc.)**	• Increased incidence of harmful viruses, bacteria and protozoa enter the water supply • Damage to assets • Increased compliance • Introduction of pests	**2**	**4**	**M**	• It is possible that that by providing fishing access that the incidence of illegal activities will occur. • More recreational access encourages community custodianship
C11	**A6**	**Rubbish is disposed incorrectly by recreational fishers**	• Increased costs of management • Damage to fauna	**4**	**1**	**L**	• Increased public access will result in more rubbish being disposed in areas where facilities

							aren't provided. Some of this rubbish may be harmful to fauna i.e. plastic bags
O1	**A1, A6**	**Recreational fishing interacts with other catchment uses (e.g. mining)**	• Disturbance to operations • Damages claims	**3**	**1**	**L**	• Likely to be minor interaction between fishers and reservoir staff undertaking work • Unlikely that fishing will interfere with water operations or other catchment ops e.g. mining
O2	**A1, A6, A3, A7, A9**	**Recreational fishers are injured**	• Injuries to users by falling, venomous invertebrates, drowning and thermal stress • Liability claims against operators • Increased costs of management • Health impacts through having contact with the water in the reservoir including chemicals, toxins and pathogens • Illness caused by consuming fish	**3**	**3**	**M**	• It is expected that increased recreational access may result in injuries but that these are most likely to be restricted to accidental falls etc.
O3	**A1, A2, A3, A6, A7, A9**	**Recreational fishing interferes with operational requirements**	• Disruption of operations • Increased costs of operations (e.g. treatment, maintenance) • Increased visitor numbers require additional staff to manage compliance	**3**	**2**	**L**	• Unlikely that operations will be disturbed to any great extent if access conditions are clearly defined • There may be an increased maintenance and compliance cost
O4	**A1, A2, A3, A6**	**Recreational fishing requires significant capital investment**	• Capital cost implications for operators • Recurrent costs implications for operators	**1**	**3**	**L**	• Unlikely that Water NSW will be required to make capital investment
O5	**A1, A6**	**Water infrastructure is damaged**	• Possible operational failure • Increased costs of management	**2**	**2**	**L**	• Hydrometric assets and security assets included • Unlikely that sufficient damage could be caused to significantly effect operations • Maybe some increased cost associated with repairs

R1	**A8**	**Baits used by fishers contaminate the water supply**	• Increased incidence of harmful viruses, bacteria and protozoa affecting the water supply	**1**	**2**	**L**	• Likely to be bacteria contamination which is controllable with chlorine • May result in increased treatment costs and possible infection of reservoir users
R3	**A1, A6**	**Deliberate contamination of the reservoir**	• Increased visitation provides greater opportunities for terrorism	**1**	**4**	**H**	• Deliberate attempts may to have significant impact if successful but unlikely to be related to allowing recreational fishing access • Incidence (and therefore likelihood) of deliberate attempts to contaminate water supply is very low – historical records

Table 9.2 Risk Assessment Results for Cataract Reservoir

Risk No.	Risk Source	Event	Possible Consequences	L	C	R	Rationale 40 kayaks and cars, single access point
C1	**A1, A6, A9,**	**Recreational fishing access causes bushfires in the catchment**	• Life and property are lost • Bushfire prevention requires the investment of more resources • Rainfall after bushfire leads to increased sediment and nutrient transport to reservoirs which can increase turbidity and cause algal blooms • Increased treatment costs	**3**	**5**	**S**	• Principle is based on increased access increases risk • Increasing residence time on the site therefore also increases risk • Current Bushfire prevention/response plans do not incorporate increased public access beyond defined areas
C2	**A1, A2, A6,**	**Vehicle and pedestrian access causes erosion on unsealed roads and tracks**	• Greater sediment transport to the reservoir increases turbidity • Greater sediment transport to the reservoir increases nutrient concentrations which may cause algal blooms	**3**	**3**	**M**	• Increased visitation and vehicle use will cause erosion and degradation of existing roads
C3	**A1, A6**	**Roads, tracks, fences and other assets area damaged (deliberate or inadvertent)**	• Increased costs of management • Interruptions to operations	**3**	**2**	**M**	• Currently low financial cost of maintenance which will increase by allowing greater access
C5	**A1, A6**	**Weeds infest the catchment area and waterbody**	• Increased costs of management to control weeds • Declared weeds enter the area	**2**	**2**	**L**	• Seeds and weed fragments can be transported on the tyres of vehicles or on the shoes of fishers
C6	**A1, A6**	**Vegetation is damaged**	• Increased costs of management • Loss of habitat	**2**	**2**	**L**	• Vegetation damage is likely only to be associated with areas of higher use e.g.: along paths • Anglers may damage vegetation in order to seek better shoreline access

C7	**A1, A6**	**Human defecation in uncontrolled areas of the catchment**	• Increased incidence of harmful viruses, bacteria and protozoans in the water supply	**2**	**4**	**M**	• Shoreline access assumed. • Kayakers might leave the kayak for toileting. • Financial impacts from pathogen management
C8	**A1, A6**	**Rare fauna and flora species are disturbed or damaged**	• Loss of species or populations • Loss of habitat	**1**	**3**	**L**	• Unlikely that recreational access will cause significant disturbance. • There may be disruption to breeding of birds • Some damage to rare vegetation may occur if not managed correctly
C9	**A1, A2**	**Petrochemical leakage from vehicles (Cars and motorbikes)**	• Petrochemical contamination has impacts on natural and amenity values • Chemical contamination may result in degradation to water quality and threaten human health	**2**	**4**	**M**	• Existing risk 20-50 cars day(?)
C10	**A6**	**Illegal recreational activities in the catchment (swimming, dog access etc.)**	• Increased incidence of harmful viruses, bacteria and protozoa enter the water supply • Damage to assets • Increased compliance • Introduction of pests	**2**	**4**	**M**	• It is possible that by providing fishing access the incidence of illegal activities will reduce. These are likely to be minor in nature but may have serious implications for water quality
C11	**A6**	**Rubbish is disposed incorrectly by recreational fishers**	• Increased costs of management • Possible damage to fauna	**4**	**1**	**L**	• Increased public access will result in more rubbish being disposed in areas where facilities aren't provided. Some of this rubbish may be harmful to fauna i.e. plastic bags
O1	**A1, A6**	**Recreational fishing interacts with other catchment uses (e.g. mining)**	• Disturbance to operations • Damages claims	**2**	**1**	**L**	• Likely to be minor interaction between fishers and reservoir staff undertaking work • Unlikely that fishing will interfere with water operations or other catchment ops e.g. mining
O2	**A1, A6, A3, A7, A9**	**Recreational fishers are injured**	• Injuries to users by falling, venomous invertebrates, drowning and thermal stress • Liability claims against operators	**3**	**3**	**M**	• It is expected that increased recreational access may result in injuries but that these are most likely to be restricted to accidental falls etc…

			• Increased costs of management • Health impacts through having contact with the water in the reservoir including chemicals, toxins and pathogens • Illness caused by consuming fish				
O3	**A1, A2, A3, A6, A7, A9**	**Recreational fishing interferes with operational requirements**	• Disruption of operations • Increased costs of operations (e.g. treatment, maintenance) • Increased visitor numbers require additional staff to manage compliance	**3**	**2**	**L**	• Unlikely that operations will be disturbed to any great extent if access conditions are clearly defined • There may be an increased maintenance and compliance cost
O4	**A1, A2, A3, A6**	**Recreational fishing requires capital investment from Water NSW**	• Capital cost implications for operators • Recurrent costs implications for operators	**1**	**3**	**L**	• Unlikely that Water NSW will be required to make capital investment
O5	**A1, A6**	**Water infrastructure is damaged**	• Possible operational failure • Increased costs of management	**2**	**1**	**L**	• Hydrometric assets and security assets included • Unlikely that sufficient damage could be caused to significantly affect operations. • Maybe some increased cost associated with repairs
R1	**A8**	**Baits used by fishers contaminate the water supply**	• Increased incidence of harmful viruses, bacteria and protozoa affecting the water supply	**1**	**2**	**L**	• Likely to be bacteria contamination which is controllable with chlorine • May result in increased treatment costs and possible infection of reservoir users
R3	**A1, A6**	**Deliberate contamination of the reservoir**	• Increased visitation may provide greater opportunities for terrorism	**1**	**5**	**H**	• Deliberate attempts may to have significant impact if successful but unlikely to be related to allowing recreational fishing access • Incidence (and therefore likelihood) of deliberate attempts to contaminate water supply is very low – historical records

Table 9.3 Risk Assessment Results for Woodford Reservoir

Risk No.	Risk Source	Event	Possible Consequences	L	C	R	Rationale 40 kayaks and cars, single access point
C1	**A1, A6, A9,**	**Recreational fishing access causes bushfires in the catchment**	• Life and property are lost • Bushfire prevention requires the investment of more resources • Rainfall after bushfire leads to increased sediment and nutrient transport to reservoirs which can increase turbidity and cause algal blooms	**2**	**4**	**M**	• Existing access at Woodford access • Principle is based on increased access = increases risk • Woodford already managed for public access therefore response plans are developed to reduce impacts (consequence)
C2	**A1, A2, A6,**	**Vehicle and pedestrian access causes erosion on unsealed roads and tracks**	• Greater sediment transport to the reservoir increases turbidity • Greater sediment transport to the reservoir increases nutrient concentrations which may cause algal blooms	**3**	**1**	**L**	• Woodford not part of water supply
C3	**A1, A6**	**Roads, tracks, fences and other assets area damaged (deliberate or inadvertent)**	• Increased costs of management • Interruptions to operations	**4**	**2**	**M**	• Increase access will damage roads etc… requiring greater maintenance
C5	**A1, A6**	**Weeds infest the catchment area and waterbody**	• Increased costs of management to control weeds • Weeds are transported to and within the reservoir on shoes and vehicle tyres • Declared weeds enter the area	**2**	**2**	**L**	• Possible on vehicle tyres • Single access point allows easy detection and control
C6	**A1, A6**	**Vegetation is damaged**	• Increased costs of management • Loss of habitat	**2**	**1**	**L**	• Associated with anglers accessing the shoreline. • Little opportunity for shoreline access at Woodford

C7	**A1, A6**	**Human defecation in uncontrolled areas of the catchment**	• Increased incidence of harmful viruses, bacteria and protozoans enter the water supply	**1**	**1**	**L**	• Woodford not part of water supply
C8	**A1, A6**	**Rare fauna and flora species are disturbed or damaged**	• Loss of species or populations • Loss of habitat	**1**	**3**	**L**	• Increased access may disturb breeding of rare species
C9	**A1, A2**	**Petrochemical leakage from vehicles (Cars and motorbikes)**	• Petrochemical contamination has impacts on natural and amenity values	**3**	**3**	**M**	• Currently no public vehicle access to Woodford • Allowing vehicle access will increase risk of spillage • Spillage is most likely to impact on aesthetics but may impact water quality
C10	**A6**	**Illegal recreational activities in the catchment (swimming, dog access etc.)**	• Damage to assets • Increased compliance • Introduction of pests	**2**	**2**	**L**	• Illegal access to the dam wall may lead to damage and injury to entrants
C11	**A6**	**Rubbish is disposed incorrectly by recreational fishers**	• Increased costs of management • Damage to fauna	**4**	**1**	**L**	• Increased public access will result in more rubbish being disposed in areas where facilities aren't provided. Some of this rubbish may be harmful to fauna i.e. plastic bags
O1	**A1, A6**	**Recreational fishing interacts with other catchment uses (e.g. mining)**	• Disturbance to operations • Damages claims	**2**	**2**	**L**	• Likely to be minor interaction between fishers and reservoir staff undertaking work • Traffic management on road
O2	**A1, A6, A3, A7, A9**	**Recreational fishers are injured**	• Injuries to users by falling, venomous invertebrates, drowning and thermal stress • Liability claims against operators • Increased costs of management	**3**	**3**	**M**	• It is expected that increased recreational access may result in injuries but that these are most likely to be restricted to accidental falls etc.

			• Health impacts through having contact with the water in the reservoir including chemicals, toxins and pathogens • Illness caused by consuming fish				
O3	**A1, A2, A3, A6, A7, A9**	**Recreational fishing interferes with operational requirements**	• Disruption of operations • Increased costs of operations (e.g. treatment, maintenance) • Increased visitor numbers require additional staff to manage compliance	**2**	**1**	**L**	• Likely to be minor interaction between fishers and reservoir staff undertaking work • Traffic management on road
O4	**A1, A2, A3, A6**	**Recreational fishing requires significant capital investment**	• Capital cost implications for operators • Recurrent costs implications for operators	**2**	**2**	**L**	• Unlikely that Water NSW will be required to make capital investment
O5	**A1, A6**	**Water infrastructure is damaged**	• Possible operational failure • Increased costs of management	**1**	**2**	**L**	• Not a Water Supply • Minor cost impact associated with repairs
C7	**A1, A6**	**Human defecation in uncontrolled areas of the catchment**	• Increased incidence of harmful viruses, bacteria and protozoans enter the water supply	**2**	**1**	**L**	• Not a Water Supply
R1	**A8**	**Baits used by fishers contaminate the water supply**	• Increased incidence of harmful viruses, bacteria and protozoa affecting the water supply	**1**	**1**	**L**	• Not a water supply
R3	**A1, A6**	**Deliberate contamination of the reservoir**	• Increased visitation provides greater opportunities for terrorism • Introduction of noxious and pest species e.g. European carp	**2**	**3**	**L**	• Not a water supply • Possible that pest fish may be introduced

10 Risk Management

An additional important phase of the Risk Assessment was to identify suitable treatment options for those High and Severe risks that were identified during the initial Risk Assessment phase so that mitigations may be developed for reducing risks to acceptable levels. A conventional approach to risk management is presented in Table 10.1.

Table 10.1: Risk Management

SEVERE	Do not go ahead with action unless significant treatments result in mitigation of risk to acceptable level
HIGH	Do not go ahead with action unless treatments result in mitigation of risk to acceptable level
MEDIUM	Risks rated at this level should be considered for further treatment, but action may still go ahead under defined conditions
LOW	Risks considered to be adequately managed and not requiring further treatment

10.1 Treatment of Risks

Management treatments are applied to minimise the likelihood or consequence of the risk by addressing the risk source and/or the risk event. For example, the risk to water quality from the leakage of petro-chemicals from vehicles entering a reservoir reserve may be treated through a variety of means including managing access, installing engineering solutions to prevent transport of chemicals to the waterbody or modifying treatment facilities and processes to remove petro-chemicals from water supplies.

10.1.1 Critical Control Points

The ADWG provides a framework for managing risks that identifies Critical Control Points (CCP's) within a water supply system (ADWG, 2016). The ADWG describes CCP's as;

> *"...an activity, procedure or process at which control can be applied and which is essential to prevent a hazard or reduce it to an acceptable level."*

CCPs may be identified at any point within the multi-barrier approach to protecting water supply and can include management responses such as upgrading water treatment facilities, implementing alternative operational procedures or managing the types of recreational fishing activities that can occur in reservoirs. Using CCPs to identify treatments for high and severe risks is a robust method for reducing or minimizing risk. CCPs need to be highly reliable, ideally continually monitored and failsafe and all significant risks must be mitigated by water utilities using multiple barriers, including CCPs.

The risk treatments presented in this report in Table 10.4 relate only to those actions that might be considered measures to control and prevent risk events rather than treat the outcome of the event such as a breakout of water borne pathogens. Treatment options for managing such an event in the GSWSS require significant investment and would involve upgrading water treatment facilities. Typically, this would include ozone with biological activated carbon or granular activated carbon treatment to mitigate organic pollutants, cyanotoxins and taste and odour compounds; as well as ultra-violet (UV) disinfection to mitigate *Cryptosporidium sp*. oocysts. Whilst costly, such treatment would bring the water supply into line with cities that do have recreation in their water supply storages; and with run-of-river water supplies, such as the River Murray; and in line with current and anticipated updates to the ADWG nominating the need to have in place such barriers for water sources with recreation in the inner catchments and source water reservoirs.

10.2 Mitigated Risk

In this Risk Assessment, **Mitigated Risk** is the term used to describe the level of risk after suitable **controls** have been identified. Mitigated risk is also known as Residual Risk. The process for defining **Mitigated Risk** necessitated a review of the rationale used to set the **likelihood** and **consequence** criteria used for the risk rating. An example of a mitigated risk outcome is shown below in Table 10.2.

Table 10.2: Example of Mitigated Risk ranking

Source	Event	Risk Assessment			Control	Mitigated Risk		
		L	C	Risk		L	C	Risk
Noxious fish species	Noxious fish species degrade water quality by destabilising aquatic processes	5	5	SEVERE	Introduce large predatory native species to control noxious species	2	2	LOW

10.3 Severe and High Risks

Each of the risks associated with recreational fishing access to the GSWSS that were assessed as Severe or High were further examined to determine the possible management treatments that may be employed to reduce risks to medium or low levels.

10.3.1 Possible Risk Treatments

An example of possible treatments for controlling recreational fishing activities in GSWSS reservoirs to prevent or reduce the risk to water supplies is shown in Table 10.3 below. These treatments represent some of the general management actions that may be applied to control the level of recreational fishing activity in each of the reservoir categories in the GSWSS and do not represent the full suite of management treatments that may be available.

Table 10.3: Possible treatment (management) options for recreational fishing access to reservoirs

Treatments	CCP	Category 1 Prospect Reservoir	Category 2 Cataract Reservoir	Category 3 Woodford Reservoir
Increased compliance	**Catchment**	✓	✓	✓
Recreational Fishing Licence	**Procedure**	✓	✓	✓
No entry on Fire Ban Days	**Catchment**	✓	✓	✓
Appropriate signage	**Catchment**	✓	✓	✓
Reservoir permits	**Procedure**	✓	✓	
Limited number access	**Procedure**	✓	✓	
Guided access only	**Procedure**	✓	✓	

Specific treatments for each of the Severe and High Risks identified during this Risk Assessment process are described in Table 10.4 and Table 10.5. below. **This information shows that through the application of the identified treatments, the Severe and High Risks identified for Prospect and Cataract Reservoir were able to be sufficiently mitigated to acceptable Medium levels.**

Note: There are no High or Severe risks for allowing recreational fishing access to Woodford Dam.

Table 10.4: Treatments and Mitigated Risk Assessment for Prospect Reservoir

Risk No.	Risk Source	Event	Unmitigated Risk Ranking			Treatment Assumed Usage: 50 cars, single access point & 100 people	Treatment Impacts	Mitigated Risk Ranking		
			L	C	R			L	C	R
C1	**A1, A6, A9,**	**Recreational fishing access causes bushfires in the catchment**	**3**	**5**	**S**	• No access on days of Total Fire Ban Days • No smoking • Daylight access • Controlled access point • No fires • Improved communications with fire authorities • Treatments likely to result in more effective response and containment thereby reducing impacts and consequences • Upgraded bushfire management planning to attend broader public access • Education and public awareness to increase surveillance activities • Access plans developed • Include NPWS and Rural Fire Service in planning for recreational access	• the proposed treatments aim to reduce both the likelihood and consequence of the risk event. preventing and controlling access reduces the likelihood of fires being started by recreational fishers. by not allowing access on these days and by upgrading response plans, less people will be impacted by fires compared to allowing uncontrolled access.	**2**	**4**	**M**
R3	**A1, A6**	**Deliberate contamination of the reservoir**	**1**	**5**	**H**	• Public education and awareness • Increased compliance and penalties • Access plans developed • Improved detection monitoring • Upgraded response plans	• the proposed treatments will reduce the consequences of deliberate contamination by encouraging community surveillance and custodianship. This will enable a better response to possible incidents thus allowing management intervention to be quickly implemented to reduce impacts.	**1**	**4**	**M**

Table 10.5: Treatments and Mitigated Risk rankings for Cataract Reservoir

Risk No.	Risk Source	Event	Unmitigated Risk Ranking			Treatment Assumed usage: 40 kayaks and cars, single access point	Treatment Impact	Mitigated Risk Ranking		
			L	C	R			L	C	R
C1	**A1, A6, A9,**	**Recreational fishing access causes bushfires in the catchment**	**3**	**5**	S	• No access on days of Total Fire Ban Days • No smoking • Daylight access • Controlled access point • No fires • Improved communications with fire authorities • Treatments likely to result in more effective response and containment thereby reducing impacts • Upgraded bushfire management planning to attend broader public access • Education and public awareness to increase surveillance activities • Access plans developed which incorporate management protocols for recreational access to public lands such as National Parks and Wilderness Areas • Include NPWS and Rural Fire Service in planning for recreational access	• the proposed treatments aim to reduce both the likelihood and consequence of the risk event. preventing and controlling access reduces the likelihood of fires being started by recreational fishers. By not allowing access on these days and by upgrading response plans, less people will be impacted by fires compared to allowing uncontrolled access.	**2**	**4**	**M**

R3	**A1, A6**	**Deliberate contamination of the reservoir**	**1**	**5**	H	• Public education and awareness • Increased compliance and penalties • Access plans developed • Improved detection monitoring • Upgraded response plans	• the proposed treatments will reduce the consequences of deliberate contamination by encouraging community surveillance and custodianship. This will enable a better response to possible incidents thus allowing management intervention to be quickly implemented to reduce impacts.	**1**	**4**	**M**

11 Summary

11.1 Risk Assessment

Table 11.1 summarises the results of the first step in the Risk Assessment undertaken for recreational fishing access to reservoirs in the GSWSS and shows that 4 risks are ranked as either Severe or High. In accordance with the Australian/New Zealand Standard for Risk Assessment (AS/NZS/ISO31000:2018) each of these four risks were assessed to identify management treatments that would adequately mitigate the risk and reduce it to a Low or Medium ranking (see Table 11.2).Table 11.3 presents the outcome of this assessment and shows that through the application of a suite of management treatments, each of the Severe And High Risks can be sufficiently mitigated to an acceptable. In each case, the Mitigated Risk Ranking was assessed as Medium. The Australian/New Zealand Standard for Risk Assessment (AS/NZS/ISO31000:2018) considers that risks ranked at this level ***"should be considered for further treatment, but management action may still go ahead under defined conditions."***

Table 11.1: Unmitigated Severe and High Risks for three reservoir categories in the GSWSS

Reservoir	Risk	Unmitigated Risk Ranking	Risk Management
Category 1 Prospect	Recreational fishing access causes bushfires in the catchment	**S**	Do not go ahead with action unless significant treatments result in mitigation of risk to acceptable level
	Deliberate contamination of the reservoir	**H**	Do not go ahead with action unless significant treatments result in mitigation of risk to acceptable level
Category 2 Cataract	Recreational fishing access causes bushfires in the catchment	**S**	Do not go ahead with action unless significant treatments result in mitigation of risk to acceptable level
	Deliberate contamination of the reservoir	**H**	Do not go ahead with action unless significant treatments result in mitigation of risk to acceptable level
Category 3 Woodford	**Nil**		

Section 9: Risk Management, describes the approach to managing risks for each of the four levels used in this project. The management approach for all risk rankings are shown in Table 11.2 below.

Table 11.2: Risk Management (Reproduced from 10.1)

SEVERE	Do not go ahead with action unless significant treatments result in mitigation of risk to acceptable level

HIGH	Do not go ahead with action unless treatments result in mitigation of risk to acceptable level
MEDIUM	Risks rated at this level should be considered for further treatment, but action may still go ahead under defined conditions
LOW	Risks considered to be adequately managed and not requiring further treatment

Table 11.3: Mitigated Risk Rankings for previously identified Severe and High Risks for three reservoir categories in the GSWSS

Reservoir	Risk	Mitigated Risk Ranking	Risk Management Action
Category 1 Prospect	Recreational fishing access causes bushfires in the catchment	**M**	Risks rated at this level should be considered for further treatment, but action may still go ahead under defined conditions
	Deliberate contamination of the reservoir	**M**	Risks rated at this level should be considered for further treatment, but action may still go ahead under defined conditions
Category 2 Cataract	Recreational fishing access causes bushfires in the catchment	**M**	Risks rated at this level should be considered for further treatment, but action may still go ahead under defined conditions
	Deliberate contamination of the reservoir	**M**	Risks rated at this level should be considered for further treatment, but action may still go ahead under defined conditions
Category 3 Woodford	**Nil**		

11.2 Summary

The aim of this project was to identify and describe the possible impacts of recreational fishing in water supply reservoirs in the Greater Sydney Water Supply System (GSWSS) and a Risk Assessment process was undertaken to achieve this aim.

The **Qualitative** Risk Assessment process adopted for the project followed the criteria of the Australian/New Zealand Standard for Risk Assessment (AS/NZS/ISO31000:2018). It is noted that The Australian Drinking Water Guidelines (https://www.nhmrc.gov.au/guidelines/publications/eh52/) provide an authoritative reference on what defines safe, good quality water, how it can be achieved and how it can be assured. The guidelines describe a complex **Quantitative** approach to assessing risk

to water supplies, which requires significant financial and technical resources to undertake and is beyond the scope of this project.

This Risk Assessment attempts to consider the broad risks associated with facilitating recreational fishing access to reservoirs within the GSWSS by focusing on three reservoirs within each of the categories used in the project (see Table 6.1: Great Sydney Water Supply System Reservoir Categories). As such it provides a substantial basis from which to progress development of this initiative however, because the assessment focuses mainly on broad risks (and specific risks where possible), it cannot claim to provide a comprehensive account of all the specific risks associated with recreational fishing access to all the reservoirs in the GSWSS. This can only be done by assessing each of the reservoirs individually.

The process of engagement with key stakeholders including recreational fishers and water management authorities provided a substantial basis for undertaking the Risk Assessment. Through this engagement process and the investigation of relevant information a substantial information base was built to inform the Risk Assessment process.

The Risk Assessment was undertaken during and after a stakeholder workshop held in Sydney on 8 August 2018 and revealed that two risks at each of Prospect and Cataract Reservoirs (4 risks in total) were considered either Severe or High and therefore required that management treatments were identified to mitigate these risks to acceptable levels. No Severe or High risks were identified for Woodford Reservoir.

Management treatments for the four risks were identified and the risks were reassessed. The outcome of this reassessment showed that all risks were able to be sufficiently mitigated to an acceptable 'Medium' level thus supporting progress of the proposal to facilitate recreational fishing access in GSWSS reservoirs.

The Risk Assessment process described in this report did not include representation from experts in bushfire prevention and planning and while it is acknowledged that WaterNSW have expertise in this field, the contributions of officers from the NPWS and the NSW Rural Fire Service would have provided greater knowledge on the topic of managing recreational access in parks and conservation zones. Since the Risk Assessment Workshop was undertaken, DPI Fisheries have sought to better inform the Risk Ranking by engaging with the NSW National Parks and Wildlife Service to seek advice on the rational and treatments that were applied to this specific risk.

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Appendix 1
Recreational Fishing Impoundments in NSW

https://www.google.com/maps/d/viewer?mid=1WLuGpT9tAGXqXco04hbbf3GcQTQ&ll=-32.77900626023939%2C147.50426600000003&z=6

Table A1: Public Access Dams

Site	Near_Town	Stocked	Public Access	Domestic Water Supply
Barham Recreational Lake	Barham	Yes	Yes	
Beardy Waters	Glen Innes	Yes	Yes	√
Ben Chifley Dam	Perthville	Yes	Yes	√
Blowering Dam	Tumut	Yes	Yes	√
Botany Wetlands	Botany	Yes	Yes	
Bowmans Lagoon	Wagga Wagga	Yes	Yes	
Brogo Dam	Brogo	Yes	Yes	√
Brooklyn Dam	Brooklyn	Yes	Yes	
Brooklyn Railway Dam	Berowra	Yes	Yes	
Bumberry Dam	Parkes	Yes	Yes	
Bundanoon Creek Dam	Werai	Yes	Yes	√
Burraga Dam	Burraga	Yes	Yes	
Burrendong Dam	Mumbil	Yes	Yes	√
Burrinjuck Dam	Burrinjuck	Yes	Yes	√
Bushmans Dam	Parkes	Yes	Yes	
Cabramurra Fishing Clinic Pond	Cabramurra	Yes	Yes	
Captains Flat Dam	Captains Flat	Yes	Yes	
Carcoar Dam	Carcoar	Yes	Yes	√
Chaffey Dam	Nundle	Yes	Yes	√
Cherrybrook Lakes	Cherrybrook	Yes	Yes	
Chinamans Dam	Young	Yes	Yes	
Clarrie Hall Dam	Uki	Yes	Yes	√
Coolumbooka Weir	Bombala	Yes	Yes	√
Coonamble Recreational Lake	Coonamble	Yes	Yes	
Copeton Dam	Gum Flat	Yes	Yes	√
Corowa Dam	Corowa	Yes	Yes	
Danjera Dam	Yalwal	Yes	Yes	√
Deniliquin Wetlands	Deniliquin	Yes	Yes	
Dry Dam	Cabramurra	Yes	Yes	√
Dumaresq Dam	Dumaresq	Yes	Yes	

Dunns Swamp	Olinda	Yes	Yes	
Elmslea Pond 1	Bungendore	Yes	Yes	
Elmslea Pond 2	Bungendore	Yes	Yes	
Fagan Park Dams	Galston	Yes	Yes	
Finley Dam	Finley	Yes	Yes	
Fitzroy Falls Reservior	Fitzroy Falls	Yes	Yes	√
Flat Rock Dam	West Nowra	Yes	Yes	
Fountains Creek Dam 1	West Gosford	Yes	Yes	
Fountains Creek Dam 2	West Gosford	Yes	Yes	
Gara Dam	Argyle	Yes	Yes	
Geehi Dam	Geehi	Yes	Yes	Hydro
Glenbawn Dam	Glenbawn	Yes	Yes	√
Glenmore Loch	Glenmore Park	Yes	Yes	
Glennies Creek Dam	St Clair	Yes	Yes	√
Googong Dam	Queanbeyan	Yes	Yes	√
Gosling Creek Reservoir	Bloomfield	Yes	Yes	
Gulligal Lagoon	Boggabri	Yes	Yes	
Gum Bend Lake	Condobolin	Yes	Yes	
Horseshoe Lagoon	Albury	Yes	Yes	
Imperial Lake	Broken Hill	Yes	Yes	
Island Bend Pondage	Island Bend	Yes	Yes	
Jounama Pondage	Talbingo	Yes	Yes	hydro
Junee Park Dam	Junee	Yes	Yes	
Keepit Dam	Somerton	Yes	Yes	√
Khancoban Pondage	Khancoban	Yes	Yes	hydro
Killarney Chain of Ponds	Killarney	Yes	Yes	
Koorawatha Dam	Koorawatha	Yes	Yes	
Lake Albert	Wagga Wagga	Yes	Yes	
Lake Arbitree	Ariah Park	Yes	Yes	
Lake Bathurst	Tarago	Yes	Yes	
Lake Bethungra	Bethungra	Yes	Yes	
Lake Canobolas	Nashdale	Yes	Yes	
Lake Cargelligo	Lake Cargelligo	Yes	Yes	√
Lake Centenary	Temora	Yes	Yes	
Lake Cowal/Bland Creek Dam	West Wyalong	Yes	Yes	√
Lake Crackenback	Crackenback	Yes	Yes	√
Lake Endeavour	Bumberry	Yes	Yes	√
Lake Eucumbene	Eucumbene	Yes	Yes	Hydro
Lake Forbes	Forbes	Yes	Yes	

Lake Gillawarna	Georges Hall	Yes	Yes	
Lake Hume	Albury	Yes	Yes	√
Lake Inverell	Inverell	Yes	Yes	
Lake Ironbark	The Ponds	Yes	Yes	
Lake Jerilderie	Jerilderie	Yes	Yes	?
Lake Jerrabomberra	Queanbeyan	Yes	Yes	
Lake Jindabyne	Jindabyne	Yes	Yes	hydro
Lake Liddell	Liddell	Yes	Yes	power
Lake Lyell	Lithgow	Yes	Yes	power
Lake Mulwala	Mulwala	Yes	Yes	
Lake Parramatta	North Parramatta	Yes	Yes	
Lake Pillans	Lithgow	Yes	Yes	
Lake Talbot	Narrandera	Yes	Yes	
Lake Toolooma	Waterfall	Yes	Yes	
Lake Wallace	Wallerawang	Yes	Yes	
Lake Williams	Nimmitabel	Yes	Yes	
Lake Windamere	Cudgegong	Yes	Yes	√
Lake Woodcroft	Woodcroft	Yes	Yes	
Lake Wyangan	Griffith	Yes	Yes	
Longneck Lagoon	Pitt Town	Yes	Yes	
Lostock Dam	Lostock	Yes	Yes	√
Malpas Dam	Black Mountain	Yes	Yes	√
Manly Dam	Manly Vale	Yes	Yes	
Mannus Lake	Tumbarumba	Yes	Yes	
Mirambeena Regional Park Lake	Lansdowne	Yes	Yes	
Moulamein Dam	Moulamein	Yes	Yes	
Narrabri Lake	Narrabri	Yes	Yes	
Newey Dam	Cobar	Yes	Yes	
Newland Reserve Lake	Milperra	Yes	Yes	
Oberon Dam	Oberon	Yes	Yes	√
Old Portland Water Supply Dam	Portland	Yes	Yes	
Paddys Dam	Tumberumba	Yes	Yes	
Pejar Dam	Pejar	Yes	Yes	√
Penrith Lakes	Cranebrook	Yes	Yes	
Pindari Dam	Ashford	Yes	Yes	√
Poon Boon Lakes	Stony Crossing	Yes	Yes	
Porters Creek Dam	Porters Creek	Yes	Yes	√
Pourmalong Creek Dam	Morisset	Yes	Yes	
Prospect Reservoir	Prospect	Yes	Yes	√

Quipolly Dam	Quirindi	Yes	Yes	√
Redground Dam	Crookwell	Yes	Yes	?
Rylstone Dam	Rylstone	Yes	Yes	√
Sheeba Dams	Nundle	Yes	Yes	
Split Rock Dam	Upper Manilla	Yes	Yes	√
St Philips Wetlands	Salamander Bay	Yes	Yes	
Talbingo Dam	Talbingo	Yes	Yes	hydro
Tallowa Dam (Lake Yarrunga)	Kangaroo Valley	Yes	Yes	√
Telarah Lagoon	Telarah	Yes	Yes	
The Ponds Lake	The Ponds	Yes	Yes	
Thegoa Lagoon	Wentworth	Yes	Yes	
Thirlmere Lakes	Thirlmere	Yes	Yes	
Thompsons Creek Dam	Portland	Yes	Yes	Power
Thornton Estate Dam	Thornton	Yes	Yes	
Three Mile Dam	Cabramurra	Yes	Yes	
Tod Kill Park Dam	Crookwell	Yes	Yes	
Tooma Dam	Jagumba	Yes	Yes	Hydro
Toonumbar Dam	Ghinni Ghi	Yes	Yes	√
Tumut Pond Dam	Cabramurra	Yes	Yes	Hydro
Urana Town Lake	Urana	Yes	Yes	
Visy Dam	Tumut	Yes	Yes	
Walka Water Works	Oakhampton Heights	Yes	Yes	
Warabrook Wetlands	Warabrook	Yes	Yes	
Welby Dam 1	Welby	Yes	Yes	
Welby Dam 2	Welby	Yes	Yes	
Wentworth Falls Lake	Wentworth Falls	Yes	Yes	
Wentworth Golf Club Dam	Orange	Yes	Yes	
Werrington Lake	Werrington	Yes	Yes	
West Wyalong Wetland	West Wyalong	Yes	Yes	
Wollundry Lagoon	Wagga Wagga	Yes	Yes	
Wyangala Dam	Wyangala	Yes	Yes	√
Yanco Lagoon	Yanco	Yes	Yes	
Yass Main Weir	Yass	Yes	Yes	√
Yass Railway Weir	Yass	Yes	Yes	

Table A2: Restricted Access dams, stocked.

SITE	**NEAR_TOWN**			**Water supply**
Bamarang Dam	Nowra	Yes	No	√
Centennial Park	Queens Park	Yes	No	

Diggers Creek Dam	Perisher Valley	Yes	No	
Grahamstown Reservoir	Medowie	Yes	No	√
Greek Church Dam	Bateman's Bay	Yes	No	
Medway Dam	Evandale	Yes	No	√
Mill Pond	Wollombi	Yes	No	
Mount Penang Gardens	Kariong	Yes	No	
Pipers Flat Dam	Portland	Yes	No	
Porters Creek Dam	Milton	Yes	No	√
Portland Dam No. 3	Portland	Yes	No	
Sydney Airport Ponds 1-3	Botany	Yes	No	
Tenterfield Dam	Tenterfield	Yes	No	√

Table A3: No access, not stocked

SITE	**NEAR_TOWN**			
Avon Dam	Avon	No	No	√
Cambewarra Dam	Cambewarra	No	No	?
Cataract Dam*	Appin	No	No	√
Cochrane Dam	Bemboka	No	No	hydro
Cordeaux Dam	Wilton	No	No	√
Deep Creek Dam	Bateman's Bay	No	No	√
Dungowan Dam	Dungowan	No	No	√
Karangi Dam	Karangi	No	No	√
Lake Nepean	Yerrinbool	No	No	√
Macnamara Swamp Creek Dam	Jennings	No	No	?
Mangrove Creek Dam	Bucketty	No	No	√
Puddledock Dam	Guyra	No	No	?
Shannon Creek Dam	Coutts Crossing	No	No	√
Steuart McIntyre Dam	Kempsey	No	No	√
Umberumberka Dam	Silverton	No	No	√
Warragamba Dam	Warragamba	No	No	√
Wingecarribee Reservoir	Mossvale	No	No	√
Yellow Pinch Dam	Wolumla	No	No	√
Woronora Dam				√

- not officially stocked but known to contain non-endemic native species.

Appendix 2 Key Pollutants and PSAT

(SOURCE: https://www.waternsw.com.au/water-quality/science/why/pollutants)

KEY POLLUTANTS

The Pollution Source Assessment Tool informs us on where in our drinking water catchments we may need to intervene.

One of the primary objectives of WaterNSW is managing our catchments to keep pollutants from reaching our waterways and water supply. To help us achieve this we conduct ongoing research which incorporates the latest scientific techniques and knowledge.

Some pollutants are of greater risk to water quality than others - in particular pathogens, nitrogen, phosphorus and suspended solids:

- Pathogens, such as Cryptosporidium and Giardia, can cause health concerns for water users and are costly to remove from drinking water
- Nitrogen can lead to the formation of cyanobacteria (blue-green algae) blooms in water bodies
- Phosphorus (like nitrogen) can lead to the formation of cyanobacteria (blue-green algae) blooms
- Suspended solids (fine particles from soil and other sources suspended in the water) can clog up water treatment plants, help transport nitrogen and phosphorus, and reduce the effectiveness of UV treatment and natural sunlight in the removal of pathogens.

To assess the risks associated with these pollutants, we use a geographic information tool known as the Pollution Source Assessment Tool (PSAT). This tool informs us on where in our drinking water catchments we may need to intervene.

WaterNSW also monitors other pollutants - such as pesticides, heavy metals and salt - as part of a comprehensive water quality monitoring program. While these pollutants have not caused significant water quality problems in our storages to date, we need to be able to monitor them so that we can adapt our catchment management activities to respond in the future if necessary.

POLLUTION SOURCE ASSESSMENT TOOL

What is it?

The Pollution Source Assessment Tool (PSAT) is a geographic information system that brings together data on the sources, causes and pathways for pollutants.

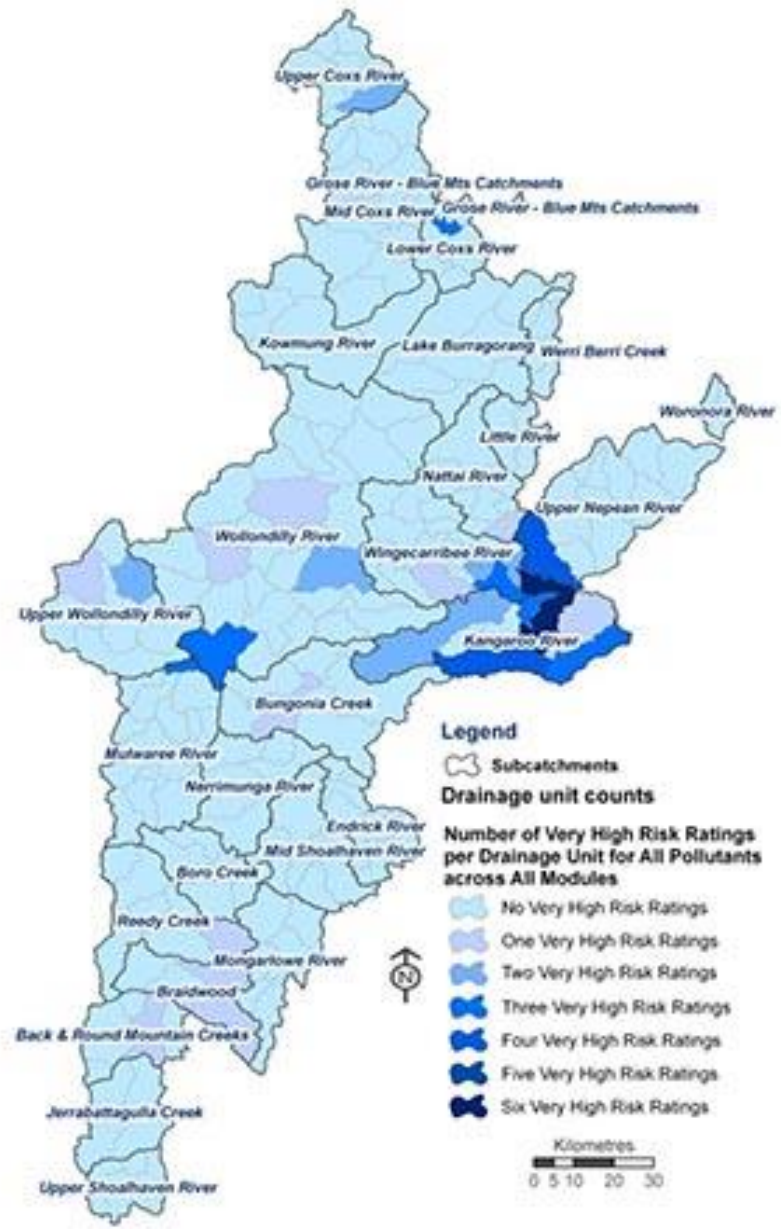
We use PSAT to understand where the high risk pollution sources are in the catchment. This allows us to prioritise our catchment actions to protect water quality.

How is it used?

PSAT is used to pinpoint the most significant potential sources of primary pollutants in our catchments. It aims to:

- improve our knowledge of pollution source risks in the catchments
- increase our confidence in the scientific methods we use to assess the risk of key pollution sources and types
- inform our strategic priorities for catchment management.

PSAT map



Assessing risks using PSAT

PSAT uses technical information, spatial data, modelling, expert knowledge and best management practices to analyse the relative risk of four priority pollutants (nitrogen, phosphorus, pathogens and suspended solids) that may impact on local waterways.

Risks are assessed against 14 land use activities or "modules" which cover most of the significant pollution sources in the catchment:

- Grazing
- Gully erosion
- Horticulture and cropping
- Intensive animal production
- Industry
- Landfills
- Mines and quarries

- Onsite wastewater management systems
- Roads
- Sewage treatment plants
- Sewers and pumping stations
- Streambank erosion
- Urban stormwater
- Forests

What have we learned so far?

The five most significant pollution sources for all priority pollutants are:

- grazing
- intensive animal production
- forests
- urban stormwater
- other urban land uses.