Appendix D

Inland water quality assessment

West Dapto Urban Release Area and Adjacent Growth Areas

WATER QUALITY, AQUATIC ECOLOGY AND PUBLIC HEALTH IMPACT ASSESSMENT

- 12 December 2011

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- 12 December 2011

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Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
Final	6-Dec-2011	T. Church	K. Byrnes	6-Dec-2011	Practice Review
Final (2)	7-Dec-2011	Sydney Water	K. Byrnes	7-Dec-2011	Client Review

Distribution of copies

Revision	Copy no	Quantity	Issued to
Final	Final	1 electronic	Jude Gregory, Sydney Water
Final (2)	Final (2)	1 electronic	Jude Gregory, Sydney Water

Printed:	12 December 2011
Last saved:	12 December 2011 08:17 AM
File name:	I:\ENVR\Projects\EN02927\Deliverables\Reports\Impact Assessment\WDURA Impact Assessment Final 121211.docx
Author:	Kate Byrnes
Project manager:	Kate Byrnes
Name of organisation:	Sydney Water
Name of project:	Water and Wastewater Servicing for the WDURA and AGAs – Water Quality. Aquatic Ecology and Public Health Assessment
Name of document:	Water Quality, Aquatic Ecology and Public Health Impact Assessment
Document version:	FINAL
Project number:	EN02927

1. Introduction

1.1. Objectives

Sinclair Knight Merz (SKM) was engaged by Sydney Water to undertake an assessment of the impact of the Proposal on water quality, aquatic ecology and public health. This assessment is necessary as Sydney Water are preparing an Environmental Assessment to seek concept approval for the entire area and project approval to service early release precincts to 2016. The Proposal refers to the construction and operation of water and wastewater infrastructure required to service the new development in West Dapto Urban Release Area (WDURA) and Adjacent Grown Areas (AGAs) in the Illawarra region.

This assessment will form a technical report to be included and assist in the preparation of the Environment Assessment for project approval under Part 3A of the Environmental Planning and Assessment Act (1997)

The objectives of this technical report are as follows:

- Describe the existing environment.
- Identify the environmental values.
- Consider the Director-General's requirements and how each requirement will be addressed.
- Prioritise direct and uncontrolled overflows using risk ranking.
- Develop and implement mass balance modelling to determine pollutant loads for priority overflows.
- Assess the impacts of the proposal and suggest mitigation measures.

1.2. Report Structure

The structure of this report is as follows:

- **Chapter 1: Introduction** – Provides an overview of the West Dapto Urban Release (WDURA) and Adjacent Growth Areas (AGA) Proposal, details where the DGRs have been addressed and provides a description of the current wastewater system.
- **Chapter 2: Description of the Existing Environment:** Describes the relevant guidelines used for the assessment and provides a description of the existing environment including the current water quality of waterways within the Proposal Area and any water quality issues of concern.

- **Chapter 3: Methodology** –Details the methodology for the risk assessment and mass balance for directed and uncontrolled overflows and the cumulative impact assessment methodology for both overflows and stormwater
- **Chapter 4: Results** – Provides the overall results of the risk assessment and the mass balance for directed and uncontrolled overflows.
- **Chapter 5: Impact Assessment Results** – Details the annual and cumulative pollutant loads from both wastewater and stormwater for a single overflow or a catchment basis.
- **Chapter 6: Analysis and Conclusion** – Details the impacts of the proposal on environmental values (aquatic ecosystems, primary and secondary contact recreation, visual amenity, aquaculture and consumption of aquatic foods) and human health, and provides mitigation measures to manage those impacts.
- **Chapter 7: References.**
- **Chapter 8: Abbreviations and Glossary**.
- **Appendix A: Statutory Framework** – Provides the legislative framework for the project.
- **Appendix B**: **Mass Balance Results** – provide a detailed discussion on the results of the mass balance assessment for high and highest priority overflows.
- **Appendix C: Directed overflow load comparison per event –** Provides a visual comparison of pollutant loads at directed overflows in 2009, 2021 and 2048.
- **Appendix D: Uncontrolled overflow load comparison per event–** Provides a visual comparison of pollutant loads at uncontrolled overflows in 2009, 2021 and 2048.
- **Appendix E: Pollutant Contribution -** Provides a visual comparison of pollutant loads generated from overflows and stormwater in a sub-catchment.

1.3. Director-General's Requirements

The Director-General Requirements (DGRs) and a summary of how and where they are addressed are presented in Table 1-1.

- **Table 1-1 Director-General's Requirements**

Item to be addressed	Requirement	How addressed	Section addressed
Water Quality/ Aquatic Ecology	The Environmental Assessment shall include an assessment of water quality impacts arising from the construction and operation of	By locating overflows and obtaining water quality data, existing water quality conditions can be determined. By applying a risk ranking and developing a mass balance model, the relative scale of	Section 2, 3

Item to be addressed	Requirement	How addressed	Section addressed
	the project taking into account applicable NSW Government policies.	overflow and potential impacts can determined This also addresses DECCW (now OEH) comments that "*the EA should include identification of sensitive downstream waterways that may be impacted by operation of the proposal*"	
Water Quality	Potential impacts to riparian areas should consider the *Riparian Corridor Management Study* (DIPNR 2004)	The operation of the proposal including wastewater overflows will not impact on the riparian corridor.	Section 2
Water Quality	Details on the impacts and management of wastewater and infrastructure must be addressed, including: - frequency and volume of overflow for dry and wet weather and pollutant load - location of infrastructure within riparian areas including reference to the *Riparian Corridor Management Study* (DIPNR 2004) - identification of wet weather effluent storage requirements	Using hydraulic modelling information, a risk assessment was undertaken to determine the overflows with the greatest potential to impact on water quality, aquatic ecosystems and public health due to their increased in frequency and volume of discharge and their location. These overflows were then subjected to a mass balance and cumulative load assessment to determine pollutant loads per event and annual and pollutant concentrations at the discharge location. Wet weather effluent storage requirements may be identified for mitigation based on the results of the impact assessment. This also addresses DECCW (now OEH) comments that "*the EA will need to assess the potential impact of the proposal against the relevant environmental aquatic values of each discharge location. DECCW considers that the potential impact of the proposal on nutrient levels in the Illawarra catchments should be a key element of the assessment",*	Section 3, 4 and 5
Water Quality	Measures to prevent or minimise sewage discharges or overflows and subsequent impacts to nearby watercourses, groundwater and water bodies shall be addressed	The risk ranking and mass balance modelling will identify overflows that may impact on waterways and describe the likely impacts. This will enable recommendation on design or operational features that could be applied to reduce overflows and/or impacts to nearby watercourses. This also addresses DECCW (OEH) comments that "*the proposal should also avoid direct discharge impacts on ecologically significant areas and sensitive ecosystems",*	Section 3, 4 and 5
Human Health	The Environmental Assessment should address	By applying both the approach and recommended guidelines documented in the	Section 3

Item to be addressed	Requirement	How addressed	Section addressed
	the human health impacts arising from the waste water infrastructure and processes including effluent disposal. The assessment should be undertaken in accordance with the *Guidelines for Managing Risks in Recreational Water* (NHMRC 2008)	NHMRC (2008) *Guidelines for Managing Risks in Recreational Waters* in our methodology.	

1.4. Background

The West Dapto Urban Release Area (WDURA) and Adjacent Growth Areas (AGA), referred to hereafter as 'the Proposal' is a key site for residential development up to the year 2048, with a projected growth equivalent to 35,000 lots. The area is generally bounded by Farmborough Heights in the north, Tullimbar Village in the south, Lake Illawarra to the east and the Illawarra Escarpment to the west (Sydney Water 2009). As part of the development of the Proposal, Sydney Water is responsible for the provision of drinking water and wastewater services, and has developed a preferred strategy to deliver these services. The key components of the wastewater infrastructure upgrade to service the Proposal would include:

- New trunk pipelines for wastewater.
- New pumping stations and upgrades to existing pumping stations.
- Transfer of wastewater flows from the new growth areas to Wollongong Water Recycling Plant or Shellharbour Wastewater Treatment Plant for treatment and either reuse or ocean discharge.
- Potential amplification and / or upgrades to Wollongong Water Recycling Plant and Shellharbour Wastewater Treatment Plant.

The wastewater system and associated wastewater treatment plants (WWTPs) are currently licensed under the *Protection of the Environment and Operations Act 1997.* This Act specifies that no more than 43 and 45 wet weather overflow events can occur in any 10-year period for the Wollongong and Shellharbour Wastewater Systems, respectively, although, the long term target for Wollongong is 40. The future development of the Proposal has been designed to comply with existing Environmental Protection Licences (EPLs) for the Wollongong and Shellharbour Wastewater Systems with respect to overflow frequency. The proposed hydraulic capacity of the system will ensure there are no dry weather overflows under normal operation. Overflows may occur during wet weather. Transfer of flow from the proposed wastewater reticulation system for the Proposal through the existing transfer system will however result in changes to the overflow performance of the system. Wastewater hydraulic modelling has been undertaken to provide a preliminary indication of the wet weather overflow frequency and volumes of both directed and uncontrolled overflows of the Proposal in 2021 and 2048. 2021 being equivalent to the year in which Project Approval area is expected to be fully developed and 2048 being equivalent to the year in which Concept Approval area is to be fully developed. Modelling of overflows directly relates to the existing system, as no overflows are predicted to occur in the new system.

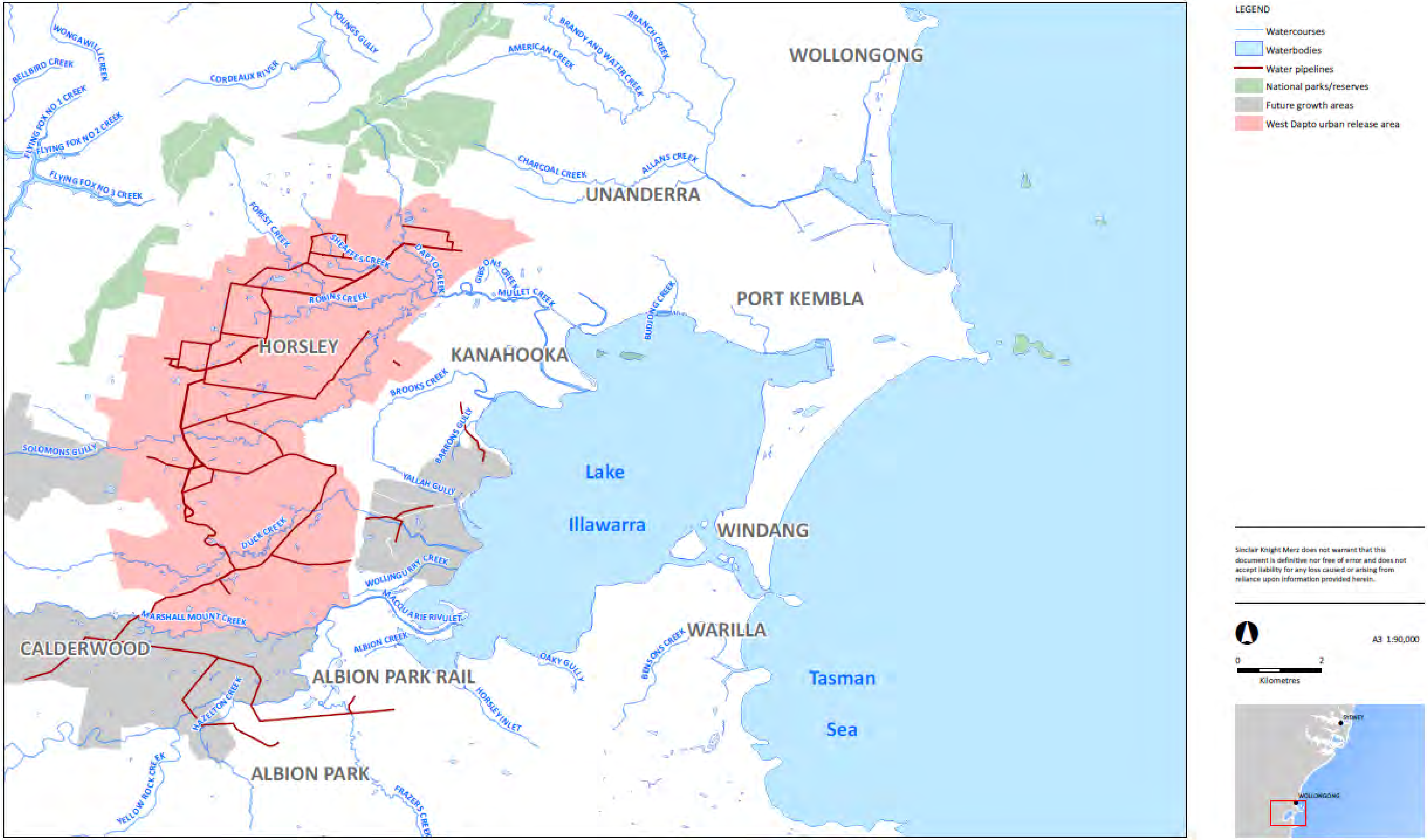


Figure 1-1 West Dapto Urban Release and Future Growth Areas

1.4.1. Existing Wastewater Systems

The existing Illawarra wastewater system is spread across two zones, Wollongong and Shellharbour. The Wollongong zone includes the Bellambi, Port Kembla and Wollongong Wastewater Treatment Plants, however only the latter two are relevant to WDURA.

1.4.2. Port Kembla Wastewater System

The Port Kembla wastewater system services Port Kembla and suburbs of the city of Wollongong located around the northern foreshores of Lake Illawarra from Windang through Pirribee, Warrawong and Berkley to Dapto. The existing systems covers a catchment area of approximately 2,750 ha and services about 48,586 residential populations.

There are 41 directed overflow points in the existing system, the majority of which drain to Lake Illawarra and Port Kembla Harbour, via Brooks Creek, Duck Creek, Mullet Creek, Hooka Creek, Budjong Creek and Minnegang Creek. Wastewater from these structures overflows either directly or via stormwater culverts into these creeks or other tributary waterways.

1.4.3. Wollongong Wastewater System

Wollongong wastewater system is located in the Illawarra region to the south of Sydney. It is a largely residential catchment of approximately 2,775 hectares, and serves for 53,460 residential populations. Industry and commercial activities occupy a small area of the catchment (less than 8%).

The system incorporates the Wollongong Water Recycling Plant (WRP), eleven SPSs and approximately 390 kilometres of wastewater pipelines. Wastewater is transported by the wastewater system to Wollongong WRP for secondary treatment before discharging to the Tasman Sea. There are 35 constructed overflow points in the existing system, the majority of which drain into Allan's Creek and Tom Thumb Lagoon. Wastewater from these structures overflows either into tributary waterways or via stormwater culverts which may discharge to receiving waters.

1.4.4. Shellharbour Wastewater System

The Shellharbour Wastewater System serves the Shellharbour township and suburbs on the southern side of Lake Illawarra from Mount Warrigal and Warilla, extending to Oak Flats and Albion Park. It covers a catchment area of approximately 2,547 ha and serves a population of approximately 64,000. The catchment includes four light industrial zones at Oak Flats, Barrack Heights, Warilla and Albion Park Rail.

The wastewater system incorporates the Shellharbour WWTP, 17 pumping stations, and approximately 465 kilometres of reticulated gravity and rising mains, including 16 major carriers. There are three pumping stations discharging to the wastewater treatment plant off Shellharbour Road where treated wastewater is discharged to the ocean after primary and secondary treatment. There are 36 constructed overflows in the existing system.

1.4.5. Defining an Overflow Event

Overflow events occur throughout wastewater systems. Due to physical pipe blocking, asset failure, excess ingress, spike loading or wet weather events, the capacity of the system is exceeded causing wastewater to escape from the system and travel down alternative flow paths. Systems are designed with overflow structures intended to control the location of overflows in order to reduce the risk to the environment and human health. They are designed to protect public health by preventing wastewater backing up into people's home if a problem occurs in the system.

Largely occurring during wet weather, these overflows usually last for only a short period of time but potentially result in large volumes of discharge. Once released into the stormwater system or natural flow channels the wastewater can impact on the natural environment, potentially causing human health issues or environmental impacts.

Overflow events can occur in wet and dry weather and can be divided into three categories; directed, uncontrolled and uncontrolled system failures.

Directed overflows occur at a location in the system designed to discharge during abnormally large wet weather overflow events (Figure 1-2 (a)). At these locations the network has been designed to channel excess volume into the adjacent stormwater system or through constructed environmental discharge locations. By their very design this makes directed overflows by far the greatest proportion of the above overflow categories.

Uncontrolled overflows on the other hand occur at any location along the system during abnormally large wet weather events. At these locations excess flow or system degradation means that the designed grade of the gravity system can no longer support the required flow volume. This causes the wastewater to collect in the system, until it reaches the surface where discharge occurs (Figure 1-2 (b)). These discharges are typically surface flows which travel via the ground contours and possibly into nearby creeks or stormwater systems.

Finally uncontrolled system failures normally occur when the pipe system chokes, typically from pipe collapse or root intrusion. This results in an uncontrolled overflow until the system is repaired. These events are largely random, normally occur in dry weather and are seen as a maintenance issue and not an operational issue. Therefore, they are not included in overflow modelling or in this report.

Increased development or additional flows entering a catchment often results in an increased number of overflows, which may lead to a licence breach. Whilst a wet weather event may result in overflows at multiple locations, from a licence perspective, this is referred to as a single event. As a result when additional loading is predicted into an existing system, modelling is carried out to assess the potential impact to the system and to determine where overflows might occur. This modelling can then be used to confirm licence compliance and determine where renewal work should be undertaken to reduce, or better control, critical discharge locations.

(a)  (b) 

- **Figure 1-2 Example of Directed Overflow (a) and Uncontrolled Overflow (b)**

1.4.6. Directed and Uncontrolled Overflow Points

There are a total of 49 directed and 621 uncontrolled overflows in the Proposal area, which all fall within the existing Port Kembla, Wollongong and Shellharbour Wastewater systems. A breakdown of these is provided in Table 1-2 and their location is provided in Figure 1-3. It should be noted that there are no directed or uncontrolled overflows in the new infrastructure associated with the Proposal.

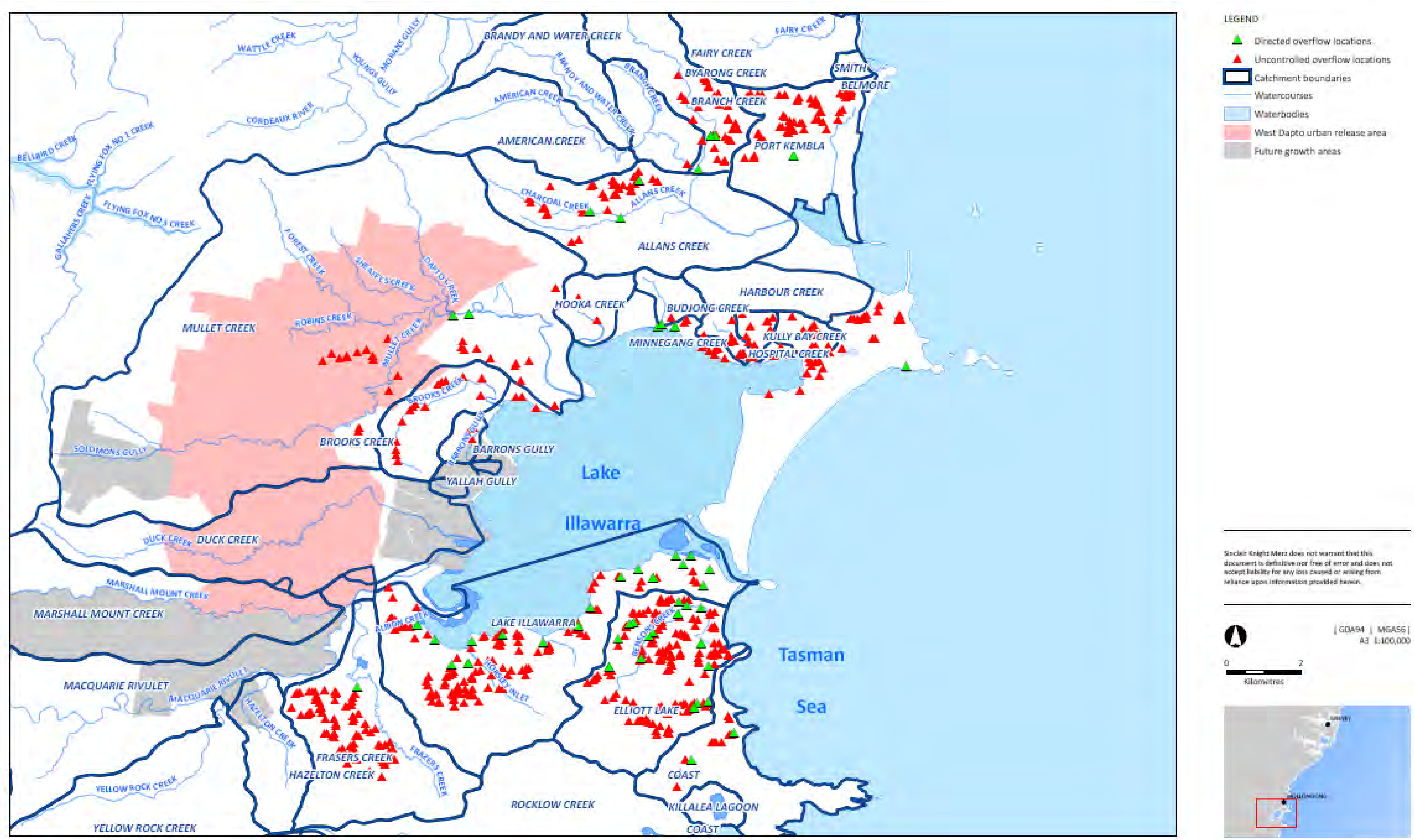
- **Table 1-2 Directed and Uncontrolled Overflow Points in WDURA and AGAs**

System	No. Directed Overflows	No. Uncontrolled Overflows
Port Kembla	6	132

System	No. Directed Overflows	No. Uncontrolled Overflows
Wollongong	7	130
Shellharbour	36	359
Total	49	621

1.4.7. Assessing Overflow Events

Unfortunately, selecting which overflows to manage is not simply a process of selecting the location where the most frequent or greatest discharge volumes occur per event. As overflows can occur throughout a catchment, no two overflows can simply be compared, based on the combined frequency or volume. Instead an integrated assessment approach must be applied, assessing the location's impact based on its potential to impact the surrounding environment or public health. This assessment when done in conjunction with the combined volume and frequency then provides a base line ranking of the potential impacts of a specific overflow relative to environmental and human health considerations.



■ **Figure 1-3 Directed and uncontrolled overflow locations**

2. Description of the Existing Environment

The following sections provide a description of the existing environment for catchments and sub-catchments and the water quality in the Proposal area. Where water quality data was available, this data were analysed and the results compared with relevant guidelines. Monitoring sites where data were interpreted are provided in Figure 2-1.

■ **Figure 2-1 Water quality monitoring sites**

2.1.1. Summary of Environmental Values

Environmental values are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit or health. They are values that require protection from the effects of pollution and waste discharges (ANZECC/ARMCANZ 2000). The Office of Environment and Heritage (OEH) have nominated a number of environmental values for the Illawarra Catchment and relevant indicators and guideline levels which are used in protecting the environmental value.

There are a number of recognised environmental values and for the purposes of this study the relevant ones are:

- Aquatic ecosystems.
- Primary and secondary contact recreation.
- Visual amenity.

These environmental values are discussed below.

2.1.1.1. Aquatic Ecosystems

Aquatic ecosystems can range from freshwater to marine and comprise the animals, plants and micro-organisms that live in water and the physical and chemical environment in which they interact. Aquatic ecosystems have been impacted upon by multiple pressures including changes in flow regime, modification or destruction of key habitats, development and poor water quality. There are number of naturally occurring physical and chemical stressors that can cause degradation of aquatic ecosystems and for the purposes of this assessment and the impact that wastewater overflows will have on aquatic ecosystems, our discussion focuses on turbidity (total suspended solids), total nitrogen, and total phosphorus.

Nutrients in aquatic environments promote the growth of algae and increase turbidity which in turn reduces light and may affect plant growth. Generally excessive nutrient inputs lead to excessive algal growth and formation of nuisance blooms. Nutrients consist of nitrogen (including total nitrogen (TN), ammonia, oxidised nitrogen (NOx)) and phosphorus (including total phosphorus (TP) and filterable reactive phosphorus (FRP)).

- **Total nitrogen**: a measure of all the nitrogen species found in a water body including ammonia, oxidised nitrogen and total organic nitrogen.
- **Ammonia**: represents the most reduced form of inorganic nitrogen available, and is preferentially utilised by plants and aquatic micro-organisms. The main sources of

ammonia in aquatic ecosystems are found to be from human and animal wastes and also by release during the decomposition of organic material by bacteria.

- **Oxidised nitrogen**: represents the level of free nitrogen within the water column that is immediately available to plants. Similarly to other nitrogen species, excessive concentrations can promote algal growth.
- **Total phosphorus**: a measure of both biologically available and unavailable species. The biologically available species is known as Filterable Reactive Phosphorus. There are two forms of dissolved phosphorus in the water body, organic phosphorus produced from the decay of plant and animal material and inorganic orthophosphates which is released through the breakdown of rock and then transported into the waterbody.
- **Filterable reactive phosphorus**: a measure of orthophosphates, which represents the component of TP which is readily available biologically. FRP concentrations within the waterbody can be influenced by variations in pH, oxygen levels and turbidity.

Total suspended solids (TSS) are a measure of the fine particles suspended in water. It is important to aquatic ecosystems as high concentrations of sediment can reduce the light available for aquatic organisms and in some cases smother the stream bed. The fine particles that comprise of total suspended solids carry nutrients, especially phosphorus, metals and other pollutants from a variety of sources, such as agricultural and residential runoff, leaching of soil contamination and point source water pollution discharges from industrial or wastewater treatment plants.

There are a number of impacts that both increased suspended solids and nutrients can have on aquatic ecosystems. Increases in total suspended solids can:

- reduce light penetration in the waterbody which can result in reduced primary production and impact on fish
- result in deleterious effects on phytoplankton, macrophytes and seagrass
- reduce water clarity which can impact on fish and aquatic plants
- increase sediments which can result in gill clogging
- smother benthic organisms and their habitats.

Increases in total nitrogen and phosphorus can alter the trophic status of a waterbody, making it more susceptible to eutrophication. Eutrophication generally promotes the excessive growth of algae and undesirable aquatic plants, micro-organisms and invertebrates (eg mosquitoes) and a reduction in water quality. The excessive growth can lead to a number of problems including:

- Reduction in dissolved oxygen concentrations when the plants die and are decomposed
- Change in biodiversity

- Toxic effects of cyanobacteria on aquatic organisms.

2.1.1.2. Primary and Secondary Contact Recreation

Recreational activities in and around water are highly valued by the community in the study area, and therefore protection of water quality for recreational use is necessary. There are two main categories of recreational water use - ‘primary’ and ‘secondary’ contact. Primary contact recreation denotes direct water contact via bodily immersion or submersion with a high potential for ingestion. It includes activities such as swimming, diving and water skiing. Secondary contact recreation denotes some direct contact with water but where ingestion is unlikely and includes activities such as boating, fishing and wading.

Pathogens are the main constituent of wastewater that are likely to impact on the recreational use of local waterways. Pathogens found in both human and animal faeces can increase the risk to public health if there are significant numbers in the overflow. As it is not feasible to monitor pathogenic organisms routinely, indicator organisms including faecal coliforms and enterococci are often used as bacteriological indicators of contamination of water. Bacteriological indicators are used to assess the suitability of water for recreation as they detect faecal contamination of water and hence the likely presence of pathogenic organisms (NHMRC 2008).

Wastewater overflows carry pathogens and other contaminants which potentially pose a risk to human health, particularly recreational users of a waterway. These risks depend on the level and duration of exposure to pathogens and/or contaminants in the overflows. Exposure to pathogens is principally through swimming (primary contact) and boating (secondary contact). Common ailments associated with recreation activities in contaminated water include eye, ear, nose and throat infections, skin diseases and gastrointestinal disorders. These risks can be mitigated by avoiding bodily contact with the waterway after heavy rainfall events, and through personal awareness of local conditions.

Excessive macrophyte and algal growth (due to increased nutrients) can impact on the recreational amenity of a waterbody by reducing clarity, algal blooms and through the accumulation of wrack along shorelines. Some species of cyanobacteria produce toxins and where direct contact is made can cause skin irritations, dermatitis and in extreme cases, liver disease. Should algal blooms occur, primary and secondary contact is not recommended.

2.1.1.3. Visual Amenity

The aesthetic appearance of a waterbody is important for passive and active recreation. As such the water should be free from obvious pollution including floating debris, oil, scum and other matter. Substances producing objectionable colour, odour, taste or turbidity and substances and conditions that produce undesirable aquatic life should not be apparent (NHMRC 2008). The aesthetic quality of a waterway will be compromised if increases of key indicators result in fish deaths, anaerobic conditions, excessive plant growth and visible algal blooms. Aesthetic quality has been identified as an environmental value for Lake Illawarra (DECCW 2006).

2.1.2. Lake Illawarra Catchment

Lake Illawarra in the south of the study area covers approximately 35km^2 and is connected to the ocean by a shallow channel approximately 3.7km long. The channel has limited flow capacity and prior to 2007 was periodically closed to the ocean. Whilst the average water level in the lake is 0.3m AHD, water levels may rise by 1.5m during storm and flood events (WCC 2006).

Flooding can occur in the catchment, particularly as water flows over very steep topography generally caused by periodic rainfall in the region and a high level of impervious surfaces reducing infiltration. Some of the creeks also have limited discharge capacity, carrying approximately 20% of peak flood flows (WCC 2006).

Lake Illawarra is a shallow saline lagoon, a Nationally Important Wetland (NSW081) and is listed under the Coastal Wetlands SEPP and Schedule 1 of the Coastal Protection SEPP for protection of conservation values (AWD, 2010). It has been defined by the Healthy Rivers Commission (2002) as a system with high sensitivity, a high conversation value and in need of targeted repair. Lake Illawarra is an important environmental, recreational and commercial resource providing habitat for seagrass, saltmarshes and natural wetlands. Water quality in the lake is generally influenced by climatic factors and is prone to algal blooms due to catchment runoff and sedimentation which increase nutrient levels and subsequently algal activity. Photosynthetic activity in the lake is also reduced due to increased sediment and turbidity (PBMHW 2009).

SEPP 14 wetlands within Lake Illawarra include 383, 380, 381 (a & b), 377, 379 and 378 which are located near the outflow of Marshall Mount Creek, Duck Creek and Bevans Island.

The entrance of Lake Illawarra has historically fluctuated between being open and closed however; in July 2007 the Lake Illawarra Authority completed the construction of twin breakwaters and major channel dredging to keep the lake predominantly open to increase tidal flushing. Lake Illawarra acts as an early-intermediate barrier estuary with its entrance to the ocean being a weakly active fluvial delta system. The entrance channel is constantly changing by shifting aeolian sands and a high energy berm and beachfront (Chaffer, 1991).

The catchment area for Lake Illawarra is 270 km^2 of which the lake surface area is 35 km^2. The greatest depth of Lake Illawarra seldom exceeds 4m, and about 10% of the lake is less than 1m in depth (Chaffer, 1991). Land uses within the Lake Illawarra catchment influence the water quality of the Lake, particularly nutrient loading. These land uses have recently changed from predominantly rural to urban, particularly in West Dapto, resulting in the clearing of vegetation and changes to hydrology such as increased stormwater discharge of poorer water quality (LIA 2010).

Lake Illawarra is made up of a number of sub-catchments, including Macquarie Rivulet and Mullet Creek which discharge into Lake Illawarra and act as major drainage paths for stormwater across the catchment (LIA 2010). These sub-catchments are provided in Table 2-1, however it is only the sub-catchments Macquarie Rivulet, Mullet Creek, Horsley and Connor Creek and Brooks Creek that have the potential to be impacted by the Proposal as these are the only ones which have directed and/or uncontrolled overflows. Many of the tributaries in these sub-catchments are small and perennial, highly degraded with altered hydrology and geomorphology which during heavy rain often experience intense flooding of short duration. The water quality of the creeks is generally poor due to urban, industrial and agricultural development combined with poor tidal flushing.

Lake Illawarra is known to suffer from algal blooms, particularly when nutrient loads and light availability are conducive to growth. Both micro-algal blooms and macro-algal blooms occur in the lake (LIA 2010).

The shallow nature and saline conditions of Lake Illawarra provide ideal conditions for seagrass including *Zostera sp.* and *Ruppia sp* (West *et al.* 1985). These seagrass are an important food and habitat resource, including the provision of food for waterfowl. A total of 24 species of waterbirds have been recorded on Lake Illawarra (Breen *et al*. 2005).

Whilst no nationally threatened or endangered aquatic species have been recorded within Lake Illawarra, several nationally endangered terrestrial species have been recorded including the Rainforest Vine *Cynanchum elegan,* Rice Flower *Pimelea spicata,* the Little Tern (*Sterna albifrons),* and the Regent Honeyeater (*Xanthomyza Phrygia*). Lake Illawarra also provides habitat for a large number of vulnerable bird species.

Table 2-1 Sub-catchments of Lake Illawarra (LIA 2000)

Catchment	Area (km^2)	Wastewater System Overflows^
Macquarie Rivulet	109.0*	✓
Mullet Creek (includes Robins Creek and Dapto Creek)	7448.0*	✓
Brooks Creek	5.0*	
Duck Creek	9.0*	
Horsley Creek	9.0*	✓
Lake Heights (north end of lake, includes Hooka, Budjong, Minnegang Ck and 4 other drainage areas)	6.0*	
Mount Warrigal	7.0*	
Windang	5.0*	

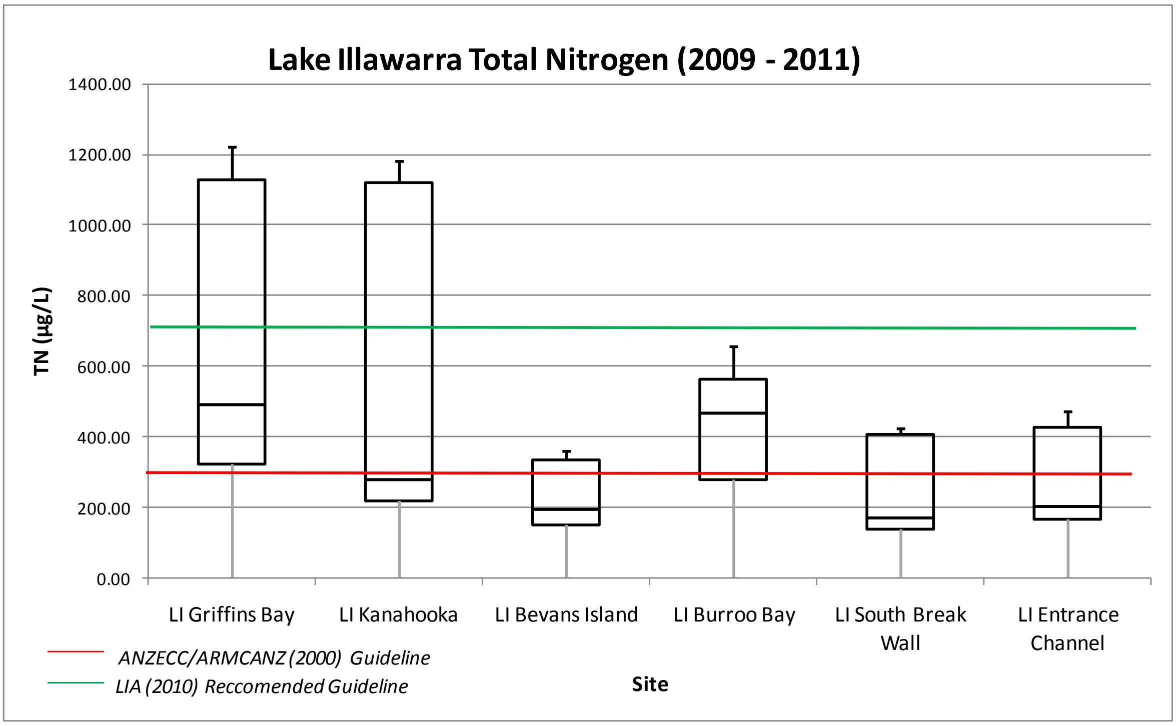
* Source: LIA (2000)
^ locations/catchments potentially impacted by the Proposal where overflows may occur in large wet weather events

2.1.2.1. Lake Illawarra Water Quality

Monthly water quality data collected between May 2009 and January 2011 for six locations (Figure 2-1) within Lake Illawarra was provided by the Lake Illawarra Authority (LIA). Summary statistics and box plots (Figure 2-5 and Figure 2-7) of key indicators were prepared, however sample numbers vary as not all indicators were sampled monthly.

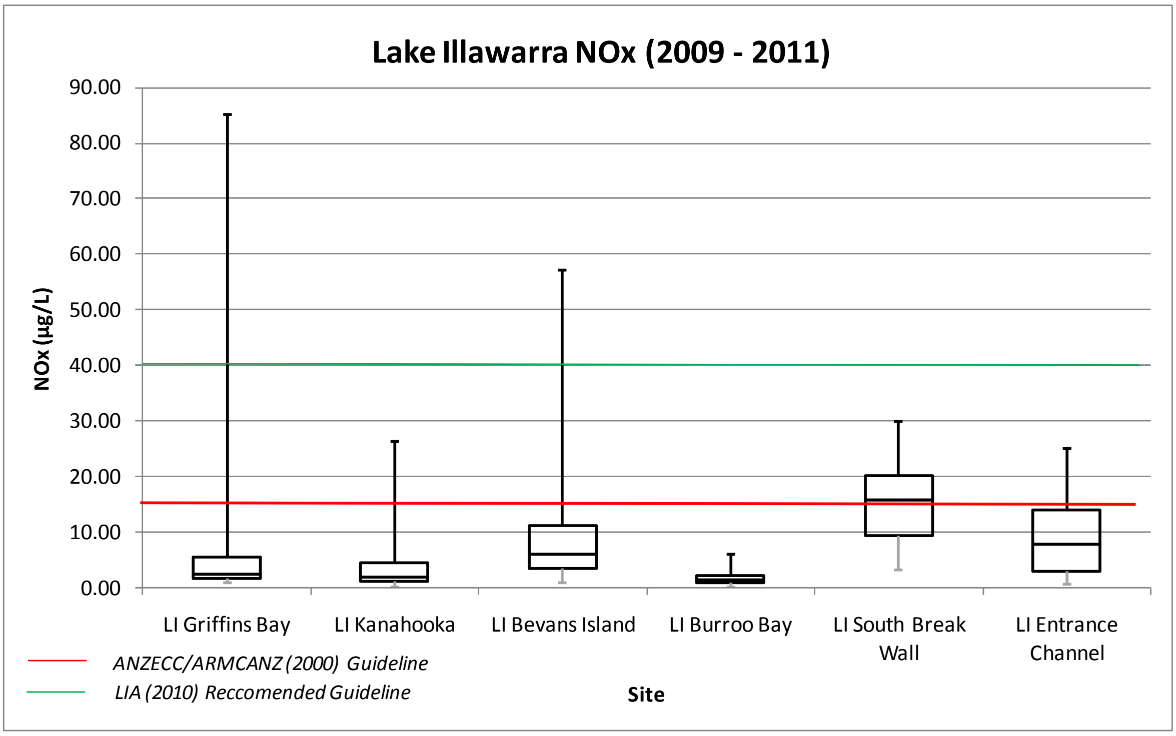
Lake Illawarra is an estuarine waterbody, as such water quality will be discussed in accordance with the ANZECC/ARMCANZ (2000) guidelines for protection of estuarine aquatic ecosystems and specific trigger values developed by the LIA and presented in Appendix A. These trigger values were derived using the 80th percentile.

Median total nitrogen (TN) concentrations were the highest at Griffins Bay (403µg/L) and Burroo Bay (374µg/L) exceeding the estuarine ANZECC/ARMCANZ (2000) guideline of 300µg/L (Figure 2-2), whilst all other sites complied. When comparing TN concentrations against the LIA developed trigger value of 720µg/L all sites complied. Total nitrogen varies throughout the lake, with greatest concentrations and variability recorded at Griffins Bay and Kanahooka. Total nitrogen varies seasonally with higher concentrations recorded during the summer to autumn period when rainfall is at its highest (LIA 2010). Sources of nitrogen include fertilisers, wastewater flows and decaying matter. Nitrogen in the lake has been reported as limiting, and increased in concentration may lead to algal blooms and changes in species and community compositions (LIA 2010).



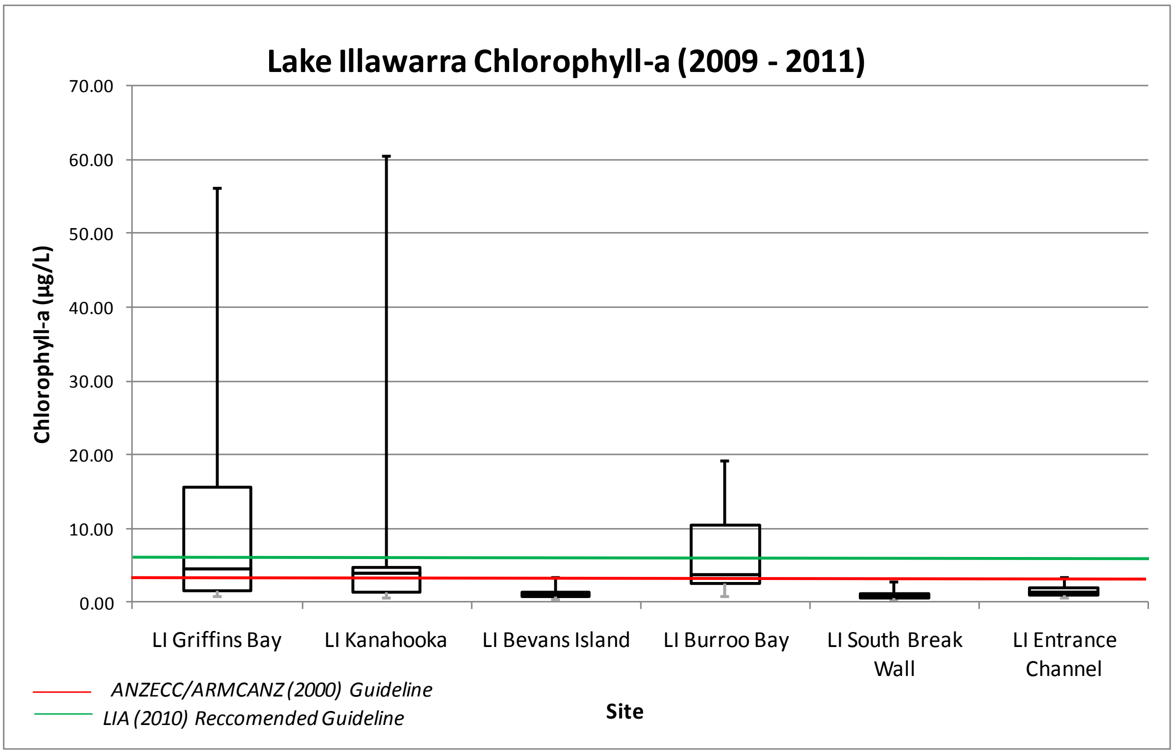
■ **Figure 2-2 Total Nitrogen (LIA 2009 – 2011)**

Median oxidised nitrogen (NO_x) concentrations in Lake Illawarra are generally good and within the LIA (2010) recommended trigger value of 40µg/L throughout Lake Illawarra. Median NO_x concentrations also complied with the ANZECC/AMRCANZ (2000) guidelines, with the exception of South Break Wall which exceeded the recommended trigger value for protection of aquatic ecosystems on 55% of sampling occasions (median 15.65µg/L) (Figure 2-3).



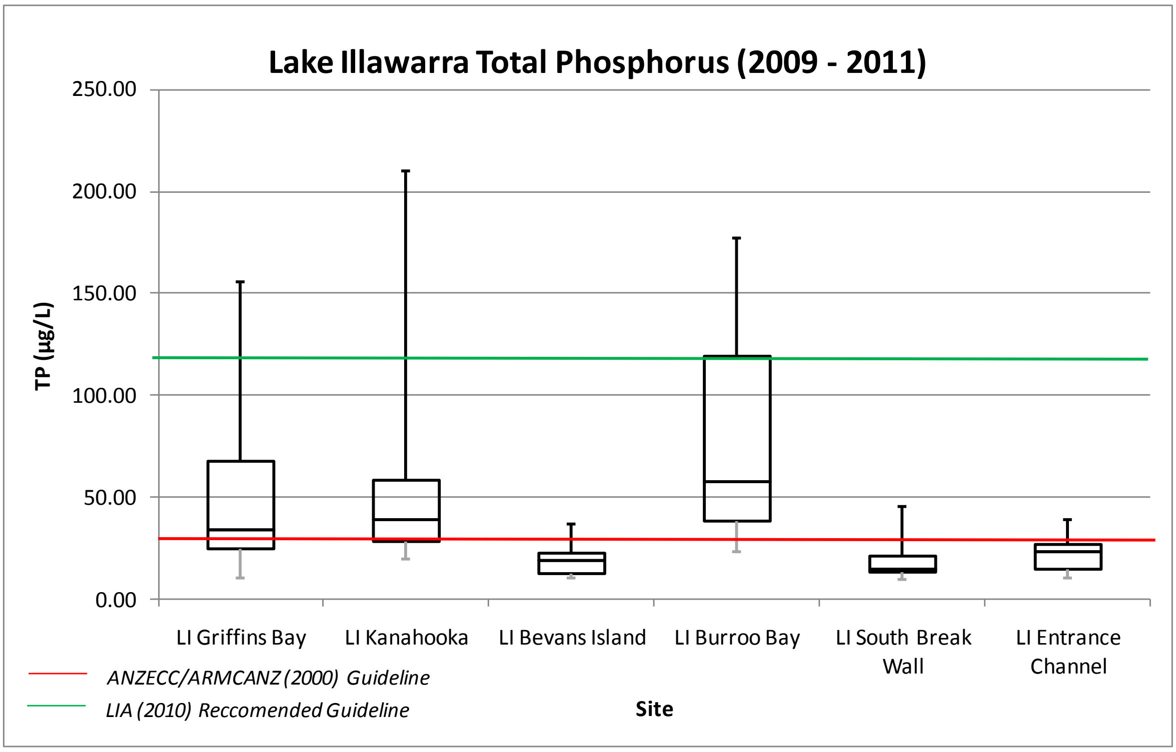
- **Figure 2-3 NOx (LIA 2009 – 2011)**

Median chlorophyll-*a* concentrations (Figure 2-4) were generally good throughout Lake Illawarra with all sites meeting the LIA (2010) trigger value of 7.01 µg/L and the ANZECC/ARMCANZ (2000) trigger value of and 4 µg/L with the exception of Griffins Bay (median = 4.6 µg/L) which only complied with the LIA trigger value. Similarly to total nitrogen, chlorophyll-*a* concentrations notably varied at Griffins Bay and Kanahooka ranging between 0.5µg/L to 60.5µg/L.



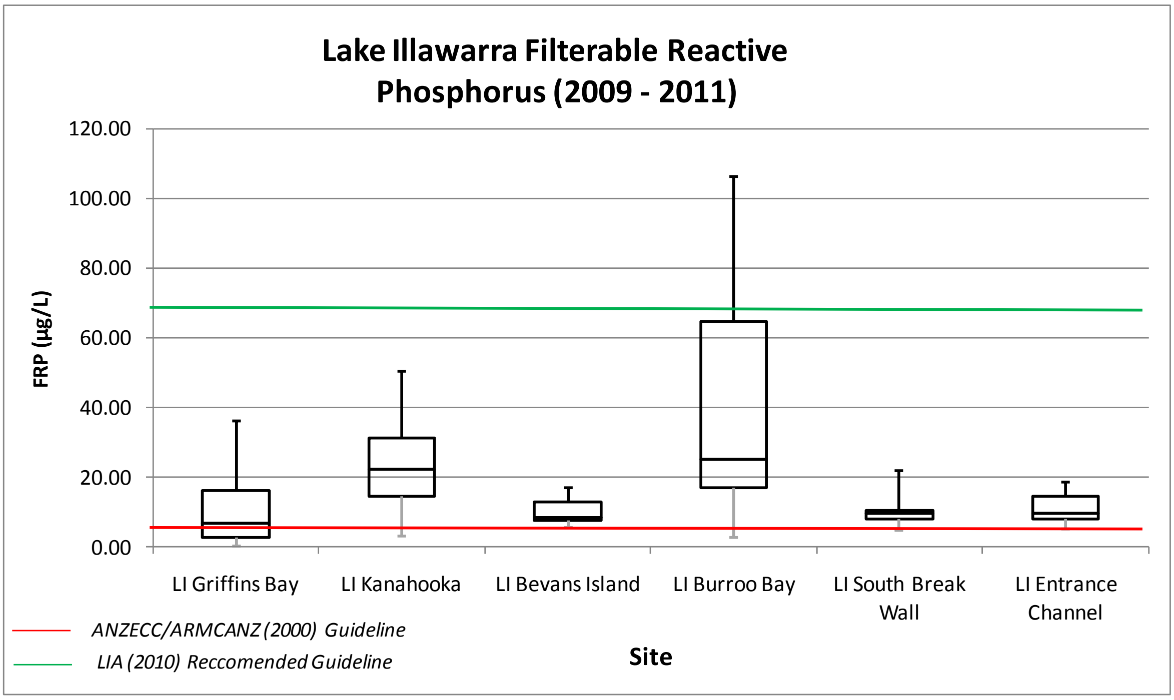
- **Figure 2-4 Chlorophyll-a (LIA 2009- 2011)**

Total phosphorus (TP) concentrations are particularly high in Lake Illawarra due to weathering of the basaltic geology underlying the lake (LIA 2010). Median TP concentrations at Griffins Bay (33.95µg/L), Kanahooka (39.85µg/L), and Burroo Bay (57.75µg/L) exceed the ANZECC/ARMCANZ (2000) guideline of 30µg/L however all sites are within the LIA (2010) recommended trigger value of 120µg/L (Figure 2-5). Griffins Bay, Kanahooka and Burroo Bay also exhibit the greatest variation in concentrations. Similarly to total nitrogen, TP varies seasonally suggesting that TP loading within Lake Illawarra may be largely directed by catchment inputs (LIA 2010).



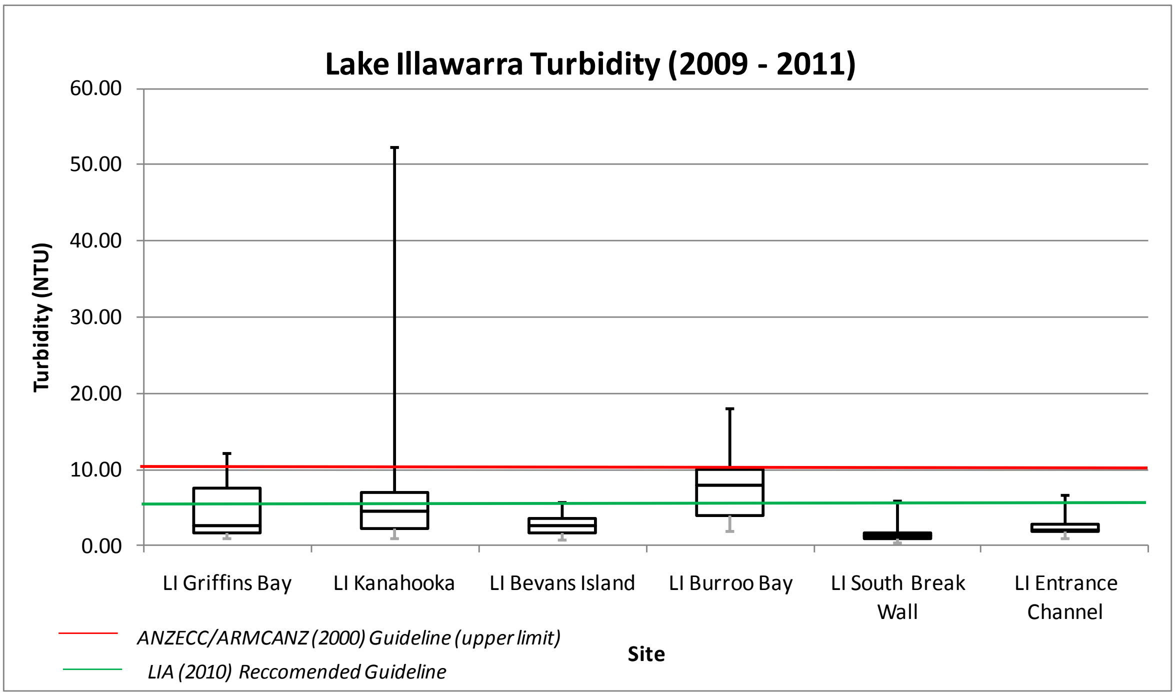
■ **Figure 2-5 Total Phosphorus (LIA 2009-2011)**

High concentrations of filterable reactive phosphorus (FRP) were observed throughout Lake Illawarra, with median FRP concentrations exceeding the ANZECC/ARMCANZ (2000) guideline (5µg/L) at each site (Figure 2-6). LIA have developed a trigger value of 68µg/L, which median concentrations of all sites complied with. Similarly to TP, median FRP concentrations were the highest at Burroo Bay (25.35µg/L) which also exhibited the greatest within site variation.



▪ **Figure 2-6 Filterable Reactive Phosphorus (LIA 2009 -2011)**

Median turbidity was within ANZECC/ARMCANZ (2000) guidelines of 0.5 to 10NTU at all Lake Illawarra monitoring sites (Figure 2-7). Burroo Bay had the highest median turbidity (7.96 NTU), exceeding the LIA (2010) recommended guideline of <6.11 NTU.



- **Figure 2-7 Turbidity (LIA 2009 -2011)**

2.1.3. Barrack Creek Catchment

The Barrack Creek system is located in south-eastern corner of Lake Illawarra. The catchment is approximately 12.26 km^2 and consists of a number of modified channels, eventually flowing into a small estuary, Little Lake (also known as Elliot Lake). Little Lake discharges to the ocean at Warilla Beach. Little Lake is used for both primary (swimming) and secondary contact recreational purposes (SCC, 2003).

The catchment contains two major creeks, Barrack Creek and Bensons Creek (also known as Tongarra Creek). Land use in the system is predominantly residential except for a small area of remnant Blackbutt forest to the west, and small pockets of commercial and light industrial activities (Sydney Water 2003). Barrack Swamp is a freshwater wetland located adjacent to the existing Shellharbour WWTP, however it is not listed as a wetland under SEPP 14. No water quality data has been obtained for Barrack Swamp. Limited water quality data is available for the Barrack Creek catchment, however data at Tongarra Creek suggests water quality in this catchment is generally good.

Bensons Creek (also known as Tongarra Creek)

Water quality data for Tongarra/Bensons Creek was obtained from Shellharbour City Council with monthly data collected between April 2001 and January 2003. The exact location of the site is not known, however the creek is classified as a lowland river due to an altitude of <150m and as such will be assessed in accordance with the ANZECC/ARMCANZ (2000) and DECCW (2006) guidelines for protection of lowland aquatic ecosystems.

Overall water quality in Tongarra Creek is good, with all indicators complying with the ANZECC/ARMCANZ (2000) guidelines for the protection of lowland aquatic ecosystems.

- **Table 2-2 Tongarra/ Bensons Creek (Shellharbour City Council 2001-2009)**

Tongarra / Bensons Creek	TN (µg/L)	TP (µg/L)	DO (mg/L)	pH	Turbidity (NTU)
Guideline	350	25	>6	6.5-8.5	6-50
Sample size	6	6	19	19	19
Median	250	25	10.4	7.25	0.3
75%tile	415	43	11.2	7.445	1.55
Max	560	56	13.2	8.47	30.6
Min	20	2	2.5	6.64	0
25%tile	55	14.5	9.45	6.885	0.05

2.1.4. Horsley Creek and Connor Creek Catchment

The Horsley and Conner Creek catchment is small with an area of 9km^2 (O'Donnell *et al*, 2004). The system consists of only two named watercourses – Horsley Creek and Connor Creek, which drain into south-western corner of Lake Illawarra. No water quality data has been located for the Horsley & Connor Creek Catchment.

2.1.5. Mullet Creek Catchment

Mullet Creek is a major tributary of Lake Illawarra covering a catchment area of 8404ha. Approximately 57.6% of the catchment area is urban, industrial or rural land (Forbes Rigby 2000). Major tributaries of Mullet Creek include Robin's Creek, Forest Creek, Dapto Creek and Reed Creek.

Mullet Creek, a largely undeveloped catchment draining an area of approximately 74km^2 and Brooks Creek an almost fully urbanised catchment draining an area of 5km^2, discharge separately to Lake Illawarra (Bewsher Consulting 2010). The development of the WDURA will predominantly occur in the Mullet Creek catchment.

Mullet Creek rises at the escarpment at an elevation of about 600m AHD and flows for approximately 22km before discharging to Lake Illawarra. This small and steep catchment and propensity for heavy rain and progressive urbanisation, results in frequent flooding, often flash floods with rapid rises and fall. Brooks Creek flows for 5km from an elevation of 120mAHD to Lake Illawarra and both catchments have a long history of flooding (Bewsher Consulting 2010).

The water quality in Mullet Creek catchment is high in TP and TN with median concentrations above the ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems. However, unlike many other catchments in the study area the catchment meets both primary and secondary recreational guidelines for faecal coliforms.

Monitoring undertaken by Wollongong City Council (WCC) has recorded elevated levels of FC in Robins creek, lower reaches of Reed creek and the middle reaches of Mullet Creek, all possibly due to stormwater runoff from urban and rural areas, particularly from beef and dairy cattle farms (WCC 2006).

Generally nutrient concentrations (TP and TN) were highest in Robins Creek, with potential sources including fertilisers, detergents, eroding soils, industrial effluent and natural and agricultural runoff and sewage overflows. Concentrations generally exceeded the guidelines in the mid and lower sections of Mullet and Reeds Creek but in all sections of Robins Creek (WCC 2006).

Mullet Creek

Water quality data for Mullet Creek was obtained from Wollongong City Council with non-routine data collected between August 2000 and August 2005. The monitoring site was located in the upper reaches of Mullet Creek at Cleveland Road. Table 2-3 provides summary statistics for the water quality at Mullet Creek. Both monitoring sites were located upstream of the weir on Mullet Creek and have an altitude of less than 150m, as such the water quality assessment has been made in accordance with the ANZECC/ARMCANZ (2000) and DECCW (2006) guidelines for protection of lowland aquatic ecosystems.

The Mullet Creek water quality site is situated upstream of the directed overflow sites 1134773 and SCOF117, but downstream of the majority of the uncontrolled overflow sites. High concentrations of TP and TN were recorded in Mullet Creek with median TP (26.5µg/L) and median TN (445µg/L) exceeding the ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems. Median wet weather concentrations were double dry weather concentrations for TP, TN, ammonia and nitrate. Median pH and ammonia met the ANZECC/ARCMANZ (2000) guidelines, and the median dissolved oxygen concentration was within the ANZECC (1992) recommended guidelines.

The Kembla Grange Golf course is located on the lower meandering section of Mullet Creek and whilst it does not directly discharge into Mullet Creek during dry weather, during wet weather overflows have the potential to enter Mullet Creek and may contribute to elevated concentrations of nutrients at this site.

Table 2-3 Mullet Creek Water Quality (Wollongong City Council 2000-2005)

Mullet Creek	pH	Conductivity (µS/cm)	Salinity	DO (mg/L)	TP (µg/L)	TN (µg/L)	TKN (µg/L)	Ammonia (µg/L)	Nitrate (µg/L)	Faecal Coliforms (cfu/100ml)
Guideline	6.5-8.5	125-2200	N/A	>6	25	350	N/A	20	N/A	<150 (primary) <1000 (secondary)#
Sample size	34	34	23	33	30	4	22	33	26	33
Median	7.685	525.85	0.31	6.56	**26.5^**	**445^**	245	10	10	23
75%tile	7.903	597.5	0.345	7.8	38.25	700	372.5	20	30	42
Max	8.4	1646	0.83	10.4	122	700	700	210	330	9100
Min	3.33	281	0.15	3.37	2	100	100	0	10	0
25%tile	7.51	417.5	0.25	5.59	17.75	167.5	205	10	10	12

^ Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers

Due to collection of faecal coliforms (as opposed to enterococci), the ANZECC/ARMCANZ (2000) guidelines have been applied instead of the NHMRC (2008) guidelines.

Robins Creek

Robins Creek is a tributary of upper Mullet Creek. Robins Creek is situated upstream of all overflows which occur within Mullet Creek, therefore data is indicative of upstream water quality conditions and does not consider the impact of overflows downstream which may currently be impacting water quality. The site is classified as a lowland river and will be assessed against relevant guidelines for lowland rivers (ANZECC/AMRCANZ 2000 and DECCW 2006).

Water quality data for Robins Creek was obtained from Wollongong City Council with non-routine data collected between August 2000 and August 2005. The monitoring site was located in the upper reaches of Robins Creek at Huxley Drive. Table 2-4 provides summary statistics for water quality at Robins Creek.

Median nutrient concentrations were higher in Robins Creek than further downstream at Mullet Creek. High median concentrations of TP and TN were recorded with median TP (37µg/L) and median TN (885µg/L) exceeding the ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems. Nutrient concentrations following wet weather increased with total phosphorus and ammonia concentrations doubling. Median ph, ammonia and DO complied with relevant guidelines.

Median faecal coliform density (55 cfu/100mL) complied for both primary and secondary recreation guidelines with little difference in median numbers during wet and dry weather.

Monitoring of Robins Creek was also undertaken July 2004 and June 2005. This monitoring indicated that Robins Creek generally had total suspended solid concentrations exceeding the recommended backgrounds site of 10mg/L at all monitoring sites (WCC 2006). Concentrations were generally higher upstream and decreased with distance downstream, possibly due to the highly erodible and dispersible soils (WCC 2006).

- **Table 2-4 Robins Creek Water Quality (Wollongong City Council 2000-2005)**

Robins Creek	pH	Conductivity (µS/cm)	Salinity	DO (mg/L)	TSS (mg/L)	TP (µg/L)	TN (µg/L)	TKN (µg/L)	Ammonia (µg/L)	Nitrate (µg/L)	Faecal Coliforms (cfu/100mL)
Guidelines	6.5-8.5	125-2200	N/A	>6	N/A	25	350	N/A	20	N/A	<150 (primary) <1000 (secondary)#
Sample size	34	35	24	34	1	31	4	23	34	28	34
Median	8.375	951.5	0.565	7.445	4	**37^**	**885^**	340	30	373	55
75%tile	8.6775	1106	0.625	8.28	4	70	900	520	50	512.5	225
Max	9.64	1312	0.79	10.17	4	227	900	830	154	810	31000
Min	6.72	244	0.15	2.78	4	2	600	160	0	10	13
25%tile	7.8975	640.4	0.3525	5.8175	4	26	802.5	215	20	180	40

^ *Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers*

Due to collection of faecal coliforms (as opposed to enterococci), the ANZECC/ARMCANZ (2000) guidelines have been applied instead of the NHMRC (2008) guidelines.

Reed Creek

Reed Creek is a tributary of Mullet Creek, entering immediately downstream of the WCC monitoring site on Mullet Creek. No directed overflows discharge into Robins Creek, however several uncontrolled overflows may enter Reed Creek.

Water quality data for Reed Creek was obtained from Wollongong City Council with non-routine data collection between August 2000 and August 2005. The monitoring site was located in the upper reaches of Reed Creek at Reed Park Place. Table 2-5 provides summary statistics for water quality at the monitoring site. Water quality has been assessed in accordance with the ANZECC/ARMCANZ (2000) guidelines for protection of lowland aquatic ecosystems. The monitoring site is situated upstream of all overflows which occur within Mullet Creek, thus data is only used to inform water quality conditions in the upstream and does not consider the impact that the overflows and other contributions currently occurring in the catchment may have on water quality. Despite this water quality was generally poor following wet weather.

Median nutrient concentrations at Reed Creek were similar to those observed in Robins Creek with median concentrations of TP and TN (34μg/L and 600μg/L respectively) exceeding the ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems. Following wet weather, median TP concentrations were six times higher than dry weather, ammonia four times higher and nitrate seven times higher. Similar to the other sites in the catchment, median pH, ammonia and DO comply with relevant guidelines.

- **Table 2-5 Reed Creek Water Quality (Wollongong City Council 2000-2005)**

Reed Creek	pH	Conductivity(μS /cm)	Salinity	DO (mg/L)	TSS (mg/L)	TP (μg/L)	TN (μg/L)	TKN (μg/L)	Ammonia (μg/L)	Nitrate (μg/L)	Faecal Coliforms (cfu/100mL)
Guidelines	6.5-8.5	125-2200	N/A	>6	N/A	25	350	N/A	20	N/A	<150 (primary) <1000 (secondary)#
Sample size	22	22	11	21	1	19	4	11	22	16	22
Median	7.76	792.7	0.33	8.66	2	**34^**	**600^**	590	10	10	145
75%tile	7.94	1319.5	0.525	9.9	2	57	700	640	35	33.25	355
Max	8.15	2511	1.18	11.9	2	165	700	900	128	220	28000
Min	7.4	329	0.19	5.23	2	2	380	380	0	10	9
25%tile	7.5125	584.525	0.275	7.42	2	7	470	510	10	10	48

^ *Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers*

Due to collection of faecal coliforms (as opposed to enterococci), the ANZECC/ARMCANZ (2000) guidelines have been applied instead of the NHMRC (2008) guidelines.

2.1.6. Macquarie Rivulet Catchment

The Macquarie Rivulet catchment located in the south-western corner of the study area and has catchment area of 109km^2 (LIA 2000). Major tributaries of Macquarie Rivulet system include Marshall Mount Creek, Cookback Creek, and Frasers Creek. Past studies have found Macquarie Rivulet generates the highest nitrogen and phosphorus loads in to Lake Illawarra (WCC 2009). There is one wetland off Frasers Creek in Albion Park which is listed under SEPP 14 (wetland no.382).

Macquarie Rivulet and Mount Marshall Creek and their catchments lie within the floodplain. Macquarie Rivulet drains a mostly forest and rural lands area of 107km^2, and discharges into Lake Illawarra. Its adjoining catchments include Duck Creek to the north and Horsley and Rocklow Creeks to the south east and Minnamurra River to the south (Rienco Consulting 2010). The drainage network of Macquarie Rivulet comprise Macquarie Rivulet being the main arm draining the central portion of the catchment, Frasers Creek, a secondary arm draining the south east section of the catchment and Marshall Mount Creek a major arm draining the northern sector. Macquarie Rivulet has a stream length of 22.5km, with a total fall from head waters to outlets of 680m and a mainstream slope of 8.4m/km (Rienco Consulting 2010).

Flows in Fraser Creek and Cooback Creek have been significantly altered as a consequence of urbanisation. Flow in these systems is impacted by a number of retarding basins, underground pipe systems and road culverts as well as changes to their plan form and bed profile (Rienco Consulting 2010).

Streams within the Macquarie Rivulet catchment have a highly variable flow regime with limited base flow, some being entirely ephemeral. Flow rate can rise rapidly following periods of intense rainfall, however these conditions only last for a short period (hours). The lower reach of Macquarie Rivulet contains permanent water due to the proximity and elevation of Lake Illawarra. A weir is constructed in these lower reaches to isolate the fresh water from the brackish water of the lake and as such acts as a terminus for this permanent backwater. (Rienco Consulting 2010)

Macquarie Rivulet

Water quality data from January 2001 to December 2010 for Upper and Lower Macquarie Rivulet was provided by Shellharbour City Council. Sampling was generally undertaken monthly to September 2002, and quarterly from then on. Summary statistics are presented in Table 2-6 and Table 2-7. Data have been compared against the ANZECC/ARMCANZ (2000) guideline for protection of lowland aquatic ecosystems in the upper reaches and estuarine aquatic ecosystems in the lower reach where Macquarie Rivulet is tidally influenced.

The water quality at the Upper Macquarie Rivulet site was generally good complying with most indicators including pH, DO, ammonia and TP. Median TN of 2400µg/L and NOx of 400µg/L at this site significantly exceed the ANZECC/ARMCANZ (2000) default trigger values of 350µg/L and 40µg/L respectively. These high nutrient concentrations may be due to current landuses practices in a predominantly rural catchment in the upstream reaches and the erosion of the waterways which contributes nutrients and sediments into the creek and Lake Illawarra, rather than the impact of stormwater overflows (Thiering et al, 1988). The enterococci density of 60cfu/100mL indicates the site complies with the NHMRC (2008) recreational guidelines category B classification.

Water quality appears to improve downstream for most indicators, with TN and NOx concentrations decreasing to 400µg/L and 260µg/L respectively, however still exceed the ANZECC/ARMCANZ (2000) guidelines for protection of estuarine aquatic ecosystems. The enterococci density also decreased to 50cfu/100mL complying with the NHMRC (2008) recreation guideline category B. Total phosphorus concentrations increased to 42µg/L exceeding the ANZECC/AMRCANZ (2000) guideline of 30µg/L.

It should be noted that only one sample was collected for TKN, NOx, and enterococci, and that these results may not accurately reflect existing water quality at these sites.

- **Table 2-6 Upper Macquarie Rivulet (lowland river) (Shellharbour City Council 2001-2009)**

Upper Macquarie Rivulet	TN (µg/L)	TP (µg/L)	DO (mg/L)	pH	Turbidity (NTU)	Chlorophyll -a (µg/L)	TSS (mg/L)	Faecal Coliforms (cfu/100mL)	TKN (µg/L)	NOx (µg/L)	Enterococci cfu/100mL
Guidelines	350	25	>6	6.5-8.5	6-50	3	NA	<150 <1000	N/A	40	Refer table 5
Sample size	56	56	48	49	51	8	8	46	1	1	1
Median	**2400^**	6	10.7	7.46	0.6	0.28	2.25	32	100	**400^**	60
75%tile	550	30.75	12.125	7.76	1.55	0.88	2.5	60	100	400	60
Max	2000	440	13.5	8.91	27.2	2.2	3	650	100	400	60
Min	50	0.2	5.2	6.01	-4.3	0.05	1	0.1	100	400	60
25%tile	260	2	9.2	7.03	0.1	0.05	1	8.5	100	400	60
95%tile	802.5	159	13.125	8.2	5.3	2.13	2.82	127.5	100	400	**60^**

^ Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers

▪ **Table 2-7 Lower Macquarie Rivulet (estuarine) (Shellharbour City Council 2001-2009)**

Lower Macquarie Rivulet	TN (µg/L)	TP (µg/L)	DO (mg/L)	pH	Turbidity (NTU)	Chlorophyll -a (µg/L)	TSS (mg/L)	Faecal Coliforms (cfu/100mL)	TKN (µg/L)	NOx (µg/L)	Enterococci (cfu/100mL)
Guidelines	300	30	>6	7-8.5	0.5-10	4	NA	<150 <1000	N/A	15	Refer Appendix A
Sample size	56	56	48	49	51	7	8	48	1	1	1
Median	**400^**	**42^**	7.85	7.25	2.2	0.5	2.5	82	400	**260^**	50
75%tile	502.5	110.75	9.15	7.41	3.45	1.25	3.75	165	400	260	50
Max	1400	770	11.8	8.82	51.3	10.3	34	4200	400	260	50
Min	1	2	3	6.24	-2.4	0.05	0.5	10	400	260	50
25%tile	247.5	24.75	6.66	6.91	1.1	0.05	2	49.5	400	260	50
95%tile	1065	220	10.9	8.03	12.25	25.57	24.2	632.5	400	260	**50^**

^ Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers

Frasers Creek

Monthly data from January 2001 to December 2010 for Frasers Creek has been provided by Shellharbour City Council. Whilst the exact location of the site along the creek is not known, the creek itself is classified as a lowland river. As such, water quality data have been compared to the ANZECC/ARMCANZ (2000) and DECCW (2006) guidelines for protection of aquatic ecosystems in lowland rivers. Some parameters were not sampled every month. Table 2-8 provides summary statistics for Frasers Creek.

There is one wetland off Frasers Creek in Albion Park which is listed under SEPP 14 (wetland no.382).

Similar to many other sites in the study area, Frasers Creek has high median concentrations of TN (550µg/L) and TP (83µg/L) which exceed the ANZECC/ARMCANZ (2000) guidelines for lowland rivers (Table 2-8). Water quality indicators DO, pH and turbidity complied with respective guidelines.

▪ **Table 2-8 Frasers Creek (Shellharbour City Council 2001-2009)**

Frasers Creek	TN (µg/L)	TP (µg/L)	DO (mg/L)	pH	Turbidity (NTU)
Guideline	350	25	>6	6.5-8.5	6-50
Sample size	30	30	25	26	26
Median	**550^**	**83^**	6.3	6.85	1.85
75%tile	727.5	162.5	8.3	7.0725	3.975
Max	1810	750	12.6	7.51	36.6
Min	1	2	1.9	6.32	0
25%tile	402.5	56	5.3	6.61	0.9
^ *Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers*					

Marshall Mount Creek

Marshall Mount Creek is a major tributary of Macquarie Rivulet. Marshall Mount Creek monitoring site is situated upstream of all overflows potentially impacted by the Proposal which occur within Macquarie Rivulet, thus data is only used to inform water quality conditions in the upstream extents of the catchment which is not currently impacted by overflows. The monitoring site is classified as a lowland river and as such, guidelines relevant to the protection of lowland aquatic ecosystems have been applied.

Monthly data from January 2001 to December 2010 for Marshall Mount Creek has been provided by Shellharbour City Council although some indicators were not sampled every month. Table 2-9 provide summary statistics for the Marshall Mount Creek monitoring site.

Overall, the water quality at Marshall Mount Creek is similar to Frasers Creek with, high median concentrations of TN (760µg/L) and TP (145µg/L) which exceed the ANZECC/ARMCANZ (2000) guidelines for lowland rivers. Similarly to Frasers Creek, median DO, pH and turbidity of Mount Marshall Creek complied with applicable guidelines.

- **Table 2-9 Marshall Mount Creek (Shellharbour City Council 2001-2009)**

Marshall Mount Creek	Total Nitrogen (µg/L)	Total Phosphorus (µg/L)	Dissolved Oxygen (mg/L)	pH	Turbidity (NTU)
Guideline	350	25	>6	6.5-8.5	6-50
Sample size	8	8	5	6	6
Median	**760^**	**145^**	9.8	6.965	0.5
75%tile	1152.5	530	11.4	7.2	5.475
Max	1330	1070	11.7	7.62	9.5
Min	1	28	6.9	6.62	0
25%tile	56	54.75	9.7	6.745	0.1
^ *Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers*					

2.1.7. Port Kembla Catchment

Port Kembla Catchment is located in the northern extent of the study area. Gurungaty Creek drains this catchment which flows into Tom Thumb Lagoon prior to entering the ocean.

Tom Thumb Lagoon is an estuarine channel with remnant saltmarsh and tidal mudflats and subject to tidal influences. It drains a catchment of about 1.64 million km^2, with about 93% of the catchment used for industrial or industrial related activities (WCC 2007). The wetland contains stands of Coastal Saltmarsh and Swamp Oak Floodplain Forest, both of which are listed as endangered ecological communities under the NSW Threatened Species Act 1995 (TSC Act). In 2009 there was a sighting of the vulnerable Green and Golden Bell Frog. Tom Thumb Lagoon has been undergoing extensive rehabilitation through the Revive our Wetlands program. In 2004 Conservation Volunteers Australia, BHP Billiton and Southern Rivers Catchment Management Authority and Wollongong City Council formed a collaborative partnership to revive wetlands in the Illawarra and Shoalhaven Regions including Tom Thumb Lagoon. The program reports that limited tidal exchange between the wetland and Port Kembla Harbour through a culvert is a key challenge to the wetland (Revive our Wetlands 2010).

Existing reports have reported that water quality at this site is generally poor in terms of suspended solids, possibly due to the tidal movements in the lagoon stirring up sediments deposited around the waterway. Nutrient concentrations are high at this site, possibly due to leachates from the decommissioned landfill sites at Greenhouse Park (WCC 2007). Faecal coliforms are generally low and not a concern for Tom Thumb Lagoon (WCC 2007). There are currently a number of pressures on the lagoon which may be attributable to the poor water quality including:

- Leachate from the former tip entering the wetland
- Channelling of tidal flow between Tom Thumb Lagoon and Port Kembla Harbour through a causeway
- The Lagoon receives storm water and other effluent from the nearby steel works and other runoff from its largely urbanised catchment via major drains
- A sewer runs through the wetland and at times of high rainfall, this discharges sewage into the area. (Wetland Link 2011).

2.1.8. Allan's Creek Catchment

The Allan's Creek Catchment is situated in the northern extents of the study area and covers a large area from the escarpment slopes through industrial areas to the Port Kembla harbour. More than half of the catchment is used for residential purposes, with a further 10% each of the catchment used for agricultural, recreational and environmental protection of vegetation purposes (WCC 2007). Several major tributaries drain the Allan's Creek Catchment with Allan's Creek originating at the junction of Charcoal Creek and Jenkins Creek. Another major tributary of Allan's Creek is American Creek which is fed by Brandy & Water Creek in its upstream reaches. Immediately upstream of the junction of American Creek and Allan's Creek is the major tributary, Byarong Creek which covers a catchment area of 8.52km^2 (WCC 2007).

Generally WCC found that dissolved oxygen and nitrate concentrations are the water quality indicators of concern, particularly at the upstream extent of the creek (WCC 2007).

Based on the existing information and type of waterway the key environmental values in this catchment are aquatic ecosystems. Overall, the water quality in the Allan's Creek catchment indicates problems with faecal coliform contamination, with faecal coliform densities exceeding the primary recreational guidelines at all locations, and also the secondary guidelines at Jenkins Creek.

In the northern extent of the study area and within the Wollongong LGA, creeks generally run from west to east and have varying sizes. Byarong to Allans Creek are generally the larger catchments of the LGA, with extensive tributaries and large sub-catchments. The coastal plain is extensive and flooding can be both extensive and long lasting (WCC 2007).

Charcoal Creek

Charcoal Creek catchment comprises of a high density of residencies, but does not contain any industry (WCC 2007). Water quality data for Charcoal Creek was obtained from Wollongong City Council with non-routine data present from August 2000 until August 2005. The Wollongong City Council monitor the upper reaches of Charcoal Creek at Coachwood Drive. Using collected data, Table 2-10 provides summary statistics for water quality of Charcoal Creek at Coachwood Drive. The monitoring site is classified as lowland river due to an altitude of <150m and water quality data has been compared to the ANZECC/ARMCANZ (2000) guidelines for protection of lowland aquatic ecosystems.

Generally water quality complied with the ANZECC/ARMCANZ (2000) guidelines for indicator parameters (including pH, DO, Ammonia and TP) at Charcoal Creek. Median TN concentrations (1500 µg/L) exceed the ANZECC/ARMCANZ guideline of 350µg/L by a factor of four whilst the median faecal coliform density (600 cfu/100ml) exceeds the Primary Contact Recreational guidelines however; it is unlikely that this site is a popular recreational location.

- **Table 2-10 Charcoal Creek Water Quality (Wollongong City Council 2000-2005)**

Charcoal Creek	pH	Conductivity	Salinity	DO (mg/L)	TSS (mg/L)	Faecal Coliforms (cfu/100mL)	TP (µg/L)	TN (µg/L)	TKN (µg/L)	Ammonia (µg/L)	Nitrate (µg/L)
Guideline	6.5-8.5	125-2200	N/A	>6	N/A	<150 <1000	25	350	N/A	20	N/A
Sample size	21	11	10	21	1	21	20	3	11	21	17
Median	8.13	575.2	0.29	10.6	4	**600^**	21	**1500^**	260	10	70
75%tile	8.33	651.8	0.335	11.7	4	3400	36	1500	390	20	250
Max	8.82	820	0.4	15.7	4	81000	77	1500	1400	237	850
Min	7.4	244	0.16	5.2	4	11	4	100	100	0	10
25%tile	7.85	420	0.1825	9.2	4	140	13.25	800	255	10	50
95%tile	8.56	766	0.382	14.2	4	26000	77	1500	1400	237	474

^ *Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers*

Jenkins Creek

Jenkins Creek is ephemeral and likely to flow only during wet weather, draining a small catchment area and a high density of residencies (WCC 2007). No specific environmental assets were identified in the region. No overflows are located in Jenkins Creek, however Jenkins Creek drains into Allan's Creek prior to entering Port Kembla, which does receive overflows from Charcoal, American and Byarong Creeks. As such the water quality of Jenkins Creek may influence water quality of downstream tributaries impacted by overflows.

Water quality data for Jenkins Creek was obtained from Wollongong City Council with non-routine data collection between August 2000 and August 2005. Sampling at this site was generally undertaken following wet weather. The Wollongong City Council monitoring site was located in the upper reaches of Jenkins Creek at Brendan Avenue which is classified as a lowland river. Table 2-11 provides summary statistics for water quality at Jenkins Creek based on data collected between 2000 and 2005.

Whilst Jenkins Creek is not impacted by overflows the water quality is generally poor. The faecal coliform density at Jenkins exceeds both the primary contact and secondary contact recreational guidelines, with a median of 1116.5 cfu/100ml. Nutrient concentrations including TP, nitrate, ammonia and TKN are also very high, with the median TP (43µg/L) exceeding the ANZECC/ARMCANZ (2000) guideline. The ephemeral nature of Jenkins Creek may partly account for the elevated median nutrient concentrations at this site compared to others in the region. Sampling only occurred following wet weather rainfall events, when contaminants from runoff in the surrounding catchment enter the system.

▪ **Table 2-11 Jenkins Creek Water Quality (Wollongong City Council 2000-2005)**

Jenkins Creek	pH	Conductivity (µS/cm)	Salinity	DO (mg/L	Faecal Coliforms (cfu/100mL)	TP (µg/L)	TKN (µg/L)	Ammonia (µg/L)	Nitrate (µg/L)
Guideline	6.5-8.5	125-2200	N/A	>6	<150 <1000	25	N/A	20	N/A
Sample size	15	15	5	15	14	13	5	15	11
Median	8.01	651	0.29	8.92	**1116.5^**	**43^**	490	20	190
75%tile	8.21	1132	0.31	10	4750	70	600	30	785
Max	11.04	1585	0.68	11.3	9100	151	800	230	1810
Min	7.54	157	0.1	1.8	8	2	350	10	50
25%tile	7.695	474	0.23	7.79	477.5	17	370	20	75
95%ile	9.206	1442.2	0.606	10.74	7735	132.4	760	118	1750

^ Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers

Brandy & Water Creek

Brandy & Water Creek drains into American Creek, prior to entering Allan's Creek. No water quality data was obtained for this system.

Byarong Creek

Byarong Creek Catchment is 8.52 km^2 with approximately two-fifths of the catchment residential and another two-fifths vegetation cover (WCC 2007).

Water quality data for Byarong Creek was obtained from Wollongong City Council with non-routine data collection between August 2000 and August 2005. Water quality was sampled at two sites within Byarong Creek. One site (the most upstream) was located at Whelan Avenue, with the second site, further downstream at The Avenue, Fig Tree. Both sites are classified as lowland river and water quality data have been compared to the ANZECC/ARMCANZ (2000) and DECCW (2006) guidelines for protection of lowland aquatic ecosystems.

Overall the water quality at the upstream and downstream sites is similar, despite the additional overflow discharges received at the downstream site. Median concentrations of pH, total phosphorus and ammonia met the ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems at both locations. Dry and wet weather results collected by Wollongong City Council, indicated generally similar water quality conditions in Byarong Creek. Concentrations of TP and ammonia were slightly higher following wet weather, particularly at the downstream site where median ammonia concentrations following wet weather, were double dry weather. This site is also located downstream of overflows. Median dissolved oxygen concentration at both locations was greater than 6mg/L, meeting the ANZECC (1992) guidelines.

The faecal coliform density at both sites exceeded the primary contract recreation guideline (<150 cfu/100mL), however both sites complied with the secondary contact recreation guideline (<1000cfu/mL). The additional stormwater overflow discharges did not appear to increase the faecal coliform density with the median concentration decreasing from 740 cfu/100mL (Site 24) to 290 cfu/100mL further downstream (Site 25).

- **Table 2-12 Byarong Creek (upstream site at Whelan Avenue) Water Quality (Wollongong City Council 2000-2005)**

Byarong Creek	pH	Conductivity	DO (mg/L)	Faecal Coliforms (cfu/100mL)	TP (µg/L)	TN (µg/L)	Ammonia (µg/L)	Nitrate (µg/L)
Guideline	6.5-8.5	125-2200	>6	<150 <1000	25	350	20	N/A
Sample size	33	33	33	33	31	0	33	28
Median	7.8	333	9.47	**740^**	18	N/A	20	20
75%tile	7.99	393.3	10.47	2800	29	N/A	37	100
Max	9.93	622	11.8	11000	88	N/A	126	3200
Min	7.3	198.4	2.16	56	2	N/A	10	10
25%tile	7.69	313	7.79	400	13.5	N/A	10	10
95%tile	8.708	484.6	11.524	8420	62.5	N/A	116.4	397.5

^ Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers

- **Table 2-13 Byarong Creek (downstream site at The Avenue, Figtree) Water Quality (Wollongong City Council 2000-2005)**

Byarong Creek	pH	Conductivity	DO (mg/L)	Faecal Coliforms (cfu/100ml)	TP (µg/L)	Ammonia (µg/L)	Nitrate (µg/L)
Guideline	6.5-8.5	125-2200	>6	<150 <1000	25	20	N/A
Sample size	34	35	35	34	32	34	29
Median	7.72	324	7.9	**290^**	21.5	20	24
75%tile	7.925	365.5	8.945	787.5	32.25	20	80
Max	8.28	460	13.6	34500	111	158	500
Min	6.97	231.1	0.82	18	2	0	10
25%tile	7.613	272.5	6.455	212.5	10	10	10
95%tile	8.158	431.43	10.89	8850	59.2	107.3	410

^ Median exceeds ANZECC/ARMCANZ (2000) guidelines for lowland rivers

2.1.9. Ocean Outfalls

Effluent from Shellharbour WWTP is discharged through an ocean outfall off Barrack Point located between Warilla in the north and Bass Point to the south. There are three beaches in the area, Warilla, North Shellharbour and South Shellharbour, between which there is a constructed ocean swimming pool on the rock platform. North Shellharbour is a popular recreational beach and South Shellharbour a popular surfing beach. A small harbour has been constructed in the lee of Cowrie Island providing mooring and launching facilities for boats.

The Port Kembla WWTP discharges wastewater into the ocean via an outfall at Red Point. The majority of wet weather overflows from the Port Kembla wastewater system either discharge directly, or drain to, receiving waters including Pacific Ocean, North Beach and Fishermans Beach, Perkins Beach (Sydney Water 1998a). Coomaditchy Lagoon and Reserve may also receive wet weather overflows. The beaches are used for primary recreation including swimming and surfing.

A number of environmental values have been identified for the area from Barrack Point to the south according to Sydney Water (2003). These values include the protection of aquatic ecosystems, aquaculture and human consumption of aquatic foods, protection of primary and secondary contact recreation and visual amenity.

The Beachwatch program involves routine monitoring and reporting of bacterial indicator levels to determine water quality at swimming locations in the Sydney region. The latest Enterococci and Faecal Coliform data from the DECCW Beachwatch program (2008 – 2009) was used to provide an indication of the ocean water quality in the ocean outfall areas (Table 2-14 and Table 2-15).

Enterococci densities at Fishermans Beach, Warilla Beach and Shellharbour Beach meet the Category A NHMRC (2008) recreational water quality guidelines with 95th percentile enterococci densities less than 40cfu/100mL (Table 2-14). Port Kembla beach (71.5 cfu/100mL) had slightly poorer microbial health, meeting the Category B NHRMC (2008) recreational water quality guidelines.

Median faecal coliform densities at all beaches met the ANZECC (2000) guidelines for primary and secondary recreation (<150cfu/100mL) (Table 2-15).

- **Table 2-14 Beachwatch Enterococci data for surrounding beaches (DECCW 2008-2009)**

Enterococci	Fishermans Beach	Port Kembla	Warilla	Shellharbour Beach
Sample size	122	122	122	122
Median	1	2	0	0
75%tile	4	15	2.75	2
Max	1400	600	75	200
25%tile	0	0	0	0
95%tile	26.8	71.5	15.85	16.8

- **Table 2-15 Beachwatch Faecal Coliforms data for surrounding beaches (DECCW 2008-2009)**

Faecal Coliforms	Fishermans Beach	Port Kembla	Warilla	Shellharbour Beach
Sample size	101	101	101	101
Median	1	3	0	0
75%tile	4	10	1	1
Max	250	680	43	510
25%tile	0	0	0	0

3. Methodology

3.1. Overview

The methodology for assessing the impacts of wet weather overflows has been developed in a manner consistent with the NHMRC (2008) *Guidelines for Managing Risks in Recreational Waters* and ANZECC/ARMCANZ (2000*) Australian Water Quality Guidelines for Fresh and Marine Waters*. Both these guidelines advocate a 'risk-based' approach to water quality management, by considering the likelihood that a hazard (eg microbial contamination) will occur and the consequences if it does. The risk will vary depending on the nature and location of the activity, how it is carried out and the sensitivity of the receiving waterway.

The methodology involves an assessment of the potential risks that increased pollutant loads (as a result of the Proposal) present to the environmental values of receiving waters in the Wollongong, Shellharbour and Port Kembla regions. The methodology and subsequent assessment, is not a fully quantitative assessment as it would normally involve monitoring and numerical modelling. This in itself can be problematic due to:

- insufficient data regarding quality of the receiving waters
- stormwater quality, lack of flow information
- the spatial complexity of the proposal and uncertainty surrounding ecosystem responses; and
- interpretation.

3.2. Risk Assessment Methodology

3.2.1. Overview

This component of the methodology is a risk-based prioritisation of overflows. This is done by assessing predicted changes in the frequency and volume of overflows that occur as a result of development of the Proposal. The frequency and volume of overflows were previously determined by Sydney Water through hydraulic modelling. The risk assessment was undertaken for each directed and uncontrolled overflow.

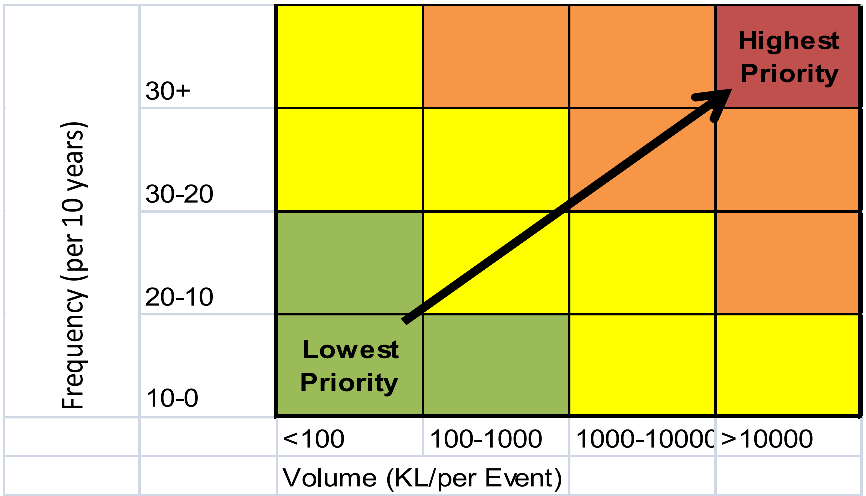
Directed and uncontrolled overflows associated with the Proposal were geographically located using GIS to determine the catchment or sub-catchment they are located in. This allowed an understanding of how downstream water quality may be impacted.

Prioritisation of the overflows was then undertaken. This was a process of determining which directed and uncontrolled overflows automatically rank as highest priority due to their discharge location and/or volume and frequency of discharge. The prioritisation process automatically gave some overflows highest priority due to their discharge location. The high and highest priority overflows would then go forward to mass balance pollutant load modelling. All directed and uncontrolled overflows were prioritised in the following order:

- Overflows (directed and uncontrolled) which may pose a risk to human health, eg discharge into primary and secondary recreation areas.
- Directed overflows which potentially exceed their licence limit (eg 40/45 overflows over 10 years).
- Overflows which change risk priority between 2009 and 2021 and between 2021 and 2048. This change in risk refers to where an overflow changes priority, eg where an overflow changes from a high priority overflow to the highest priority overflow due to an increase in frequency and volume between those time periods. This could occur through an increase in frequency and/or volume over time.
- Overflows which change in scale between 2009 and 2021 and between 2021 and 2048. This change in scale refers to where there may be an increase in the frequency and/or volume of a particular overflow, but the increase is not sufficient to change risk priority.
- Overflows which present a low or medium risk priority.

3.2.2. Directed Overflows

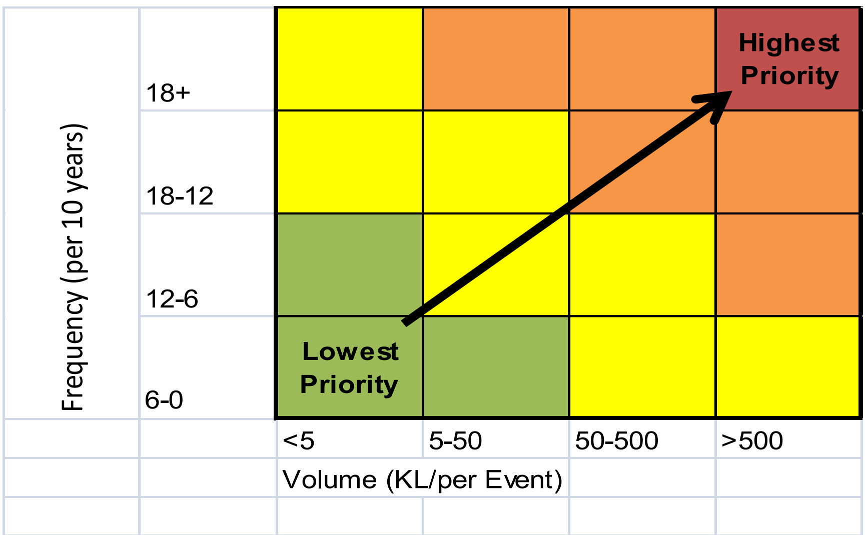
All directed overflows were ranked according to the frequency they overflow over the 10 year period and the volume discharged per overflow event as shown in Figure 3-1. Highest priority directed overflows will have both the greatest frequency of overflow and volume of discharge. It should be noted that those overflows already identified as discharging into receiving waters that are popular recreational sites or sensitive environmental sites, would automatically rank as highest priority, irrespective of their volume/frequency.



▪ **Figure 3-1 Risk matrix for directed overflows**

3.2.3. Uncontrolled Overflows

The ranking of uncontrolled overflows will be undertaken using the same approach as directed overflows. However, the scale of frequency and volume of overflows will be different due to uncontrolled overflows discharging smaller volumes less frequently. An example of the risk ranking matrix that will be applied to uncontrolled overflows is presented in Figure 3-2.



▪ **Figure 3-2 Risk matrix for uncontrolled overflows**

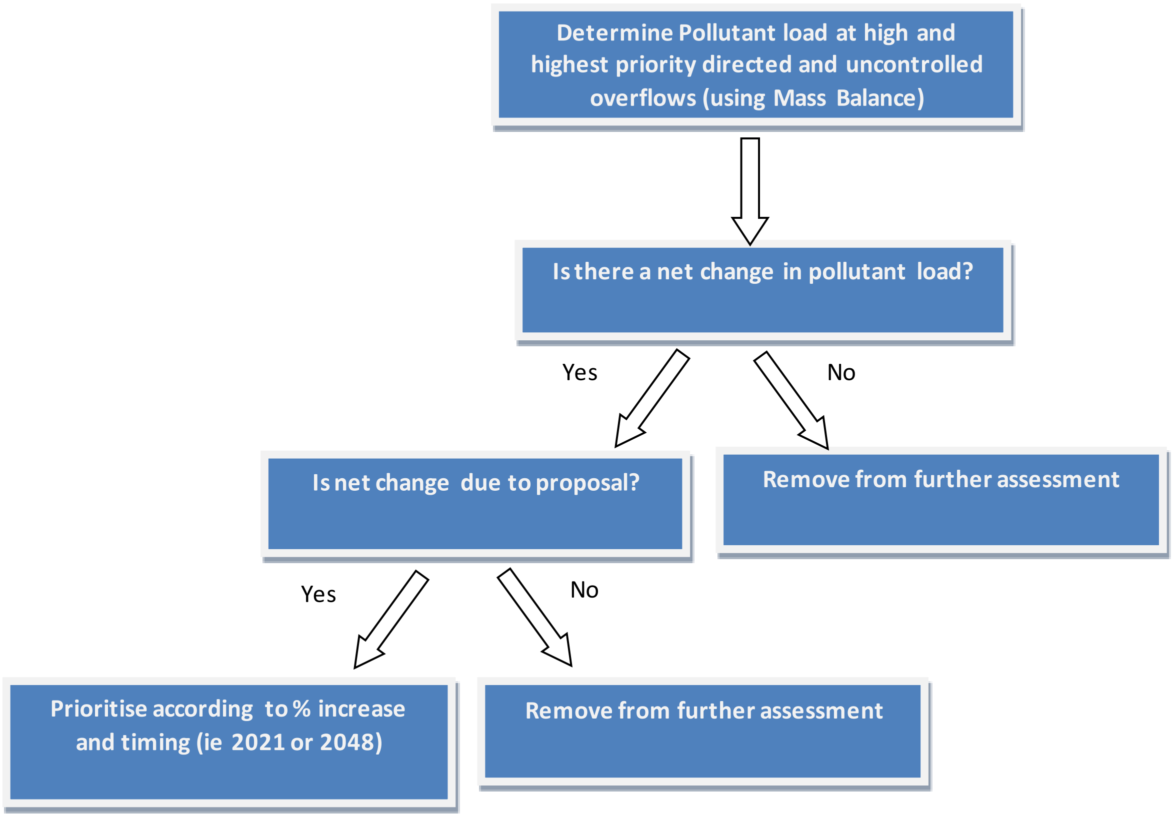
3.3. Mass Balance Methodology

3.3.1. Overview

In this stage of the methodology, the impacts of the Proposal on water quality, aquatic ecology and public health were assessed via the development and implementation of a mass balance model. The mass balance model determines the scale of change in the loads of key water quality indicators at a specific location, for an average event between 2009 and 2021 and 2021 and 2048. Mass balance was undertaken on the high and highest priority overflows potentially impacted by the Proposal based on WDURA, infill and deterioration. Key indicators examined using the mass balance model included nutrients, faecal coliforms and suspended solids. Whilst ANZECC/ARMCANZ (2000) provides trigger values for assessment as concentrations, they recommend that for more complex water quality issues, water quality indicators such as nutrients be expressed as nutrient loads. As such pollutant levels have been discussed in loads and event-averaged concentrations (where possible).

In establishing the mass balance model the key inputs into the model were wastewater pollutant loads, hydraulic capacity and dilution ratio at each overflow location. This allowed the relative contributions from each source to be determined. By comparing pollutant loads over time, any increase in pollutant loads that are a direct result of the Proposal became apparent. These overflows were subject to impact assessment.

A flow diagram of the mass balance process is provided in Figure 3-3, whereby the first task at each high and highest priority overflow was to determine both the current (2009) load and future (2021 and 2048) loads due to the Proposal. The output of this will determine whether there was a 'net change' or 'no net change' in pollutant loads per event as a result of the Proposal. If an overflow was determined to have 'no net change' then was removed from further assessment, However if there was a 'net change' then the overflow was categorised according to the scale of the increase in pollutant loads and when these increases become apparent.



- **Figure 3-3 Process for determining pollutant loads/event and categorising overflows**

For any particular overflow location, there are four key steps in implementing the mass balance model:

1) Locating the overflow site and determining the hydraulic system capacity. This was done by identifying where the overflow is located in the transfer system and then determining the hydraulic capacity of the system at that location.
2) Determining the minimum dilution ratio at each overflow. Using the hydraulic capacity at the overflow location, the proportion of wastewater versus stormwater was determined.
3) Determining the pollutant concentration at the overflow. This was done using the dilution ratio and standard wastewater concentrations (SWC 1998)

   The key water quality indicators and assumed concentrations in wastewater are as follows:

   - total suspended solids 300mg/L
   - Nutrients TN 55mg/L; TP 10mg/L
   - faecal coliforms 10,000,000cfu/100mL

4) Determining the annual pollutant load at the overflow site, by multiplying the pollutant concentration by the volume of overflow for each site each year. This can then be summed across years at each site.

At the completion of this mass balance assessment, if there was a net change (ie. percentage increase) in pollutant load at an overflow due to the proposal, then that overflow was categorised and subject to impact assessment.

3.4. Cumulative Overflow Impact Assessment Methodology

In order to assess the cumulative impacts of the Proposal on the environmental values identified for the project, the annual volumes and loads associated with high and highest priority directed and uncontrolled overflows were examined on a sub-catchment basis. Seven sub-catchments were delineated in the project area using GIS data provided by Wollongong City Council and Shellharbour City Council. These catchments were the ones that contained overflows that fell into the high and highest priority as per the risk assessment. The annual loads of the high and highest priority categories were combined to estimate an annual cumulative load for each sub-catchment. The results of the mass balance modelling were then used to estimate the annual cumulative overflow volume and load for TSS, TN, TP and FCs for each sub-catchment for 2009, 2021 and 2048.

3.5. Cumulative Stormwater Impact Assessment Methodology

In order to place the annual cumulative wastewater overflow loads into perspective, annual stormwater loads for TSS, TN, TP and FC's were also estimated on a sub-catchment basis for comparative purposes. For each sub-catchment, six land use classes were identified and the area for each landuse estimated (Table 3-1, Figure 4-1 to Figure 4-7). Landuse areas and type used to predict stormwater loads are conservative. They are based on the current situation and do not consider landuse changes with the development of the Proposal. Each landuse was then allocated a generation rate for TN and TP based on Marston (1993) (Table 3-2). Generation rates for TSS and FCs were allocated based on McAuley *et al* (2011).

■ **Table 3-1 WDURA and AGA sub-catchments and associated landuse**

Sub-catchment	Landuse (Ha)						
	Urban	Bushland	Industrial and Commercial	Peri-Urban	Horticulture	Grazing	Total
Allans Creek*	2,422	707	12	455	-	588	4,184
Barrack Creek	948	27	-	84	-	190	1,249
Horsley and Connor Creek	581	6	-	65	-	257	909
Lake Illawarra	1,453	758	-	70	-	286	2,567
Macquarie Rivulet	85	612	-	848	3	1,520	3,068
Mullet Creek	1,822	731	13	1,488	8	3,144	7,207
Port Kembla	734	8	-	-	-	-	742

*= for the purposes of this assessment Allan's Creek catchment contains stormwater contributions from Allan's Creek, American Creek, Branch Creek, Brandy and Water Creek and Byarong Creek which all drain to the Allan's Creek catchment.

■ **Table 3-2 Landuse Generation rates**

Pollutant	Land Use					
	Urban	Bushland	Industrial and Commercial	Intensive vegetable growing	Peri-Urban	Grazing
TSS (mg/L)^	140	40	140	140	100	140
TN (kg/ha/yr)*	5	4	6	8	4	0.9
TP (kg/ha/yr)*	1.3	0.6	1.8	8	0.6	0.25
Faecal Coliforms (CFU/L)^	200,000	6,000	40,000	10,000	10,000	200,000

*Marston F. (1993) Diffused Source Nutrient Generation Rates in the Hawkesbury-Nepean Basin. *Technical Memorandum 93/3,* Division of Water Resources, CSIRO Australia

^ McAuley, A, and Knights, D (2011). Addressing wastewater overflows in catchment management planning. Equatica

The annual stormwater loads for TN and TP for each sub-catchment were estimated as follows:

- Annual TN & TP loads (kg/yr) = TN & TP Generation rates (kg/ha/yr) * Area (ha)

The annual stormwater loads for FCs and TSS for each sub-catchment were estimated as follows:

- Annual FC load (cfu/yr) = FC concentration (cfu/100ml) * annual rainfall (mm/yr) * catchment area (ha) * Run-off coefficient (unit less) * unit conversion factor (100,000)

- Annual TSS load (kg/yr) = TSS concentration (mg/L) * annual rainfall (mm/yr) * catchment area (ha) * Run-off coefficient (unit less) * unit conversion factor (1/100)

Annual rainfall was estimated as the annual median rainfall for the region for the period 2000 to 2010 taken from BoM rainfall gauge #68241 at Albion Park. This estimate of 815mm is conservative compared to other studies which have reported average rainfall within the catchment ranging between 1100mm and 1500mm. Runoff coefficients were set as 0.5 for urban, industrial and commercial and 0.1 for bushland, peri-urban, intensive horticulture and grazing (Singh et al, 2009).

3.6. Stormwater v wastewater contribution methodology

Further assessment was carried out if an overflow showed a positive increase in pollutant load (either annually or on an event basis). This assessment stage compared the relative contribution of pollutant loads from these selected overflows, with the loads from stormwater. The results were analysed on a catchment basis.

Impacts on water quality may occur when an overflow contributes excessive nutrients to a waterway where nutrient levels are already elevated. This may in turn have the potential to cause eutrophication and algal blooms. Impacts to aquatic ecology as a result of wastewater generated by the proposal were assessed, for example high levels of ammonia are toxic to fish or high suspended sediments can smother seagrass.

Impacts on public health may occur if the discharge location is considered to be a popular area for aquatic recreation. The severity of impact will be assessed in accordance with the NHMRC (2008) guidelines using a risk-based desk-top public health survey approach.

Those overflows that present an issue to the environment as a result of increased percentage change in event loading were documented and mitigation measures to minimise potential impacts suggested.

4. Risk Assessment and Mass Balance Results

4.1. Risk Assessment

4.1.1. Overview

A risk assessment was undertaken for each directed and uncontrolled overflow location. The risk assessment for each overflow location was undertaken for current (2009) conditions, the year 2021 (for which project approval is sought) and the year 2048 (for which concept approval is sought). The frequency and volume of the discharge and the environmental sensitivity of the receiving environment were used to determine the risk. For each year (i.e. current, year 2021 and 2048), the sensitivity of the receiving environment remained with same, but estimated frequency and volume changed based on the different modelled years for each overflow location.

There were 49 directed and 621 uncontrolled overflow locations that were subject to the risk assessment. The results of the risk assessment showed that only 20 directed and 45 uncontrolled overflows were identified as having the greatest potential to impact on public health and aquatic ecosystems (including wetlands), These overflows were therefore prioritised high or highest risk, for current (2009), 2021 or 2048. These are summarised below and in Table 4-1.

- **Table 4-1 Risk priority for directed and uncontrolled overflows**

Overflow ID	System	Catchment	2009	2021	2048	Reason
Directed						
SCOF106	Port Kembla	Lake Illawarra	Low	Medium	Medium	Impact on aquatic ecosystems and public health
SCOF108	Port Kembla	Lake Illawarra	High	High	High	Impact on aquatic ecosystems and public health
SCOF107	Port Kembla	Lake Illawarra	High	High	Highest	Impact on aquatic ecosystems and public health
SCOF117	Port Kembla	Mullet Creek	Highest	Highest	Highest	Impact on aquatic ecosystems
CMSP343	Shellharbour	Barrack Creek	High	High	High	Impact on aquatic ecosystems
1400028	Shellharbour	Barrack Creek	Medium	High	High	Impact on aquatic ecosystems
1123473	Shellharbour	Barrack Creek	Highest	Highest	Highest	Impact on aquatic ecosystems
1125705	Shellharbour	Barrack Creek	Highest	Highest	Highest	Impact on aquatic ecosystems
1122981	Shellharbour	Barrack Creek	Highest	Highest	Highest	Impact on aquatic ecosystems
1125953	Shellharbour	Barrack Creek	Highest	Highest	Highest	Impact on aquatic ecosystems

Overflow ID	System	Catchment	2009	2021	2048	Reason
1120960	Shellharbour	Horsley & Connor Ck	Highest	Highest	Highest	Impact on aquatic ecosystems and public health
1400000	Shellharbour	Lake Illawarra	High	Highest	Highest	Impact on aquatic ecosystems
1119924	Shellharbour	Lake Illawarra	Highest	Highest	Highest	Impact on aquatic ecosystems
1121017	Shellharbour	Lake Illawarra	Highest	Highest	Highest	Impact on aquatic ecosystems
1131051	Wollongong	Allan's Creek	High	High	High	Impact on aquatic ecosystems
1129001	Wollongong	Allan's Creek	Highest	Medium	High	Impact on aquatic ecosystems
1130399	Wollongong	Allan's Creek	Highest	High	Highest	Impact on aquatic ecosystems
1128785	Wollongong	Allan's Creek	Highest	High	Highest	Impact on aquatic ecosystems
1128317	Wollongong	Allan's Creek	High	High	High	Impact on aquatic ecosystems
8121785	Wollongong	Port Kembla	Highest	Highest	Highest	Impact on aquatic ecosystems
Uncontrolled						
1141135	Port Kembla	Lake Illawarra	Medium	Medium	High	Frequency and/or volume of overflows
1141999	Port Kembla	Lake Illawarra	High	High	High	Impact on aquatic ecosystems
1142022	Port Kembla	Lake Illawarra	Medium	Medium	High	Frequency and/or volume of overflows
1139143	Port Kembla	Lake Illawarra	High	High	High	Impact on aquatic ecosystems
1139339	Port Kembla	Lake Illawarra	High	High	High	Impact on aquatic ecosystems
1135796	Port Kembla	Mullet Creek	Medium	Medium	High	Frequency and/or volume of overflows
1133545	Port Kembla	Mullet Creek	Medium	Medium	High	Frequency and/or volume of overflows
1142018	Port Kembla	Mullet Creek	High	High	High	Frequency and/or volume of overflows
1136273	Port Kembla	Mullet Creek	Medium	High	High	Frequency and/or volume of overflows
1135500	Port Kembla	Mullet Creek	High	High	Highest	Frequency and/or volume of overflows
1132832	Port Kembla	Mullet Creek	High	High	High	Frequency and/or volume of overflows
1140820	Port Kembla	Ocean Outfalls	High	High	High	Frequency and/or volume of overflows
1123653	Shellharbour	Barrack Creek	Medium	High	High	Impact on aquatic ecosystems
1127548	Shellharbour	Barrack Creek	High	High	High	Frequency and/or volume of overflows
1119176	Shellharbour	Horsley & Connor Ck	High	Medium	Medium	Frequency and/or volume of overflows
1121644	Shellharbour	Horsley & Connor Ck	Medium	Medium	High	Frequency and/or volume of overflows

Overflow ID	System	Catchment	2009	2021	2048	Reason
1396642	Shellharbour	Lake Illawarra	High	High	High	Frequency and/or volume of overflows
1118692	Shellharbour	Lake Illawarra	High	High	Highest	Frequency and/or volume of overflows
1551095	Shellharbour	Macquarie Rivulet	Medium	High	High	Impact on public health
1117919	Shellharbour	Macquarie Rivulet	Medium	High	High	Frequency and/or volume of overflows
1117911	Shellharbour	Macquarie Rivulet	Medium	Medium	High	Frequency and/or volume of overflows
1395591	Shellharbour	Macquarie Rivulet	Medium	Medium	High	Frequency and/or volume of overflows
1121559	Shellharbour	Macquarie Rivulet	Medium	High	High	Frequency and/or volume of overflows
1117699	Shellharbour	Macquarie Rivulet	Medium	Medium	High	Frequency and/or volume of overflows
1117799	Shellharbour	Macquarie Rivulet	Medium	High	High	Frequency and/or volume of overflows
1119031	Shellharbour	Macquarie Rivulet	Medium	Medium	High	Frequency and/or volume of overflows
1121555	Shellharbour	Macquarie Rivulet	Medium	High	High	Frequency and/or volume of overflows
1121635	Shellharbour	Macquarie Rivulet	High	High	Highest	Frequency and/or volume of overflows
1130679	Wollongong	Allan's Creek	Medium	Medium	High	Frequency and/or volume of overflows
1136262	Wollongong	Allan's Creek	Medium	High	High	Frequency and/or volume of overflows
1129143	Wollongong	Allan's Creek	Medium	Medium	High	Frequency and/or volume of overflows
1128713	Wollongong	Allan's Creek	Medium	Medium	High	Frequency and/or volume of overflows
1131717	Wollongong	Allan's Creek	High	High	High	Frequency and/or volume of overflows
1128997	Wollongong	Allan's Creek	High	Medium	Medium	Impact on aquatic ecosystems
1129135	Wollongong	Allan's Creek	High	High	High	Frequency and/or volume of overflows
1129893	Wollongong	Allan's Creek	Medium	High	High	Impact on public health
1130584	Wollongong	Allan's Creek	Medium	High	Medium	Frequency and/or volume of overflows
1129697	Wollongong	Allan's Creek	High	High	High	Frequency and/or volume of overflows
1128841	Wollongong	Allan's Creek	High	High	High	Frequency and/or volume of overflows
1128668	Wollongong	Allan's Creek	Medium	Medium	High	Frequency and/or volume of overflows
1129389	Wollongong	Allan's Creek	High	High	High	Frequency and/or volume of overflows
1131184	Wollongong	Allan's Creek	High	High	High	Frequency and/or volume of overflows
1134082	Wollongong	Port Kembla	Medium	High	High	Frequency and/or volume of overflows

Overflow ID	System	Catchment	2009	2021	2048	Reason
1377705	Wollongong	Port Kembla	High	Medium	Medium	Frequency and/or volume of overflows
1133831	Wollongong	Port Kembla	High	Medium	High	Frequency and/or volume of overflows

Note: impact on aquatic ecosystems may include wetlands, seagrass and impacts to public health refers to overflows located in primary and secondary contract recreation areas

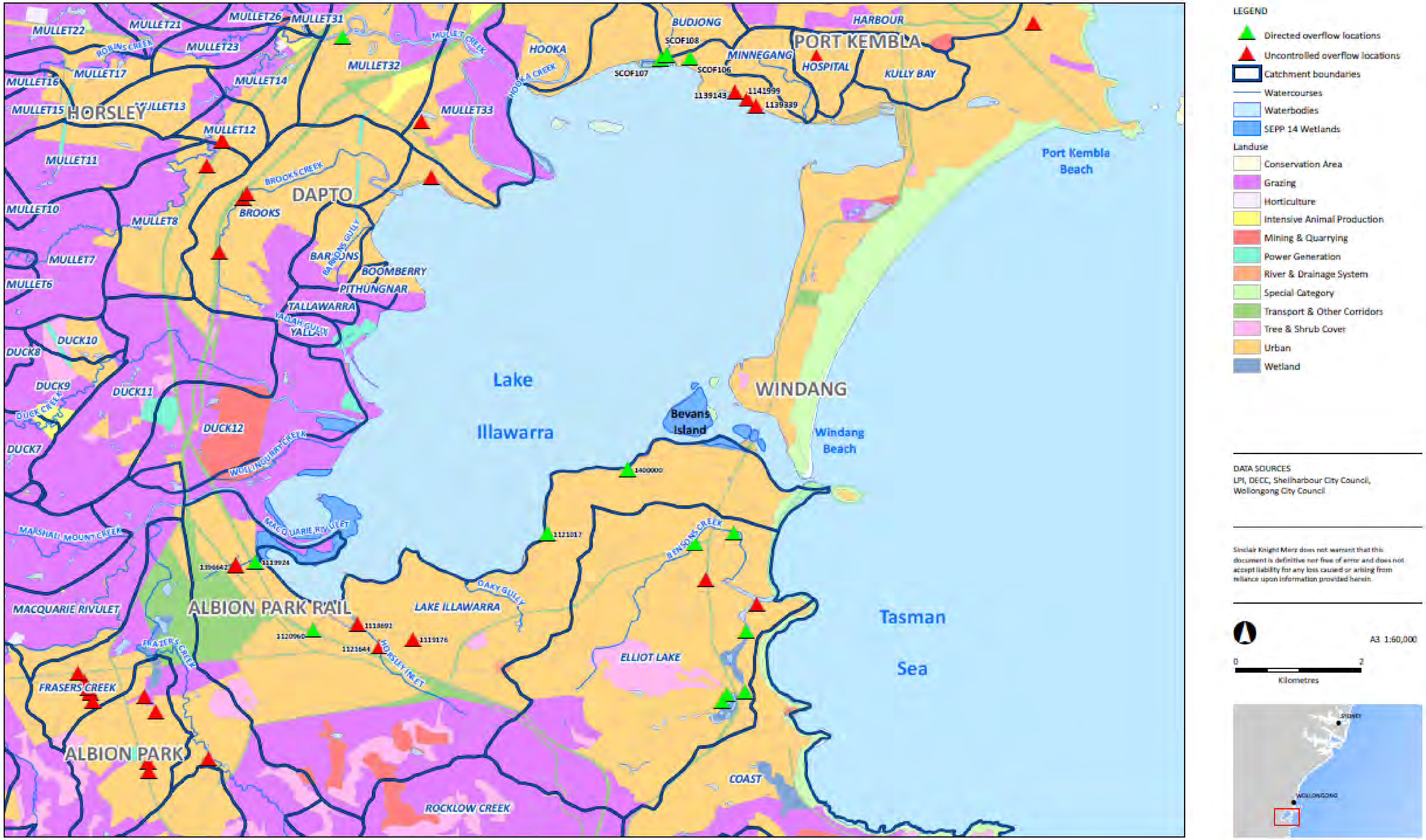
4.1.2. Directed Overflows

Lake Illawarra Catchment

Six directed overflows SCOF106, SCOF108, SCOF107, 1400000, 1119924 and 1121017 located in the Lake Illawarra Catchment were identified to be carried forward to the impact assessment. The frequency and volume are provided in Table 4-2 and the location together with catchment landuses are shown in Figure 4-1.

- **Table 4-2 Frequency and volumes risk prioritised directed overflows in the Lake Illawarra Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
SCOF106	9	79	88	10	110	108	13	180	138
SCOF108	12	1,200	1000	13	1,394	1,079	15	1,831	1,221
SCOF107	13	5,746	4,420	19	9,326	4,949	32	17,383	5,432
1400000	9	1,066	1,185	11	1,393	1,215	17	2,129	1,252
1119924	13	2,619	2,015	15	3,087	2,080	19	4,141	2,180
1121017	20	2,621	1,310	22	2,997	1,372	26	3,842	1,478



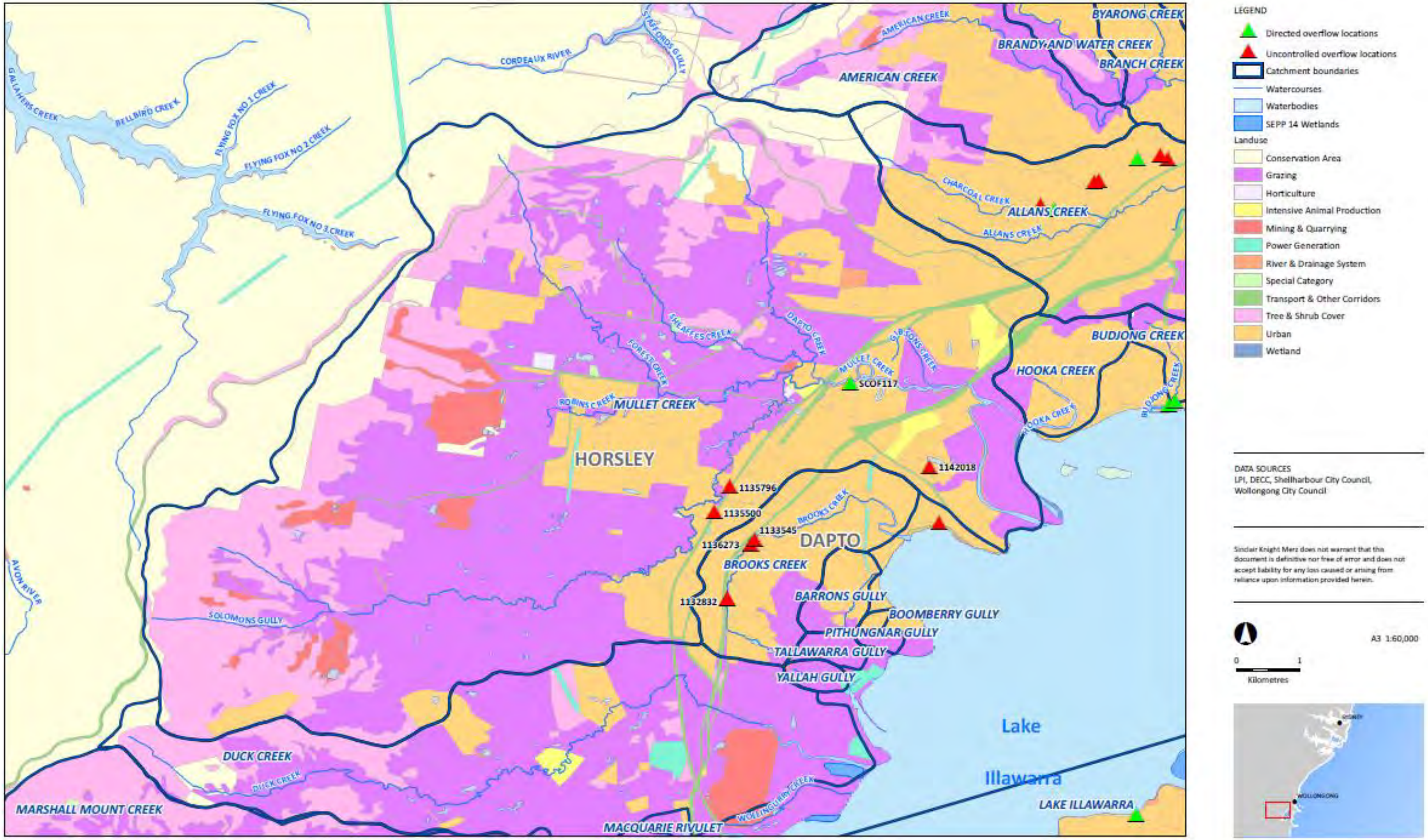
■ **Figure 4-1 Directed and uncontrolled (high and highest) overflows in the Lake Illawarra Catchment**

Mullet Creek Catchment

One directed overflow (SCOF117) was identified to be carried forward to the impact assessment. The site is shown in Figure 4-2 and summarised in Table 4-3.

- **Table 4-3 Frequency and volumes risk prioritised directed overflows in the Mullet Creek Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
SCOF117	13	17,576	13,520	21	35,756	17,027	39	76,662	19,657



■ **Figure 4-2 Directed and uncontrolled (high and highest) overflows in the Mullet Creek Catchment**

Barrack Creek Catchment

Six directed overflow sites (CMSP343, 1400028, 1123473, 1125705, 1122981 and 1125953) located in the Barrack Creek Catchment were identified to be carried forward to the impact assessment. The locations are shown in Figure 4-3 and the frequency and volume for 2009, 2021 and 2048 are provided in Table 4-4.

- **Table 4-4 Frequency and volumes of risk prioritised directed overflows in the Barrack Creek Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
CMSP343	2	40	200	3	52	198	4	78	195
1400028	23	2,295	998	25	2,652	1,042	31	3,458	1,115
1123473	35	7,203	2,058	38	7,923	2,064	46	9,545	2,075
1125705	34	15,284	4,495	37	17,684	4,809	43	23,084	5,368
1122981	29	20,920	7,214	32	23,325	7,202	40	28,735	7,184
1125953	35	37,138	10,611	39	40,937	10,497	48	49,486	10,310

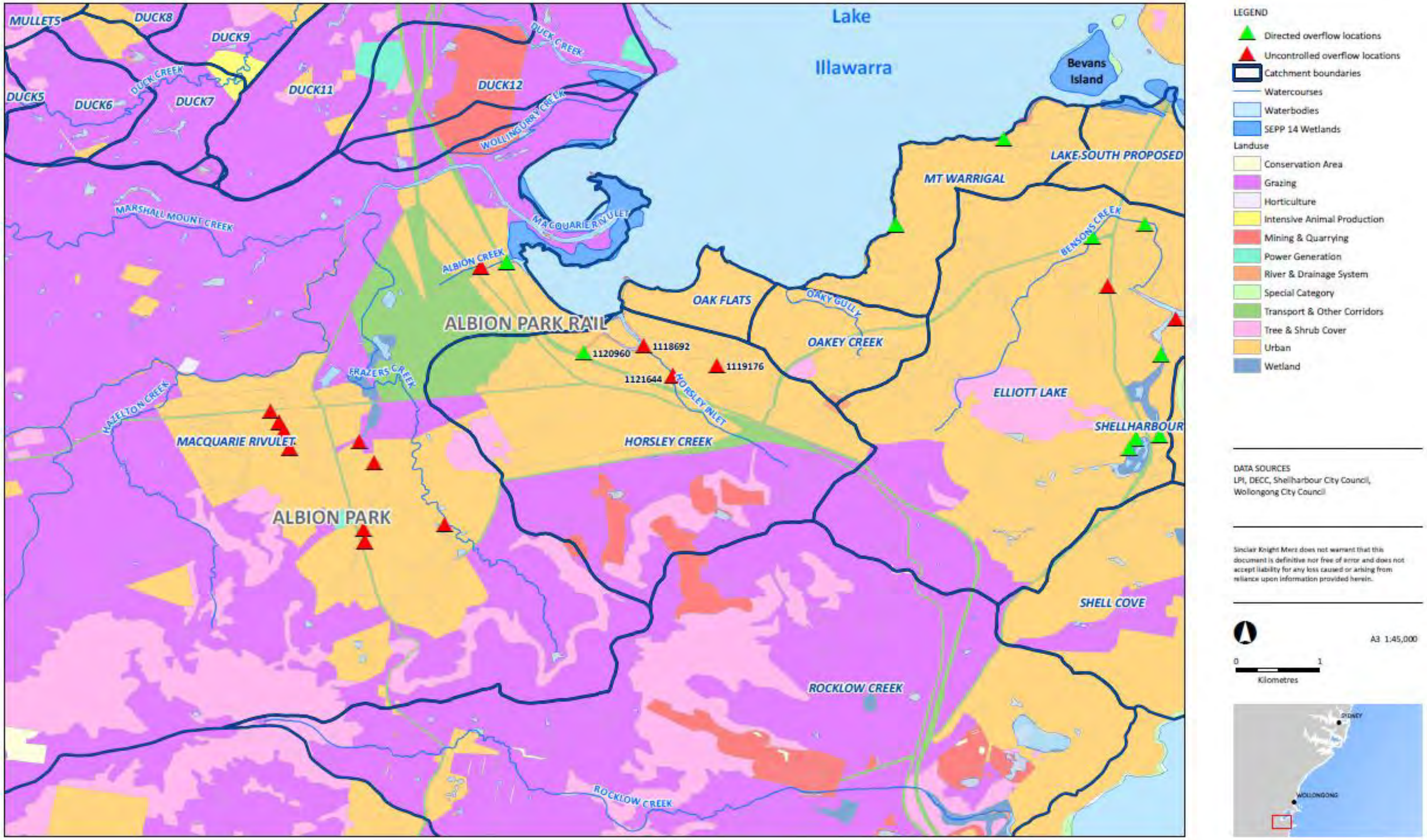
- **Figure 4-3 Directed and Uncontrolled (high and highest) overflows in the Barrack Creek catchment**

Horsley and Connor Creek Catchment

One directed overflow site (1120960) was identified to be carried forward to the impact assessment. This site is shown in Figure 4-4 and the frequency and volume of overflows are summarised in Table 4-5.

- **Table 4-5 Frequency and volumes of risk prioritised directed overflows in the Horsley and Connor Creek Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
1120960	23	17,242	7,497	28	22,810	8,260	38	35,337	9,299



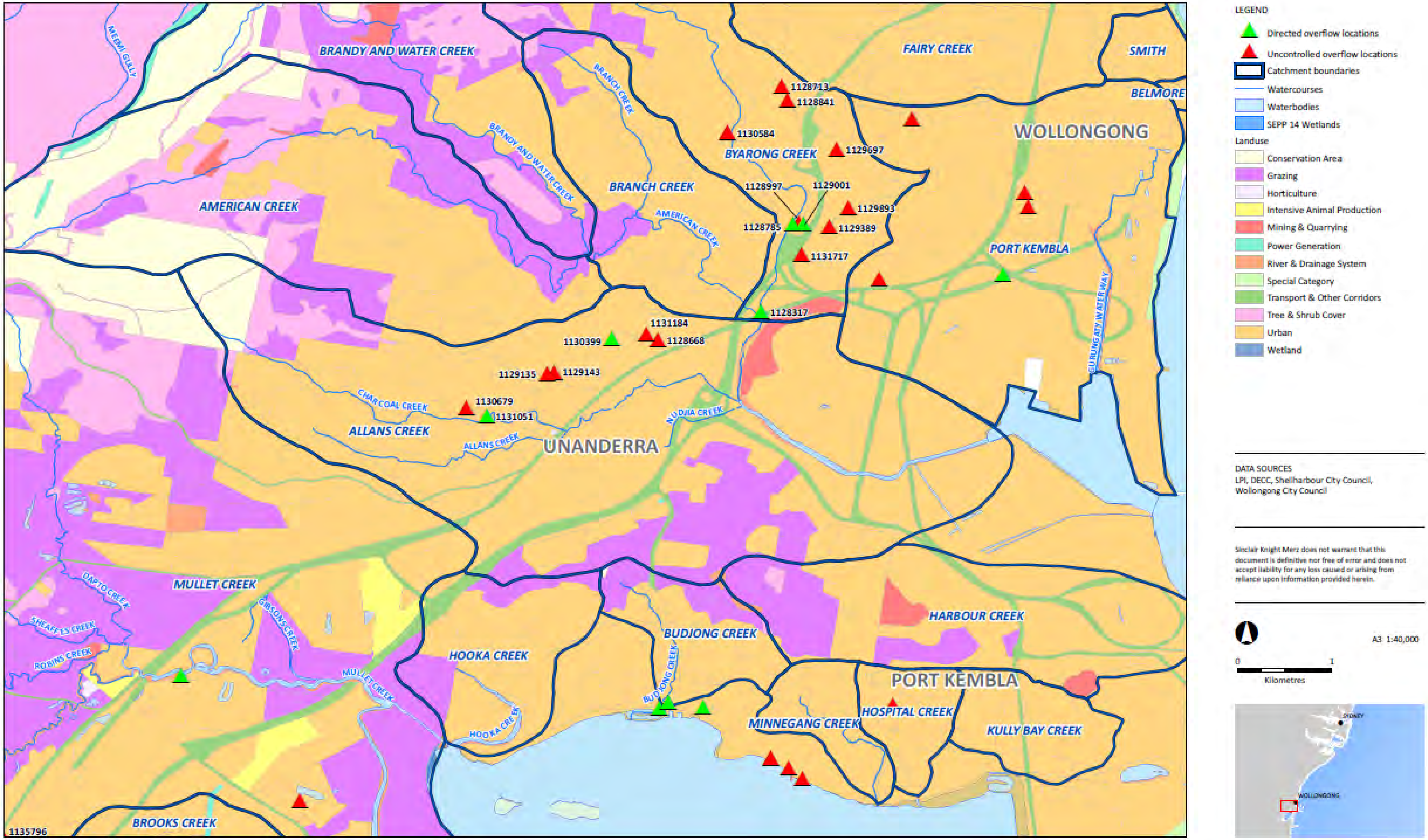
■ **Figure 4-4 Directed and uncontrolled (high and highest) Overflows in the Horsley and Connor Creek Catchment**

Allan’s Creek Catchment

Five directed overflow sites (1131051, 1129001, 1130399, 1128785 and 1128317) located in the Allan’s (and Byarong) Creek Catchment were identified to be carried forward to the impact assessment. These locations are shown in Figure 4-5 and the frequency and volume of overflows in 2009, 2021 and 2048 are summarised in Table 4-6.

- **Table 4-6 Frequency and volumes of risk prioritised directed overflows in the Allan’s Creek Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
1131051	12	327	272	13	367	284	15	457	305
1129001	34	1,470	432	8	409	511	26	1,330	511
1130399	31	5,130	1,655	9	2,567	2,780	30	8,341	2,780
1128785	33	7,607	2,305	10	3,088	3,237	31	10,036	3,237
1128317	12	2,677	2,231	18	5,439	3,029	21	6,361	3,029



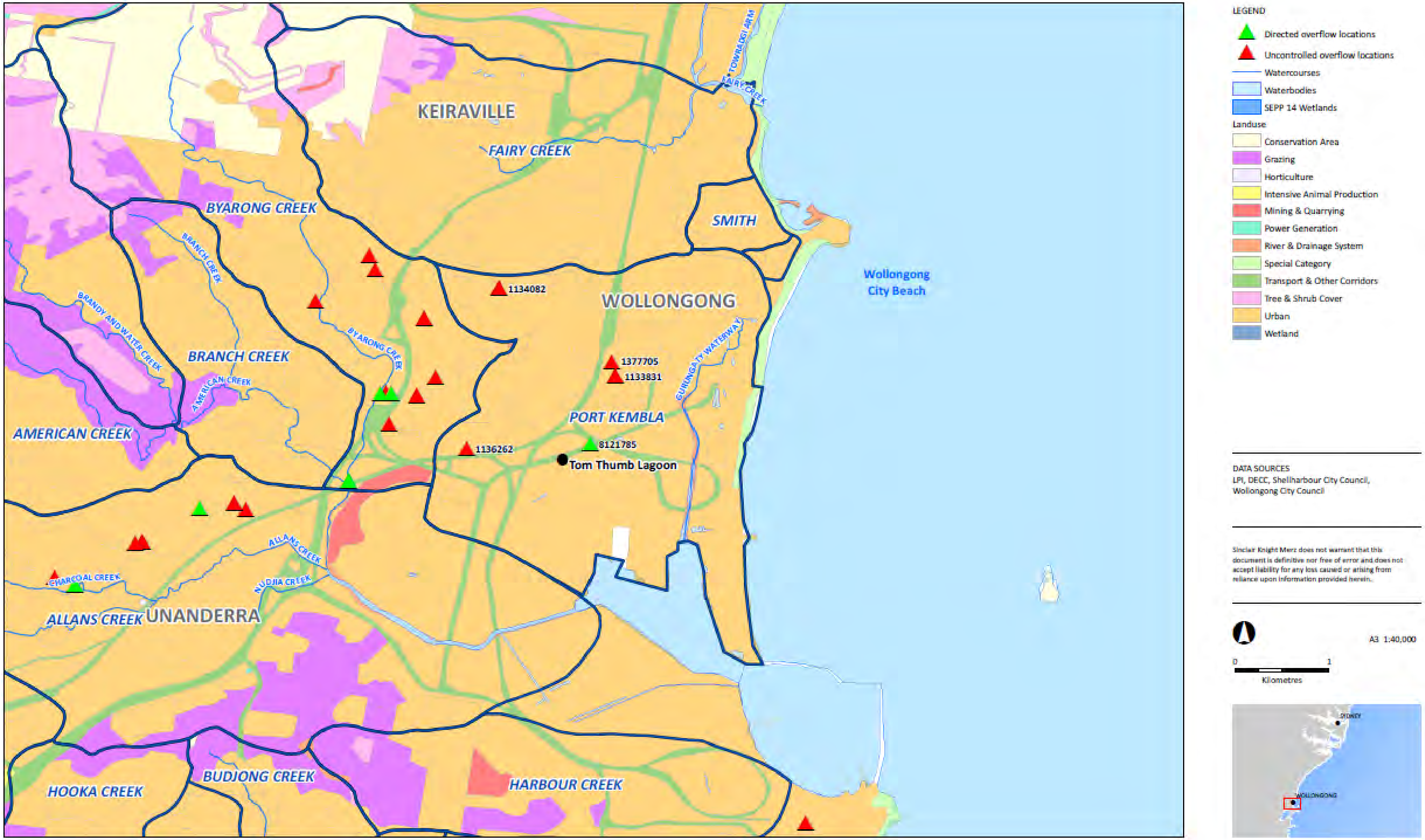
■ **Figure 4-5 Directed and uncontrolled (high and highest) overflows in the Allan's Creek Catchment**

Port Kembla Catchment

One directed overflow (8121785) located in the Port Kembla Catchment was identified to be carried forward to the impact assessment. This site is shown in Figure 4-6 and summarised in Table 4-7.

- **Table 4-7 Frequency and volumes of risk prioritised directed overflows in the Port Kembla Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
8121785	23	22,120	9617	29	33,365	11,478	34	39,024	11,478



- **Figure 4-6 Directed and uncontrolled (high and highest) overflows in the Port Kembla Catchment**

4.1.3. Uncontrolled Overflows

Port Kembla Wastewater System

Lake Illawarra Catchment

Seven uncontrolled overflow sites (1141135, 1141999, 1142022, 1139143, 1139339, 1396642 and 1118692) located in the Lake Illawarra catchment were identified to be carried forward to the impact assessment. The frequency and volume of these overflows in 2009, 2021 and 2048 are summarised in Table 4-8. The location of overflows is shown in Figure 4-1.

- **Table 4-8 Frequency and volumes of risk prioritised uncontrolled overflows in the Lake Illawarra Catchment (Port Kembla Wastewater System)**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
1141135	9	174	193	10	214	216	12	304	253
1141999	29	671	231	31	757	248	34	952	280
1142022	18	682	379	19	747	395	21	894	426
1139143	29	863	297	31	989	318	36	1,274	354
1139339	40	2,851	713	42	3,188	756	47	3,947	840
1396642	11	1,884	1,713	13	2,217	1,685	18	2,964	1,647
1118692	22	4,331	1,969	24	5,266	2,153	30	7,495	2,418

Mullet Creek Catchment

Six uncontrolled overflow sites (1135796, 1133545, 1142018, 1136273, 1135500 and 1132832) located in the Mullet Creek catchment were identified to be carried forward to the impact assessment. These sites are shown in Figure 4-2 and summarised in Table 4-9.

- **Table 4-9 Frequency and volumes of uncontrolled overflows in the Mullet Creek Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
1135796	6	186	310	8	473	603	12	1,119	933
1133545	9	281	312	10	336	350	11	462	420
1142018	17	672	395	18	805	457	19	1,105	582
1136273	10	715	715	11	833	742	14	1,100	786
1135500	6	756	1,260	12	4,130	3,487	25	11,722	4,689
1132832	12	2,101	1,751	14	2,532	1,870	17	3,503	2,060

Ocean Outfalls

One uncontrolled overflow site (1140820) from ocean outfalls is subject to impact assessment and summarised in Table 4-10.

- **Table 4-10 Frequency and volumes of uncontrolled overflows from ocean outfalls**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
1140820	21	2,363	1,125	22	2,560	1,185	23	3,004	1,306

Barrack Creek Catchment

Two uncontrolled overflow sites (1123653 and 1127548) located in the Barrack Creek catchment are subject to impact assessment. The frequency and volume of overflows for 2009, 2021 and 2048 are presented in Table 4-11. The overflows locations are shown in Figure 4-3.

- **Table 4-11 Frequency and volumes of uncontrolled overflows in the Barrack Creek Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequecy/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
1123653	29	881	304	31	970	318	34	1,170	344
1127548	28	7,781	2,779	30	8,473	2,781	36	10,032	2,866

Horsley and Connor Creek Catchment

Two uncontrolled overflow sites (1119176 and 1121644) located in the Horsley and Connor Creek are subject to impact assessment. These sites are shown in Figure 4-4 and summarised in Table 4-12.

- **Table 4-12 Frequency and volumes of uncontrolled overflows in the Horsley and Connor Creek Catchment**

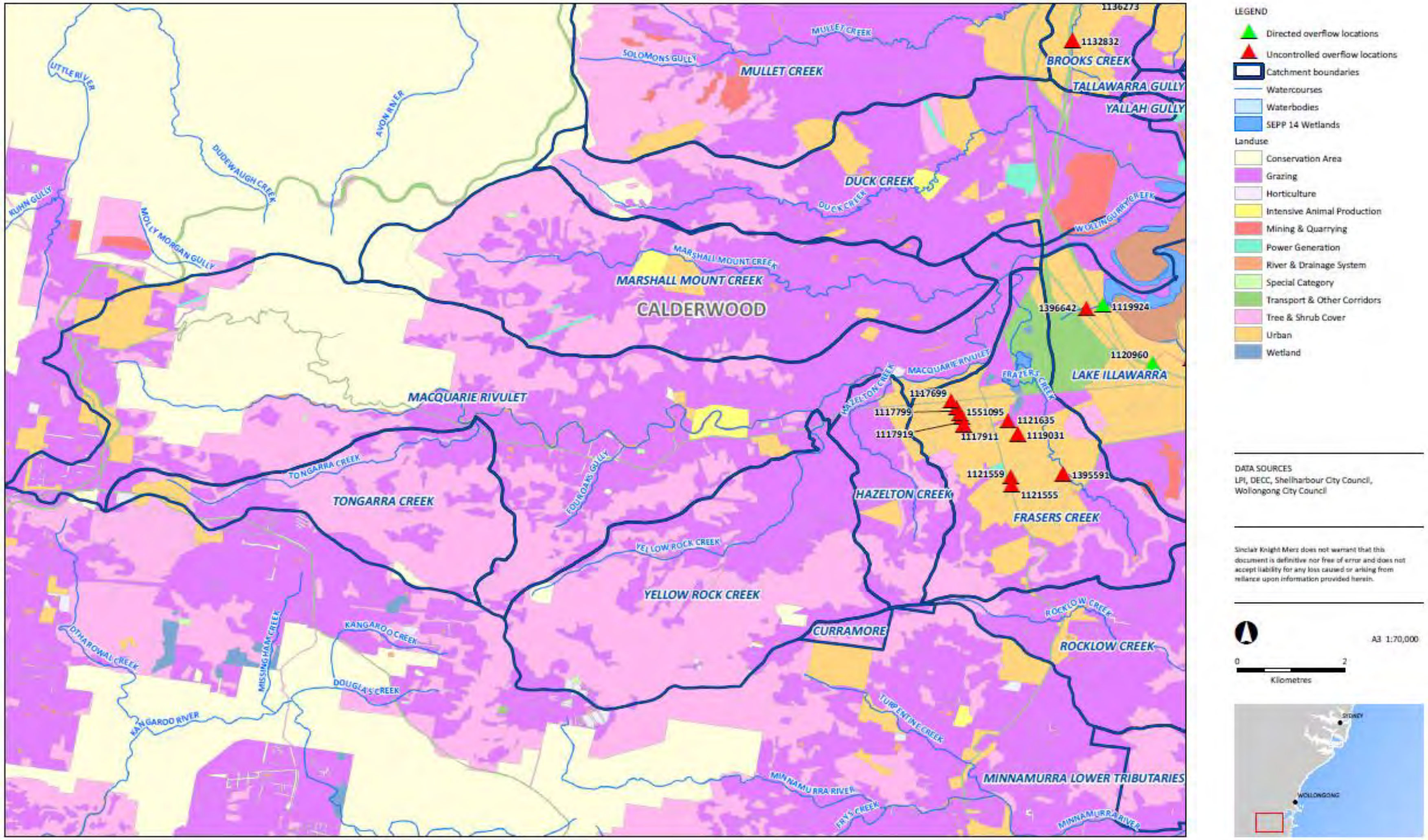
Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
1119176	2	233	1,164	3	287	982	5	410	820
1121644	6	461	768	7	605	914	8	934	1,168

Macquarie Rivulet Catchment

Ten uncontrolled overflow sites (1551095, 1117919, 1117911, 1395591, 1121559, 1117699, 1117799, 1119031, 1121555 and 1121635) located in the Macquarie Rivulet catchment are subject to further assessment. The location of overflows is shown in Figure 4-7and the frequency and volume of overflow are summarised in Table 4-13.

- **Table 4-13 Frequency and volumes of uncontrolled overflows in the Macquarie Rivulet Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
1551095	10	124	124	11	137	125	13	167	128
1117919	9	185	206	10	207	203	13	257	197
1117911	8	299	374	9	344	386	11	445	405
1395591	7	329	470	9	400	453	13	561	431
1121559	9	349	388	11	406	364	16	533	333
1117699	9	472	524	10	537	541	12	686	572
1117799	10	572	572	11	631	562	14	764	546
1119031	7	598	854	9	690	729	15	898	599
1121555	9	847	941	11	1,012	907	16	1,382	863
1121635	13	3,665	2,819	16	4,208	2,618	23	5,431	2,361



- **Figure 4-7 Uncontrolled (high and highest) overflows in the Macquarie Rivulet catchment**

Allan's Creek Catchment

Fourteen uncontrolled overflow sites (1130679, 1136262, 1129143, 1128713, 1131717, 1128997, 1129135, 1129893, 1130584, 1129697, 1128841, 1128668, 1129389 and 1131184) located in the Allan's Creek catchment are subject to further assessment. These sites are shown in Figure 4-5 and summarised in Table 4-14.

- **Table 4-14 Frequency and volumes of uncontrolled overflows in the Allan's Creek Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
1130679	9	25	28	10	61	59	13	140	108
1136262	19	100	52	21	118	58	24	160	67
1129143	13	111	85	14	129	92	16	169	105
1128713	15	128	85	15	145	95	16	185	115
1131717	27	128	47	28	150	54	30	200	67
1128997	14	186	133	1	3	26	4	10	26
1129135	14	191	136	15	221	145	18	288	160
1129893	9	200	222	10	238	232	13	324	249
1130584	8	221	276	2	310	1258	8	510	637
1129697	16	228	142	19	266	142	25	352	141
1128841	18	293	163	20	370	181	26	542	209
1128668	6	331	552	8	614	753	13	1,251	962
1129389	24	836	348	26	949	367	30	1,204	401
1131184	13	1,211	932	15	1,471	971	20	2,056	1,028

Port Kembla Catchment

Three uncontrolled overflow sites (1134082, 1377705 and 1133831) located in the Port Kembla are subject to further assessment. These sites are shown in Figure 4-6 and summarised in Table 4-15.

- **Table 4-15 Frequency and volumes of uncontrolled overflows in the Port Kembla Catchment**

Overflow ID	2009			2021 (project approval)			2048 (concept approval)		
	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/ yr)	Volume (KL/ event)	Frequency/ 10yr	Volume (KL/yr)	Volume (KL/ event)
1134082	19	308	162	21	345	168	24	428	178
1377705	23	310	135	6	46	74	20	148	74
1133831	33	1,117	339	7	246	333	24	799	333

4.2. Mass Balance

4.2.1. Overview

A mass balance assessment was undertaken for both directed and uncontrolled overflows that were prioritised as high or highest risk. The mass balance for each overflow location was undertaken for current (2009) conditions, the year 2021 (for which project approval is sought) and the year 2048 (for which concept approval is sought). Pollutant indicator loads examined using the mass balance model were total suspended solids (TSS), total nitrogen (TN), total phosphorous (TP), and faecal coliforms (FC). The results of the mass balance assessment are provided in detail in Appendix B and summarised below.

4.2.2. Summary of Mass Balance Results

Table 4-16 presents the percentage change in event loading for both directed and uncontrolled overflows from 2009 to 2021 and from 2009 to 2048 relative to the 2009 event loading. This allows the identification of those overflows that present a potential impact between 2009 and 2021 that will need to be addressed for project approval. Those overflows that present a potential impact between 2009 and 2048 that will need to be addressed for concept approval. Any overflows that have no change or reduced load/event are considered to not have an impact and therefore will not be subject to any further assessment. Alternatively, those overflows that increase in event loading will be subject to impact assessment.

- **Table 4-16 Percentage change in event loading for directed and uncontrolled overflows**

Overflow	System	Catchment	Percentage Change in Event Loading		Subject to Impact Assessment
			2009-2021	2009-2048	
Directed Overflows					
SCOF106	Port Kembla	Lake Illawarra	-34.1%	-15.2%	No
SCOF108	Port Kembla	Lake Illawarra	-37.7%	-29.5%	No
SCOF107	Port Kembla	Lake Illawarra	60.7%	76.4%	Yes
1400000	Shellharbour	Lake Illawarra	-17.3%	-14.8%	No
1119924	Shellharbour	Lake Illawarra	-20.7%	-16.9%	No
1121017	Shellharbour	Lake Illawarra	-18.4%	-12.1%	No
SCOF117	Port Kembla	Mullet Creek*	195.0%	240.6%	Yes
CMSP343	Shellharbour	Barrack Creek	-12.8%	-14.0%	No
1400028	Shellharbour	Barrack Creek	4.4%	11.8%	Yes
1123473	Shellharbour	Barrack Creek	-5.2%	-4.7%	No
1125705	Shellharbour	Barrack Creek	45.2%	62.1%	Yes

Overflow	System	Catchment	Percentage Change in Event Loading		Subject to Impact Assessment
			2009-2021	2009-2048	
1122981	Shellharbour	Barrack Creek	28.6%	28.3%	Yes
1125953	Shellharbour	Barrack Creek	-16.0%	-17.5%	No
1120960	Shellharbour	Horsley & Connor Ck*	-3.7%	8.4%	Yes
1131051	Wollongong	Allan's Creek	-13.7%	-7.4%	No
1129001	Wollongong	Allan's Creek	-4.3%	-4.3%	No
1130399	Wollongong	Allan's Creek	43.0%	43.0%	Yes
1128785	Wollongong	Allan's Creek	31.0%	31.0%	Yes
1128317	Wollongong	Allan's Creek	43.7%	43.7%	Yes
8121785	Wollongong	Port Kembla	19.2%	19.2%	Yes
Uncontrolled Overflows					
1141135	Port Kembla	Lake Illawarra	-26.2%	-13.3%	No
1141999	Port Kembla	Lake Illawarra	2.0%	15.2%	Yes
1142022	Port Kembla	Lake Illawarra	3.2%	11.2%	Yes
1139143	Port Kembla	Lake Illawarra	-17.0%	-7.5%	No
1139339	Port Kembla	Lake Illawarra	-13.1%	-3.6%	No
1135796	Port Kembla	Mullet Creek*	98.9%	207.4%	Yes
1133545	Port Kembla	Mullet Creek*	-6.3%	12.4%	Yes
1142018	Port Kembla	Mullet Creek*	7.4%	36.6%	Yes
1136273	Port Kembla	Mullet Creek*	-16.0%	-11.0%	No
1135500	Port Kembla	Mullet Creek*	168.8%	261.5%	Yes
1132832	Port Kembla	Mullet Creek*	-14.4%	-5.7%	No
1140820	Port Kembla	Ocean Outfalls	-25.0%	-17.3%	No
1123653	Shellharbour	Barrack Creek	2.9%	11.4%	Yes
1127548	Shellharbour	Barrack Creek	-20.2%	-28.0%	No
1119176	Shellharbour	Horsley & Connor Ck*	-28.1%	-40.0%	No
1121644	Shellharbour	Horsley & Connor Ck*	-8.1%	17.4%	Yes
1396642	Shellharbour	Lake Illawarra	-24.5%	-26.2%	No
1118692	Shellharbour	Lake Illawarra	-11.9%	-1.0%	No
1551095	Shellharbour	Macquarie Rivulet*	-14.6%	-12.7%	No
1117919	Shellharbour	Macquarie Rivulet*	-3.8%	-6.2%	No
1117911	Shellharbour	Macquarie Rivulet*	4.6%	9.8%	Yes
1395591	Shellharbour	Macquarie Rivulet*	1.1%	-3.7%	Yes
1121559	Shellharbour	Macquarie Rivulet*	-19.3%	-26.1%	No
1117699	Shellharbour	Macquarie Rivulet*	-13.3%	-8.4%	No
1117799	Shellharbour	Macquarie Rivulet*	-6.2%	-8.9%	No

Overflow	System	Catchment	Percentage Change in Event Loading		Subject to Impact Assessment
			2009-2021	2009-2048	
1119031	Shellharbour	Macquarie Rivulet*	-28.3%	-41.1%	No
1121555	Shellharbour	Macquarie Rivulet*	-17.0%	-20.9%	No
1121635	Shellharbour	Macquarie Rivulet*	-20.2%	-28.0%	No
1130679	Wollongong	Allan's Creek	86.7%	238.9%	Yes
1136262	Wollongong	Allan's Creek	1.1%	17.3%	Yes
1129143	Wollongong	Allan's Creek	-0.7%	13.2%	Yes
1128713	Wollongong	Allan's Creek	1.9%	24.1%	Yes
1131717	Wollongong	Allan's Creek	7.6%	33.5%	Yes
1128997	Wollongong	Allan's Creek	-84.0%	-84.0%	No
1129135	Wollongong	Allan's Creek	8.5%	19.8%	Yes
1129893	Wollongong	Allan's Creek	5.1%	12.7%	Yes
1130584	Wollongong	Allan's Creek	303.9%	104.5%	Yes
1129697	Wollongong	Allan's Creek	-37.1%	-37.5%	No
1128841	Wollongong	Allan's Creek	0.8%	16.4%	Yes
1128668	Wollongong	Allan's Creek	24.3%	58.8%	Yes
1129389	Wollongong	Allan's Creek	0.8%	10.2%	Yes
1131184	Wollongong	Allan's Creek	-6.4%	-0.9%	No
1134082	Wollongong	Port Kembla	-10.0%	-4.4%	No
1377705	Wollongong	Port Kembla	-50.0%	-50.0%	No
1133831	Wollongong	Port Kembla	-6.1%	-6.1%	No

* Sub-catchment of Lake Illawarra
No = no change therefore no impact assessment
Yes = increased loads/event and will be further assessed
A negative percent change indicates a reduction in overflow loadings in average events during that time period

It can be seen from Table 4-30 that the Proposal results in no net increase in pollutant loads per event at 10 of the 20 directed overflows. In fact it is predicted there will be modest reductions in event pollutant loads at these overflows due to reduced overflow frequency. Frequency of overflow is reduced due to increased hydraulic capacity of the system and/or the overflow is the subject of programmed maintenance works. Loads per event at directed overflows are predicted to reduce by 3.7 to 37.7% of loads currently occurring. Of the 10 directed overflows that have a net increase, nine present potential increases in loads per event between 2009 and 2021 and between 2009 and 2048. These overflows will be subject to further impact assessment to determine potential impact on water quality, aquatic ecology and public health, mitigation measures will be suggested. Directed overflow 1120960 in the Allan's Creek catchment shows no increase in event loads between 2009 and 2021, but between 2021 and 2048 loads per event increase relative to 2009 and therefore require further impact assessment in order to gain concept approval.

There were 45 uncontrolled overflows subjected to the mass balance assessment with 24 found to have no increase in loads per event as a result of the Proposal. There were, however, 17 overflows where loads per event potentially increase and will therefore require further assessment to determine their impact on environmental values in order to obtain project and concept approval. Of the remaining 4 uncontrolled overflows, overflow 1395591 presents a potential impact between 2009 and 2021 only, and therefore needs to be assessed for project approval, and overflows 1133545, 1121644 and 1129143 present a potential impact between 2021 and 2048 relative to 2009 and therefore need to be assessed for concept approval.

5. Impact Assessment Results

5.1 Directed Overflows

Given that the purpose of this assessment is to determine the impact of the Proposal on relevant environmental values, if loads per event do not change or decrease from the 2009 base case, then the Proposal will not have an impact at these locations. As such those overflows in Table 4-16 with 'no' will not be considered further. Through a combination of hydraulic modelling, risk analysis and mass balance modelling the directed overflows that have been found to have an increase in loads per event due to the Proposal and that will be further considered are:

- SCOF107 in the Lake Illawarra Catchment (Port Kembla System)
- SCOF117 in the Mullet Creek Catchment
- 1400028, 1125705 and 1122981 in the Barrack Creek Catchment
- 1120960 in the Horsley and Connor Creek Catchment
- 1130399, 1128785 and 1128317 in the Allan's Creek Catchment
- 8121785 in the Port Kembla Catchment.

Each will be discussed in the light of potential impacts on relevant environmental values and associated mitigation measures where necessary. Graphical representations of loads per event for these directed overflows can be found at Appendix C and D and Tables 5-1 to 5-30.

5.1.1. Lake Illawarra

Overflow reference # SCOF107

This directed overflow was included for further assessment because of its high and highest risk to environmental values in 2021 and 2048 respectively. It discharges directly to Budjong Creek which discharges to Lake Illawarra. It is a popular area for recreation and has a boat ramp located in the vicinity of the overflow. Aquatic ecosystems such as seagrass also exist in Budjong Creek.

The frequency of overflows at SCOF107 was found to increase from 13 per 10 year period in 2009 to 19 and 32 events in 2021 and 2048 respectively. As shown in Table 5-1, whilst the number of overflow events, loads (annually and per event) and concentrations at SCOF107 increase as a result of the Proposal, the actual contribution of loads annually from this directed overflow is quite small compared to estimated stormwater loads into Lake Illawarra.

▪ **Table 5-1 SCOF107 annual pollutant loads and overflow concentration, and Lake Illawarra annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	57	133	247	891934	10	24	45	8939
Overflow Concentration (mg/L)	9.9	14.2	14.2	-	1.82	2.61	2.61	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	2	4	8	2078	1.9×10^{13}	4.4×10^{13}	8.2×10^{13}	1.2×10^{15}
Overflow Concentration (mg/L)	0.33	0.47	0.47	-	3.3×10^{5}	4.7×10^{5}	4.7×10^{5}	-

5.1.2. Mullet Creek

Overflow reference # SCOF117

This directed overflow was included for further assessment because of its highest risk to environmental values (aquatic ecosystems and recreation) in 2009, 2021 and 2048. SCOF117 discharges directly to Mullet Creek which then discharges to Lake Illawarra. The frequency of overflows at SCOF117 was found to increase from 13 per 10 year period in 2009 to 21 and 39 events in 2021 and 2048 respectively. As shown in Table 5-32 the number of overflow events, loads (annually and per event) and concentrations at SCOF117 noticeably increase as a result of the Proposal. Whilst the actual contribution of loads annually from this directed overflow is less than estimated annual stormwater loads in the Mullet Creek Catchment, the ratio between the two is noticeable. These high loads of nutrients and TSS may present an impact to aquatic ecosystems, and the increased loads in faecal coliforms may impact on recreational suitability, however these will be discussed further in Section 6.

- **Table 5-2 SCOF117 annual pollutant loads and overflow concentration, and Mullet Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	527	2512	5385	1551983	97	461	987	19136
Overflow Concentration (mg/L)	30	70	70	-	5.5	12.9	12.9	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	18	84	180	4211	$1.7x10^{14}$	$8.4x10^{14}$	$1.8x10^{15}$	$2.02x10^{15}$
Overflow Concentration (mg/L)	1	2.3	2.3	-	$1x10^{6}$	$2.3x10^{6}$	$2.3x10^{6}$	-

5.1.3. Barrack Creek

Overflow reference # 1400028

This directed overflow 1400028 was included for further assessment because of its high risk to the aquatic ecosystem value in both 2021 and 2048. It discharges (via stormwater drains) to Bensons Creek which enters Little Lake. Little Lake contains important aquatic ecosystems such as seagrass. The frequency of overflows at 1400028 was found to increase from 23 per 10 year period in 2009 to 25 and 31 events in 2021 and 2048 respectively.

As shown in Table 5-3, whilst the number of events (and loads) increase at this directed overflow from 25 to 31 events per 10 year period between 2009, 2021 and 2048, the concentrations of TSS, TN and TP per event are predicted not to change. This is primarily due to the fact that the predicted increase in infiltration and associated stormwater dilution within the system will effectively lead to similar concentrations of these constituents in 2021 and 2048.

- **Table 5-3 1400028 annual pollutant loads and overflow concentration, and Barrack Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	59	69	90	570479	11	13	16	5289
Overflow Concentration (mg/L)	25.9	25.9	25.9	-	4.7	4.7	4.7	-

Pollutant	TP				FC			
Annual Loads (kg/year)	1.9	2.2	2.9	1334	1.98×10^{13}	2.29×10^{13}	2.99×10^{13}	2.08×10^{15}
Overflow Concentration (mg/L)	0.86	0.86	0.86	-	8.64×10^{5}	8.64×10^{5}	8.64×10^{5}	-

Overflow reference # 1125705

This directed overflow was included for further assessment because of its highest risk to environmental values including human health in both 2021 and 2048. It discharges to Little Lake and Barrack Swamp, a freshwater wetland where important aquatic ecosystems, including seagrass exist. Little Lake discharges to the ocean at Warilla Beach. The Lake is used for both primary and secondary contact recreational purposes. The frequency of overflows at 1125705 was found to increase from 34 per 10 year period in 2009 to 37 and 43 events in 2021 and 2048 respectively.

Table 5-4 shows that whilst the number of overflow events, loads (annually and per event) and concentrations at 1125705 increase as a result of the Proposal, the actual contribution of loads annually from this directed overflow is less than estimated annual stormwater loads into Lake Illawarra. Considering it discharges to the same location as 1122981 (discussed below) which also shows increased loads, there is the potential for overflows to impact on environmental values if the pollutants are not readily assimilated by the receiving wetland.

- **Table 5-4 1125705 annual pollutant loads and overflow concentration, and Barrack Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	TSS				TN			
Annual Loads (kg/year)	467	733	957	570479	86	134	175	5289
Overflow Concentration (mg/L)	30.5	41.4	41.4	-	5.6	7.6	7.6	-
Pollutant	TP				FC			
Annual Loads (kg/year)	16	24	32	1334	1.56×10^{14}	2.44×10^{14}	3.19×10^{14}	2.08×10^{15}
Overflow Concentration (mg/L)	1.02	1.38	1.37	-	1.02×10^{6}	1.38×10^{6}	1.38×10^{6}	-

Overflow reference # 1122981

This directed overflow was included for further assessment because it presents the highest risk to the environmental value aquatic ecosystems in both 2021 and 2048 as it discharges directly to man-made wetlands near Barrack Creek. The frequency of overflows at 1122981 was found to increase from 29 per 10 year period in 2009 to 32 and 40 events in 2021 and 2048 respectively. Similarly to directed overflow 1125705, this directed overflow shows an increase in overflow events, loads (annually and per event) and concentrations as a result of the Proposal (Table 5-5). Annual overflow loads, are estimated to be less than annual stormwater loads, however depending on the capacity of the wetlands and if overflows are occurring simultaneously, overflow loads may impact on environmental values.

- **Table 5-5 1122981 annual pollutant loads and overflow concentration, and Barrack Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	643	923	1137	570479	118	169	208	5289
Overflow Concentration (mg/L)	30.7	39.6	39.6	-	5.6	7.3	7.3	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	21	31	38	1334	$2.1x10^{14}$	$3.1x10^{14}$	$3.8x10^{14}$	$2.08x10^{15}$
Overflow Concentration (mg/L)	1.02	1.3	1.3	-	$1.02x10^{6}$	$1.32x10^{6}$	$1.32x10^{6}$	-

5.1.4. Horsley and Connor Creek

Overflow reference # 1120960

This directed overflow was included for further assessment because of its highest risk to environmental values aquatic ecosystems and recreation in both 2021 and 2048. It discharges to Horsley Creek which discharges to Lake Illawarra where aquatic ecosystems such as seagrass exist. Horsley Creek also drains to Koona Bay Beach, a popular recreational area. The frequency of overflows at 1120960 was found to increase from 23 per 10 year period in 2009 to 28 and 27 events in 2021 and 2048 respectively.

It is noteworthy that while the number of events increase (loads per event decrease) at this directed overflow between 2009 and 2021 and decrease between 2021 and 2048, the concentrations of TSS, TN and TP per event are predicted to decrease between 2009 and 2021/2048 (Table 5-6). This is primarily due to the fact that the predicted increase in infiltration and associated stormwater dilution within the system will effectively lead to similar concentrations of these constituents in 2021 and 2048. Annual overflow loads show relatively small increases, particularly between 2009 and 2021 and are noticeably less than estimated annual stormwater loads in the Horsley and Connor Creek catchment.

- **Table 5-6 1120960 annual pollutant loads and overflow concentration, and Horsley and Connor Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	327	378	585	366302	60	69	107	3404
Overflow Concentration (mg/L)	18.9	16.5	16.5	-	3.4	3.04	3.04	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	11	13	20	859	$1.1x10^{14}$	$1.2x10^{14}$	$1.9x10^{14}$	$5.2x10^{15}$
Overflow Concentration (mg/L)	0.63	0.55	0.55	-	$6.3x10^{5}$	$5.5x10^{5}$	$5.5x10^{5}$	-

5.1.5. Allan's Creek

Overflow reference # 1130399

This directed overflow was included for further assessment because of its high and highest risk to the environmental value aquatic ecosystems in 2021 and 2048 respectively. It discharges directly to Allan's Creek which flows into Port Kembla Harbour. The frequency of overflows at 1130399 was found to decrease from 31 per 10 year period in 2009 to 9 events in 2021 and increase to 30 events per 10 year period in 2048 respectively.

It is noteworthy that while the number of events (and loads) decrease between 2009 and 2021 but increase between 2021 and 2048, the concentrations of TSS, TN and TP per event are predicted to decrease (Table 5-7). This is primarily due to the fact that the predicted increase in infiltration and associated stormwater dilution within the system will effectively lead to similar concentrations of these constituents in 2021 and 2048. Annual wastewater loads at this directed overflow are small compared to estimated annual stormwater loads in the Allan's Creek Catchment.

- **Table 5-7 1130399 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	242	103	335	1515670	44	19	61	15593
Overflow Concentration (mg/L)	47.2	40.2	40.2	-	8.66	7.37	7.37	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	8	3	11	3663	8.1×10^{13}	3.4×10^{13}	1.1×10^{14}	2.08×10^{15}
Overflow Concentration (mg/L)	1.57	1.34	1.34	-	1.57×10^{6}	1.34×10^{6}	1.34×10^{6}	-

Overflow reference # 1128785

This directed overflow was included for further assessment because of its high risk to the environmental value of aquatic ecosystems in 2021 and highest risk in 2048. It discharges directly to Byarong Creek which enters Brandy and Water Creek before Allan's Creek. Allan's Creek flows into Port Kembla Harbour. The frequency of overflows at 1128785 was found to decrease from 33 per 10 year period in 2009 to 10 events in 2021 and increase to 29 events per 10 year period in 2048 respectively.

Table 5-8 shows that whilst number of events per 10 year period essentially decreases, and the event loads increase (between 2009 and 2021) the concentrations of TSS, TN and TP per event are predicted to decrease after 2009. This is primarily due to the fact that the predicted increase in infiltration and associated stormwater dilution within the system will effectively lead to similar concentrations of these constituents in 2021 and 2048. Whilst annual loads are expected to increase as a result of the Proposal, and are greater than other overflows in this catchment, the relative contribution is still small compared to estimated annual stormwater loads.

- **Table 5-8 1128785 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	386	146	475	1515670	71	27	87	15593

Overflow Concentration (mg/L)	50.68	47.29	47.29	-	9.3	8.7	8.7	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	13	5	16	3663	1.29x10^{14}	4.87x10^{13}	1.58x10^{14}	2.08x10^{15}
Overflow Concentration (mg/L)	1.7	1.6	1.6	-	1.7x10^{6}	1.6x10^{6}	1.6x10^{6}	-

Overflow reference # 1128317

This directed overflow was included for further assessment because of its high risk to the environmental value aquatic ecosystems in both 2021 and 2048. It discharges directly to Byarong Creek and then to Allan's Creek and Port Kembla Harbour. The frequency of overflows at 1128317 was found to increase from 12 events per 10 year period in 2009 to 18 and 21 events in 2021 and 2048 respectively.

As shown in Table 5-9, whilst the number of overflow events, loads (annually and per event) and concentrations at 1128317 increase as a result of the Proposal, the actual contribution of loads annually from this directed overflow is quite small compared to estimated stormwater loads in the Allan's Creek catchment.

- **Table 5-9 1128317 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	111	240	280	1515670	20	44	51	15593
Overflow Concentration (mg/L)	41.6	44.1	44.1	-	7.6	8.1	8.1	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	4	8	9	3663	3.71x10^{13}	8x10^{13}	9.3x10^{13}	2.08x10^{15}
Overflow Concentration (mg/L)	1.39	1.47	1.47	-	1.4x10^{6}	1.47x10^{6}	1.47x10^{6}	-

5.1.6. Port Kembla

Overflow reference # 8121785

This directed overflow was included for further assessment because of its highest risk to the environmental value of aquatic ecosystems in 2021 and 2048. It discharges to Tom Thumb Lagoon and wetlands before entering the ocean. Tom Thumb Lagoon contains endangered ecological communities. The frequency of overflows at 8121785 was found to increase from 23 events per 10 year period in 2009 to 29 and 30 events in 2021 and 2048 respectively.

It is noteworthy that while the frequency of events and pollutant loads increase at this directed overflow from 29 to 30 events per 10 year period between 2021 and 2048, the concentrations of TSS, TN and TP per event are predicted to decrease slightly from 2009 (Table 5-10). This is primarily due to the fact that the predicted increase in infiltration and associated stormwater dilution within the system will effectively lead to similar concentrations of these constituents in 2021 and 2048. Whilst annual loads are expected to increase as a result of the Proposal, the relative contribution is still small compared to estimated annual stormwater loads in Port Kembla, with the exception of faecal coliforms. In both 2021 and 2048, annual faecal coliforms loads are expected to be greater in overflows.

- **Table 5-10 8121785 annual pollutant loads and overflow concentration, and Port Kembla annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	1205	1815	2123	419106	221	333	389	3683
Overflow Concentration (mg/L)	54.5	54.4	54.4	-	9.98	9.97	9.97	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	40	61	71	955	$4x10^{14}$	$6x10^{14}$	$7x10^{14}$	$5.98x10^{14}$
Overflow Concentration (mg/L)	1.82	1.81	1.81	-	$1.82x10^{6}$	$1.81x10^{6}$	$1.81x10^{6}$	-

5.2. Uncontrolled Overflows

Following the same approach applied to the directed overflows, where event loads are not predicted to increase beyond existing loads during this timeframe, associated overflows have not been considered further. Through a combination of hydraulic modelling, risk analysis and mass balance modelling the following uncontrolled overflows have been found to have an increase in event loads due to the Proposal:

- 1141999 and 1142022 in the Lake Illawarra Catchment;
- 1135796, 1133545, 1142018 and 1135500 in the Mullet Creek Catchment;
- 1123653 in the Barrack Creek Catchment;

- 1121644 in the Horsley and Connor Creek Catchment;
- 1117911, 1395591in the Macquarie Rivulet Catchment;
- 1130679, 1136262, 1129143, 1128713, 1131717, 1129135, 1129893, 1130584, 1128841, 1128668 and 1129389 in the Allan's Creek Catchment.

Each will be discussed in the light of potential impacts on relevant environmental values and associated mitigation measures where necessary. Graphical representations of event loads for uncontrolled overflows can be found at Appendix B.

5.2.1. Lake Illawarra

Overflow reference # 1141999

This uncontrolled overflow was included for further assessment because of its high risk to aquatic ecosystems. It discharges directly to Windang Estuary which is located on Lake Illawarra. The estuary contains important aquatic ecosystems such as seagrass and is known habitat for migratory and non-migratory birds. . The frequency of overflows at 1141999 was found to increase from 29 per 10 year period in 2009 to 31and 34 events in 2021 and 2048 respectively.

Table 5-11 shows that whilst event loads and annual wastewater loads increase as a result of the Proposal, the contribution is minor compared to annual stormwater loads into Lake Illawarra.

- **Table 5-11 1141999 annual pollutant loads and overflow concentration, and Lake Illawarra annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	14	15	18	891934	2.5	2.6	3.3	8939
Overflow Concentration (mg/L)	20.2	19.2	19.2	-	3.7	3.5	3.5	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.45	0.48	0.6	2078	$4.5x10^{12}$	$4.85x10^{12}$	$6.1x10^{12}$	$1.2 x10^{15}$
Overflow Concentration (mg/L)	0.67	0.64	0.64	-	$6.7x10^{5}$	$6.4x10^{5}$	$6.4x10^{5}$	-

Overflow reference # 1142022

This uncontrolled overflow was included for further assessment as it presents medium risk to environmental values in 2009 and 2021 and high risk in 2048. The frequency of this overflow which discharges to Lake Illawarra increases from 18 per 10 year period in 2009 to 19 and 21 events in 2021 and 2048 respectively.

Table 5-12 shows that whilst event loads and annual wastewater loads increase as a result of the Proposal, the contribution is minor compared to annual stormwater loads into Lake Illawarra.

- **Table 5-12 1142022 annual pollutant loads and overflow concentration, and Lake Illawarra annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	13	14	16	891934	2.3	2.5	3	8939
Overflow Concentration (mg/L)	18.6	18.4	18.4	-	3.42	3.38	3.38	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.42	0.46	0.55	2078	4.24×10^{12}	4.6×10^{12}	5.5×10^{12}	1.2×10^{15}
Overflow Concentration (mg/L)	0.62	0.61	0.61	-	6.2×10^{5}	6.1×10^{5}	6.1×10^{5}	-

5.2.2. Mullet Creek

Overflow reference # 1135796

This uncontrolled overflow was included for further assessment because the risk to aquatic ecosystems shifts from medium (2009 and 20210) to high in 2048. It is located in the Mullet Creek Catchment and the frequency of overflows increase from 6 per 10 year period in 2009 to 8 and 12 events in 2021 and 2048 respectively.

Table 5-13 shows that the number of overflow events, pollutant concentrations, and pollutant loads (per event and annually) increase at 1135796 as a result of the Proposal, the relative contribution is very small compared to the estimated annual pollutant loads generated from stormwater in the Mullet Creek Catchment.

■ **Table 5-13 1135796 annual pollutant loads and overflow concentration, and Mullet Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	3	8	19	1551983	1	2	4	19136
Overflow Concentration (mg/L)	17	17.4	17.4	-	3.12	3.19	3.19	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.1	0.27	0.64	4211	$1.1x10^{12}$	$2.7x10^{12}$	$6.4x10^{12}$	$2.02x10^{15}$
Overflow Concentration (mg/L)	0.57	0.58	0.58	-	$5.76x10^{5}$	$5.8x10^{5}$	$5.8x10^{5}$	-

Overflow reference # 1133545

This uncontrolled overflow was included for further assessment because the risk to aquatic ecosystems shifts from medium (2009 and 20210) to high in 2048 The frequency of overflows was increase from 9 per 10 year period in 2009 to 10 and 11 events in 2021 and 2048 respectively.

Despite an increase in overflow events due to the Proposal there is no increase in pollutant loads at the uncontrolled overflow 1133545 between 2009 and 2021 (Table 5-14). Following 2021, annual wastewater loads increase but remain significantly less than the estimated annual stormwater loads in the Mullet Creek catchment. Overflow concentrations decrease as a result of the Proposal.

■ **Table 5-14 1133545 annual pollutant loads and overflow concentration, and Mullet Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	14	14	20	1551983	2.6	2.6	4	19136
Overflow Concentration (mg/L)	51.4	42.9	42.9	-	9.4	7.8	7.8	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.4	0.4	0.6	4211	$4.8x10^{12}$	$4.8x10^{12}$	$6.6x10^{12}$	$2.02x10^{15}$
Overflow Concentration (mg/L)	1.7	1.4	1.4	-	$1.7x10^{5}$	$1.4x10^{5}$	$1.4x10^{5}$	-

Overflow reference # 1142018

This uncontrolled overflow located in the Mullet Creek Catchment was included for further assessment because it presents a high risk to aquatic ecosystems, under current conditions, and in 2021 and 2048. The frequency of overflows at 1142018 increase from 17 per 10 year period in 2009 to 18 and 19 events in 2021 and 2048 respectively. Table 5-15 shows that whilst event loads and annual wastewater loads increase as a result of the Proposal, the contribution is minor compared to annual stormwater loads into Lake Illawarra.

- **Table 5-15 1142018 annual pollutant loads and overflow concentration, and Mullet Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	16	18	25	1551983	2.9	3.3	4.5	19136
Overflow Concentration (mg/L)	24.1	22.3	22.3	-	4.4	4.1	4.1	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.5	0.6	0.8	4211	$4.8x10^{12}$	$5.4x10^{12}$	$8.2x10^{12}$	$2.02x10^{15}$
Overflow Concentration (mg/L)	0.8	0.75	0.75	-	$8x10^{5}$	$7.4x10^{5}$	$7.4x10^{5}$	-

Overflow reference # 1135500

This uncontrolled overflow was included for further assessment because of its high risk to aquatic ecosystems in 2009 and 2021 and highest risk in 2048. The frequency of overflows at 1135500 were are one of the largest in the Mullet Creek Catchment, increasing from 6 per 10 year period in 2009 to 12 and 25 events in 2021 and 2048 respectively.

This uncontrolled overflow had the most noticeable increase in annual wastewater loads as a result of the Proposal, however overflow concentrations decrease slightly in 2021/2048 (Table 5-16). Despite noticeable increases in overflow events and annual loads, the relative contribution of pollutant loads from this overflow are minor compared to annual stormwater loads within the catchment.

- **Table 5-16 1135500 annual pollutant loads and overflow concentration, and Mullet Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	13	68	192	1551983	2	12	35	19136
Overflow Concentration (mg/L)	16.8	16.3	16.3	-	3.1	3	3	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.4	2	6	4211	4.25×10^{12}	2.3×10^{13}	6.4×10^{13}	2.02×10^{15}
Overflow Concentration (mg/L)	0.56	0.55	0.55	-	5.6×10^{5}	4.2×10^{5}	4.2×10^{5}	-

5.2.3. Barrack Creek

Overflow reference # 1123653

This uncontrolled overflow was included for further assessment because of his high risk to the environmental value aquatic ecosystems in 2021 and 2048. It discharges into Little Lake in the Barrack Creek Catchment. Little Lake contains important aquatic ecosystem values such as seagrass. The frequency of overflows at 1123653 increase from 29 per 10 year period in 2009 to 31 and 34 events in 2021 and 2048 respectively. Table 5-17 shows that despite an increase in overflow events due to the Proposal there are only small increases in pollutant loads at the uncontrolled overflow 1123653 between 2009 and 2021. Following 2021, annual wastewater loads increase but remain significantly less than the estimated annual stormwater loads in the Barrack Creek catchment. Overflow concentrations decrease as a result of the Proposal.

- **Table 5-17 1123653 annual pollutant loads and overflow concentration, and Barrack Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	13	14	17	570479	2.3	2.5	3.1	5289
Overflow Concentration (mg/L)	14.8	14.5	14.5	-	2.7	2.67	2.67	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.43	0.47	0.56	1334	4.3×10^{12}	4.7×10^{12}	5.6×10^{12}	2.08×10^{15}

Overflow Concentration (mg/L)	0.48	0.48	0.48	-	$4.9x10^5$	$4.85x10^5$	$4.85x10^5$	-

5.2.4. Horsley and Connor Creek

Overflow reference # 1121644

This uncontrolled overflow located in the Horsley and Connor Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2048. The frequencies of overflows are predicted to increase from 6 per 10 year period in 2009 to 7 and 8 events per 10 year period in 2021 and 2048 respectively. Table 5-18 shows that despite an increase in overflow events due to the Proposal there are only small increases in pollutant loads at the uncontrolled overflow 1121644 between 2009 and 2021. Following 2021, annual wastewater loads increase but remain small and significantly less than the estimated annual stormwater loads in the Horsley and Connor Creek catchment. Overflow concentrations decrease as a result of the Proposal.

- **Table 5-18 1121644 annual pollutant loads and overflow concentration, and Horsley and Connor Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	4.7	4.8	7.4	366302	0.87	0.88	1.4	3404
Overflow Concentration (mg/L)	10.35	8	8	-	1.9	1.47	1.47	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.16	0.16	0.2	859	$1.59x10^{12}$	$1.61x10^{12}$	$2.49x10^{12}$	$5.2x10^{15}$
Overflow Concentration (mg/L)	0.35	0.27	0.27	-	$3.45x10^5$	$2.67x10^5$	$2.67x10^5$	-

5.2.5. Macquarie Rivulet

Overflow reference # 1117911

This uncontrolled overflow in the Macquarie Rivulet Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2048. The frequencies of overflows are predicted to increase from 8 per 10 year period in 2009 to 9 and 11 events per 10 year period in 2021 and 2048 respectively. Whilst event loads and annual wastewater loads increase as a result of the Proposal, the contribution is minor compared to annual stormwater loads in the Macquarie Rivulet Catchment (Table 5-19).

▪ **Table 5-19 1117911 annual pollutant loads and overflow concentration, and Macquarie Rivulet annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	3.8	4.4	5.7	311343	0.7	0.8	1	6127
Overflow Concentration (mg/L)	12.69	12.87	12.87	-	2.33	2.36	2.36	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.13	0.15	0.19	1083	1.27×10^{12}	1.48×10^{12}	1.91×10^{12}	3.27×10^{14}
Overflow Concentration (mg/L)	0.42	0.43	0.43	-	4.23×10^{5}	4.29×10^{5}	4.29×10^{5}	-

Overflow reference # 1395591

This uncontrolled overflow in the Macquarie Rivulet Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2048. The frequency of overflows is predicted to increase from 7 per 10 year period in 2009 to 9 and 13 events per 10 year period in 2021 and 2048 respectively.

Table 5-20 shows that whilst the Proposal has resulted in an increase in uncontrolled overflow events, overflow concentrations and event loads, the annual pollutant loads from wastewater overflows at 1395591 are minor compared to estimated annual stormwater overflows.

▪ **Table 5-20 1395591 annual pollutant loads and overflow concentration, and Macquarie Rivulet annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	6	8	11	311343	1.1	1.4	2	6127
Overflow Concentration (mg/L)	18.79	19.73	19.73	-	3.45	3.62	3.62	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.2	0.26	0.36	1083	2.06×10^{12}	2.63×10^{12}	3.69×10^{12}	3.27×10^{14}
Overflow Concentration (mg/L)	0.63	0.66	0.66	-	6.26×10^{5}	6.58×10^{5}	6.58×10^{5}	-

5.2.6. Allan's Creek

Overflow reference # 1130679

This uncontrolled overflow in the Allan's Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2048. The frequency of overflows is predicted to increase from 9 per 10 year period in 2009 to 10 and 13 events per 10 year period in 2021 and 2048 respectively. Despite the frequency of overflows increasing as a result of the Proposal, the annual increase in pollutant loads is small, and minor compared to the pollutant loads generated annually from stormwater (Table 5-21).

- **Table 5-21 1130679 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	0.8	1.8	4.1	1515670	0.15	0.33	0.76	15593
Overflow Concentration (mg/L)	33.3	29.6	29.6	-	6.1	5.4	5.4	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.02	0.06	0.14	3663	2.8×10^{11}	6×10^{11}	1.39×10^{12}	2.08×10^{15}
Overflow Concentration (mg/L)	1.1	0.9	0.9	-	1.1×10^{6}	9.8×10^{5}	9.8×10^{5}	-

Overflow reference # 1136262

This uncontrolled overflow in the Allan's Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2021 and 2048. The frequency of overflows is predicted to increase from 19 per 10 year period in 2009 to 21 and 24 events per 10 year period in 2021 and 2048 respectively.

Whilst the number of events (and loads) increases at this uncontrolled overflow increase as a result of the Proposal the concentrations of indicators in wastewater are predicted to decrease (Table 5-22). Annual wastewater loads from this overflow are very small compared to annual stormwater loads entering Allan's Creek.

- **Table 5-22 1136262 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	3.5	3.9	5.3	1515670	0.65	0.71	0.97	15593
Overflow Concentration (mg/L)	35.9	33	33	-	6.58	6	6	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.11	0.13	0.17	3663	$1.19x10^{12}$	$1.30x10^{12}$	$1.77x10^{12}$	$2.08x10^{15}$
Overflow Concentration (mg/L)	1.2	1.1	1.1	-	$1.2x10^{6}$	$1.1x10^{6}$	$1.1x10^{6}$	-

Overflow reference # 1129143

This uncontrolled overflow in the Allan's Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2048. The frequency of overflows is predicted to increase from 13 per 10 year period in 2009 to 14 and 16 events per 10 year period in 2021 and 2048 respectively.

Whilst the number of events (and loads) increases at this uncontrolled overflow increase as a result of the Proposal the concentrations of indicators in wastewater are predicted to decrease (Table 5-23). Annual wastewater loads from this overflow are very small compared to annual stormwater loads entering Allan's Creek.

- **Table 5-23 1129143 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	4	4.2	5.5	1515670	0.7	0.78	1	15593
Overflow Concentration (mg/L)	36.1	33.1	33.1	-	6.63	6.1	6.1	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.13	0.14	0.18	3663	$1.34x10^{12}$	$1.42x10^{12}$	$1.86x10^{12}$	$2.08x10^{15}$
Overflow Concentration (mg/L)	1.2	1.1	1.1	-	$1.2x10^{6}$	$1.1x10^{6}$	$1.1x10^{6}$	-

Overflow reference # 1128713

This uncontrolled overflow in the Allan's Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2048. The frequency of overflows is predicted to remain at 15 per 10 year period in 2009 and 2021, but increase to 16 events per 10 year period in 2048.

Similarly to other uncontrolled overflows in the Allan's Creek Catchment, Table 5-24 shows that whilst number of events (and loads) increase at this 1128713 increase as a result of the Proposal the concentrations of indicators in wastewater are predicted to decrease. Annual wastewater loads from this overflow are also very small compared to annual stormwater loads entering Allan's Creek.

- **Table 5-24 1128713 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	2.6	2.8	3.5	1515670	0.49	0.51	0.64	15593
Overflow Concentration (mg/L)	20.97	19.18	19.18	-	3.84	3.52	3.52	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.08	0.09	0.11	3663	$8.91x10^{11}$	$9.27x10^{11}$	$1.18x10^{12}$	$2.08x10^{15}$
Overflow Concentration (mg/L)	0.7	0.64	0.64	-	$6.99x10^{5}$	$6.39x10^{5}$	$6.39x10^{5}$	-

Overflow reference # 1131717

This uncontrolled overflow located in the Allan's Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2009, 2021 and 2048. The frequency of overflows at 1131717 are 27 per 10 year period in 2009 increasing to 28 and 30 events per 10 year period in 2021 and 2048 respectively. Table 5-25 shows that whilst the number of events (and loads) increase at this uncontrolled overflow increase as a result of the Proposal the concentrations of indicators in wastewater are predicted to decrease. Annual wastewater loads from this overflow are very small compared to annual stormwater loads entering Allan's Creek.

- **Table 5-25 1131717 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	5.9	6.5	8.7	1515670	1.1	1.2	1.6	15593
Overflow Concentration (mg/L)	46.35	43.91	43.91	-	8.5	8.05	8.05	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.19	0.21	0.29	3663	1.98×10^{12}	2.2×10^{12}	2.9×10^{12}	2.08×10^{15}
Overflow Concentration (mg/L)	1.54	1.46	1.46	-	1.54×10^{6}	1.46×10^{6}	1.46×10^{6}	-

Overflow reference # 1129135

This uncontrolled overflow located in the Allan's Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2009, 2021 and 2048. The frequency of overflows at 1129135 are 14 per 10 year period in 2009 increasing to 15 and 18 events per 10 year period in 2021 and 2048 respectively. The Proposal will result in increased overflows, increased event and annual pollutant loads and increased concentrations (Table 5-26). Despite these increases, overall pollutant contribution from wastewater remains significantly less than stormwater per annum.

- **Table 5-26 1129135 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	5.4	6.4	8.4	1515670	1	1.2	1.5	15593
Overflow Concentration (mg/L)	28.8	29.4	29.4	-	5.3	5.4	5.4	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.18	0.21	0.28	3663	1.84×10^{12}	2.17×10^{12}	2.83×10^{12}	2.08×10^{15}
Overflow Concentration (mg/L)	0.96	0.98	0.98	-	9.6×10^{5}	9.8×10^{5}	9.8×10^{5}	-

Overflow reference # 1129893

This uncontrolled overflow in the Allan's Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2021 and 2048. The frequency of overflows at 1129893 are 9 per 10 year period in 2009 increasing to 10 and 13 events per 10 year period in 2021 and 2048 respectively.

Small increases in the frequency of overflow events, annual and event loads and concentrations are expected as a result of the Proposal (Table 5-27). However, the annual loads from this uncontrolled overflow are very small compared to the annual loads from stormwater within the Allan's Creek catchment.

- **Table 5-27 1129893 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	3.4	4.1	5.6	1515670	0.6	0.7	1	15593
Overflow Concentration (mg/L)	17.25	17.3	17.3	-	3.16	3.16	3.17	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.11	0.13	0.18	3663	$1.15x10^{12}$	$1.37x10^{12}$	$1.87x10^{12}$	$2.08x10^{15}$
Overflow Concentration (mg/L)	0.58	0.58	0.58	-	$5.75x10^{5}$	$5.77x10^{5}$	$5.77x10^{5}$	-

Overflow reference # 1130584

This uncontrolled overflow was included for further assessment because of its high risk to environmental values in 2021. It is located in the Allan's Creek Catchment and presents medium risk in 2009, shifting to high risk in 2021 and back to medium in 2048. The frequency of overflows at 1130584 are 8 per 10 year period in 2009 which decrease to 2 events per 10 year period in 2021 and then increase back to 8 events per 10 year period in 2048.

As shown in Table 5-28 the proposal results in a reduced or similar number of overflows at 1130584, however loads are expected to increase annually due to the increased volume of overflows. Event concentrations decrease in 2021/2048. The annual load from wastewater overflows is minor compared to the annual stormwater loads.

- **Table 5-28 1130584 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	6.4	7.9	13	1515670	1.2	1.5	2.4	15593
Overflow Concentration (mg/L)	29.1	25.7	25.7	-	5.3	4.7	4.7	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.21	0.26	0.43	3663	$2.14x10^{12}$	$2.66x10^{12}$	$4.38x10^{12}$	$2.08x10^{15}$
Overflow Concentration (mg/L)	0.97	0.86	0.86	-	$6.69x10^{5}$	$8.59x10^{5}$	$8.59x10^{5}$	-

Overflow reference # 1128841

This uncontrolled overflow located in the Allan's Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2009, 2021 and 2048. The frequency of overflows at 1128841 are 18 per 10 year period in 2009 increasing to 20 and 26 events per 10 year period in 2021 and 2048 respectively. This uncontrolled overflow, 1128841 is one of the more frequent ones to overflow as a result of the Proposal. Despite increased annual and event loads from wastewater, stormwater loads per annum are significantly higher in this catchment (Table 5-29).

- **Table 5-29 1128841 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	8.8	10.1	14.8	1515670	1.6	1.8	2.7	15593
Overflow Concentration (mg/L)	30.17	27.37	27.37	-	5.5	5	5	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.29	0.33	0.49	3663	$2.94x10^{12}$	$3.37x10^{12}$	$4.95x10^{12}$	$2.08x10^{15}$
Overflow Concentration (mg/L)	1.01	0.91	0.91	-	$1.01x10^{6}$	$9.12x10^{5}$	$9.12x10^{5}$	-

Overflow reference # 1128668

This uncontrolled overflow in the Allan's Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2048. The frequency of overflows at 1128668 are 6 per 10 year period in 2009 increasing to 8 and 13 events per 10 year period in 2021 and 2048 respectively.

This uncontrolled overflow is the highest contributor of pollutant loads compared with other uncontrolled overflows in the Allan's Creek catchment (Table 5-30). Despite decreased concentrations of pollutants, there are significant increases in annual loads as a result of the Proposal in both 2021 and 2048. Despite these increased wastewater loads, stormwater is a much greater contributor of pollutants in the Allan's Creek catchment.

- **Table 5-30 1128668 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	16	27	56	1515670	3	5	10	15593
Overflow Concentration (mg/L)	49.4	45	45	-	9.06	8.25	8.25	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.5	0.9	1.8	3663	$5.45x10^{12}$	$9.2x10^{12}$	$1.8x10^{13}$	$2.08x10^{15}$
Overflow Concentration (mg/L)	1.65	1.5	1.5	-	$1.65x10^{6}$	$1.5x10^{5}$	$1.5x10^{5}$	-

Overflow reference # 1129389

This uncontrolled overflow located in the Allan's Creek Catchment was included for further assessment because of its high risk to aquatic ecosystems in 2009, 2021 and 2048. The frequency of overflows at 1129389 are 13 per 10 year period in 2009 increasing to 15 and 20 events per 10 year period in 2021 and 2048 respectively.

The increased frequency of overflows as result of the Proposal, results in only small increases in pollutant loads per event and per annum (Table 5-31). Concentrations of pollutant decrease from 2009 to 2021/2048. In comparison to annual stormwater loads within the Allan's Creek Catchment, wastewater overflow loads from 1129389 are very minor.

- **Table 5-31 1129389 annual pollutant loads and overflow concentration, and Allan's Creek annual stormwater loads**

	2009	2021	2048	Catchment Stormwater	2009	2021	2048	Catchment Stormwater
Pollutant	**TSS**				**TN**			
Annual Loads (kg/year)	18	19	24	1515670	3.2	3.5	4.4	15593
Overflow Concentration (mg/L)	21.13	20.21	20.21	-	3.87	3.7	3.7	-
Pollutant	**TP**				**FC**			
Annual Loads (kg/year)	0.5	0.6	0.8	3663	5.89×10^{12}	6.39×10^{12}	8.1×10^{12}	2.08×10^{15}
Overflow Concentration (mg/L)	0.7	0.67	0.67	-	7.04×10^{5}	6.74×10^{5}	6.74×10^{5}	-

5.3. Cumulative Impacts

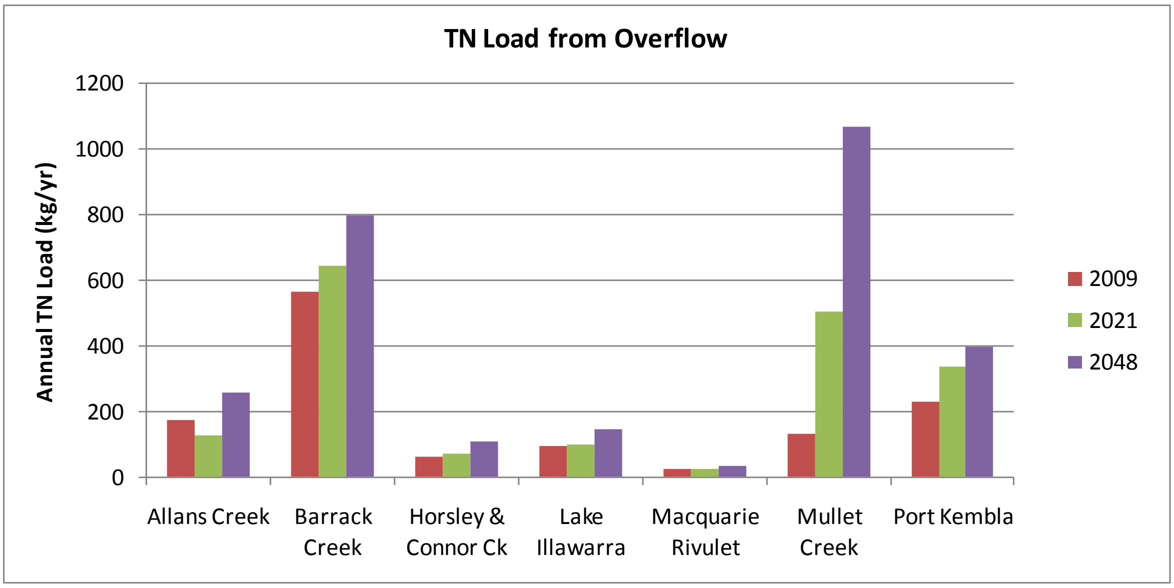
A desktop assessment was undertaken using spreadsheet calculations to compare the average annual pollutant loads from stormwater runoff and wastewater overflows in selected catchments potentially impacted by the Proposal.

5.3.1. Results

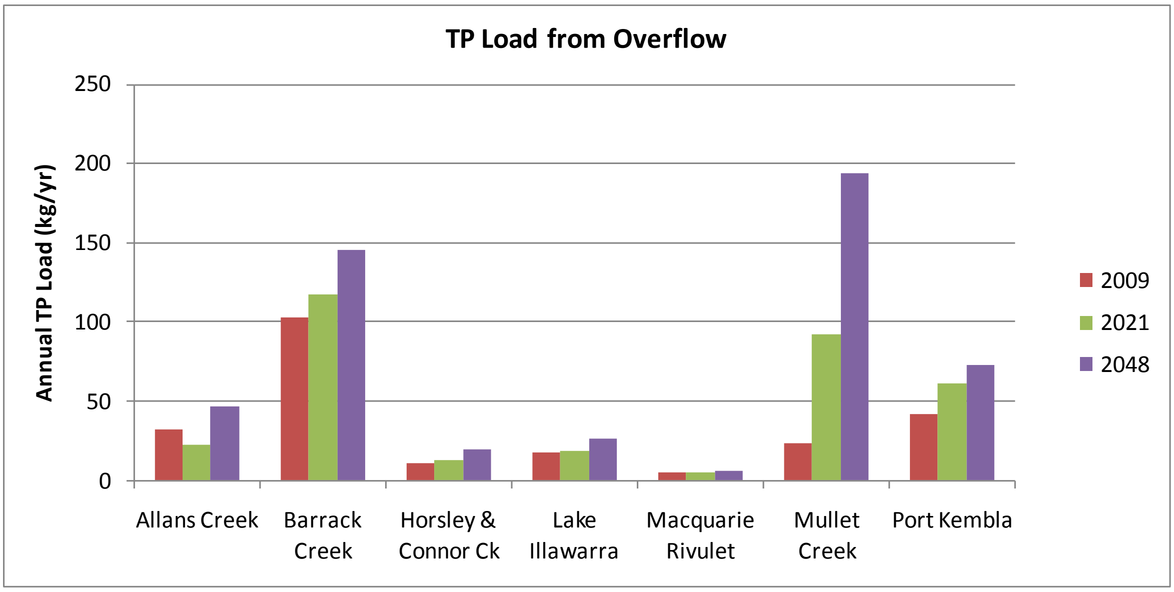
The results of the mass balance modelling for combined (high and highest priority) overflows on a sub-catchment basis are shown below in

to Figure 5-3 Annual Cumulative Loads of Total Suspended Solids

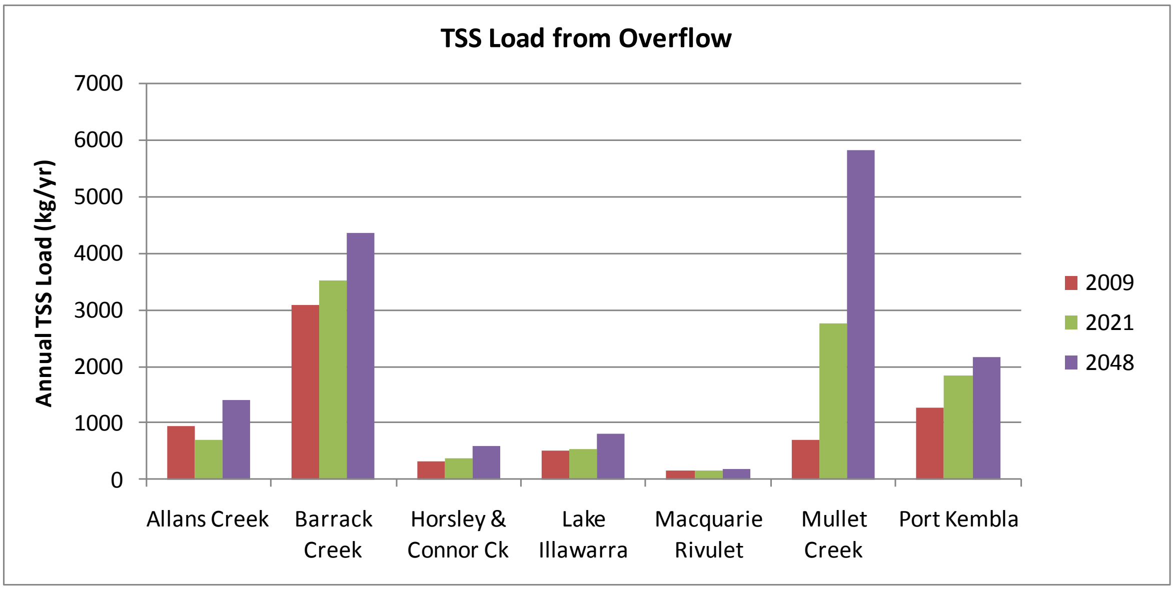
. The calculated stormwater loads are conservative as mentioned in Section 3 due to the lower annual rainfall applied and application of current landuses practices which are likely to change in with development of the Proposal.



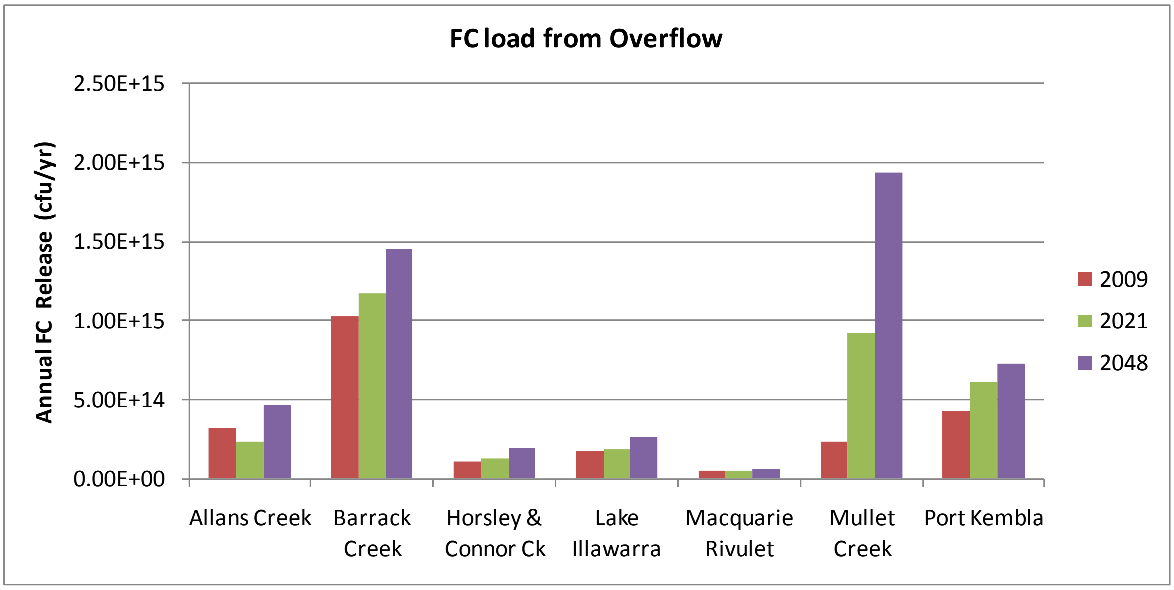
■ **Figure 5-1 Annual Cumulative Loads of Total Nitrogen**



■ **Figure 5-2 Annual Cumulative Loads of Total Phosphorus**



- **Figure 5-3 Annual Cumulative Loads of Total Suspended Solids**



- **Figure 5-4 Annual Cumulative Loads of Faecal Coliforms**

The sub-catchments with the highest loads are those dominated by the individual directed overflows identified previously in Section 4 including Barrack Creek, Mullet Creek and to a lesser extent Port Kembla. In addition, the trends in cumulative loads through time are also similar to those shown at the dominant overflow locations.

The results of the cumulative stormwater assessment are provided in Table 5-32 to Table 5-35 (and Appendix E). This shows the contribution to annual sub-catchment loads (expressed as loads and as a percentage) of the combined wastewater overflows relative to stormwater. Figure 5-5 to Figure 5-8 show the absolute annual loads of TN, TP, TSS and FCs estimated from stormwater and wastewater overflows for 2009, 2021 and 2048.

- **Table 5-32 The contribution and ratio of annual TN loads from wastewater and stormwater**

Catchment	Stormwater Contribution (kg/year)	Wastewater overflow contribution (kg/year)[1]			Relative percentage from wastewater overflows (%)		
		2009	2021	2048	2009	2021	2048
Lake Illawarra	8,939	95	100	146	1.06	1.12	1.63
Mullet Creek	19,136	130	504	1,067	0.68	2.64	5.58
Barrack Creek	5,289	565	646	797	10.69	12.21	15.08
Horsley and Connor Creek	3,404	61	70	109	1.79	2.07	3.20
Macquarie Rivulet	6,127	26	27	35	0.43	0.44	0.57
Allan's Creek[2]	15,593	174	126	256	1.12	0.81	1.64
Port Kembla	3,683	253	382	450	6.31	9.17	10.82

1= from directed and uncontrolled overflows identified as high and highest risk

2= for the purposes of this assessment Allan's Creek catchment contains stormwater contributions from Allan's Creek, American Creek, Branch Creek, Brandy and Water Creek and Byarong Creek which all drain to the Allan's Creek catchment.

Shaded cells denote TN loads from high and highest priority overflows >10% overall (wastewater + stormwater) TN loads in catchment

- **Table 5-33 The contribution and ratio of annual TP loads from wastewater and stormwater**

Catchment	Stormwater Contribution (kg/year)	Wastewater overflow contribution (kg/year)[1]			Relative percentage from wastewater overflows (%)		
		2009	2021	2048	2009	2021	2048
Lake Illawarra	2,078	17	18	27	0.83	0.88	1.28
Mullet Creek	4,211	24	92	194	0.56	2.18	4.61
Barrack Creek	1,334	103	117	145	7.71	8.80	10.87
Horsley and Connor Creek	869	11	13	20	1.29	1.49	2.31
Macquarie Rivulet	1,083	5	5	6	0.44	0.45	0.58
Allan's Creek[2]	3,663	32	23	47	0.87	0.63	1.27
Port Kembla	955	46	69	82	4.42	6.43	7.58

1= from directed and uncontrolled overflows identified as high and highest risk

2= for the purposes of this assessment Allan's Creek catchment contains stormwater contributions from Allan's Creek, American Creek, Branch Creek, Brandy and Water Creek and Byarong Creek which all drain to the Allan's Creek catchment.

Shaded cells denote TP loads from high and highest priority overflows >10% overall (wastewater + stormwater) TP loads in catchment

Table 5-34 The contribution and ratio of annual TSS loads from wastewater and stormwater

Catchment	Stormwater Contribution (kg/year)	Wastewater overflow contribution (kg/year)[1]			Relative percentage from wastewater overflows (%)		
		2009	2021	2048	2009	2021	2048
Lake Illawarra	891,934	516	547	796	0.06	0.06	0.09
Mullet Creek	1,551,983	711	2,752	5,821	0.05	0.18	0.38
Barrack Creek	570,479	3,084	3,521	4,349	0.54	0.62	0.76
Horsley and Connor Creek	366,302	333	384	595	0.09	0.10	0.16
Macquarie Rivulet	311,343	144	146	189	0.05	0.05	0.06
Allan's Creek[2]	1,515,670	951	687	1,399	0.06	0.05	0.09
Port Kembla	419,106	1,379	2,081	2,453	0.33	0.44	0.52

1= from directed and uncontrolled overflows identified as high and highest risk

2= for the purposes of this assessment Allan's Creek catchment contains stormwater contributions from Allan's Creek, American Creek, Branch Creek, Brandy and Water Creek and Byarong Creek which all drain to the Allan's Creek catchment.

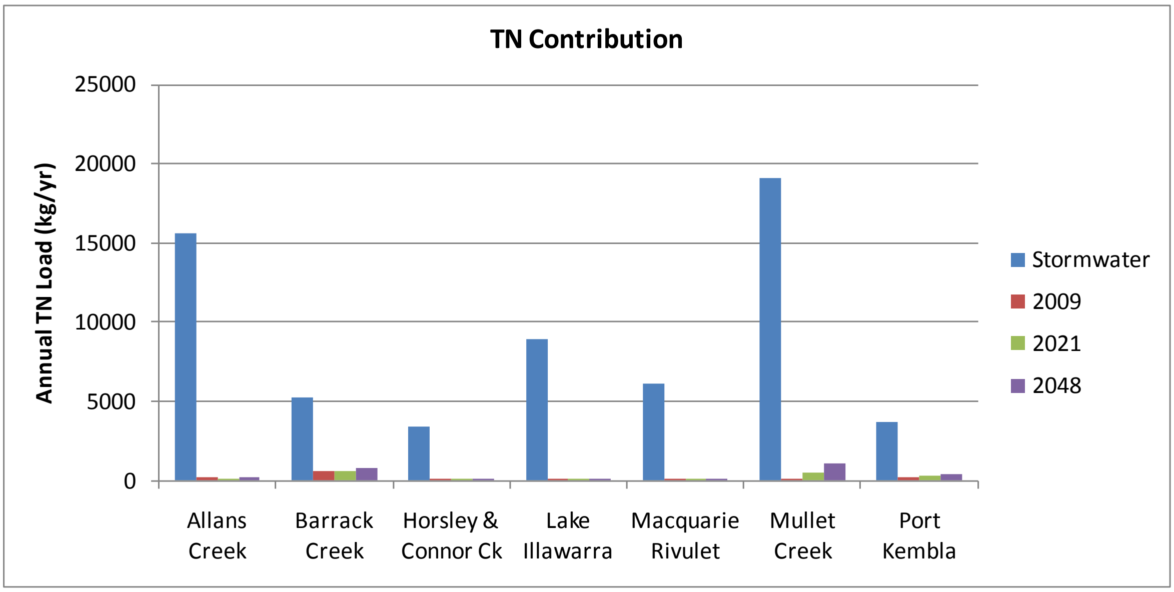
Table 5-35 The contribution and ratio of annual FC from wastewater and stormwater

Catchment	Stormwater Contribution (CFU/year)	Wastewater overflow contribution (CFU/year)[1]			Relative percentage from wastewater overflows (%)		
		2009	2021	2048	2009	2021	2048
Lake Illawarra	1.24×10^{15}	1.72×10^{14}	1.82×10^{14}	2.65×10^{14}	14	14	21
Mullet Creek	2.02×10^{15}	2.37×10^{14}	9.17×10^{14}	1.94×10^{15}	12	46	96
Barrack Creek	8.05×10^{14}	1.03×10^{15}	1.17×10^{15}	1.45×10^{15}	128	146	180
Horsley and Connor Creek	5.16×10^{14}	1.11×10^{14}	1.28×10^{14}	1.98×10^{14}	22	25	38
Macquarie Rivulet	3.27×10^{14}	4.80×10^{13}	4.86×10^{13}	6.31×10^{13}	15	15	19
Allan's Creek[2]	2.08×10^{15}	3.18×10^{14}	2.29×10^{14}	4.66×10^{14}	15	11	22
Port Kembla	5.98×10^{14}	4.22×10^{14}	6.14×10^{14}	7.24×10^{14}	71	103	121

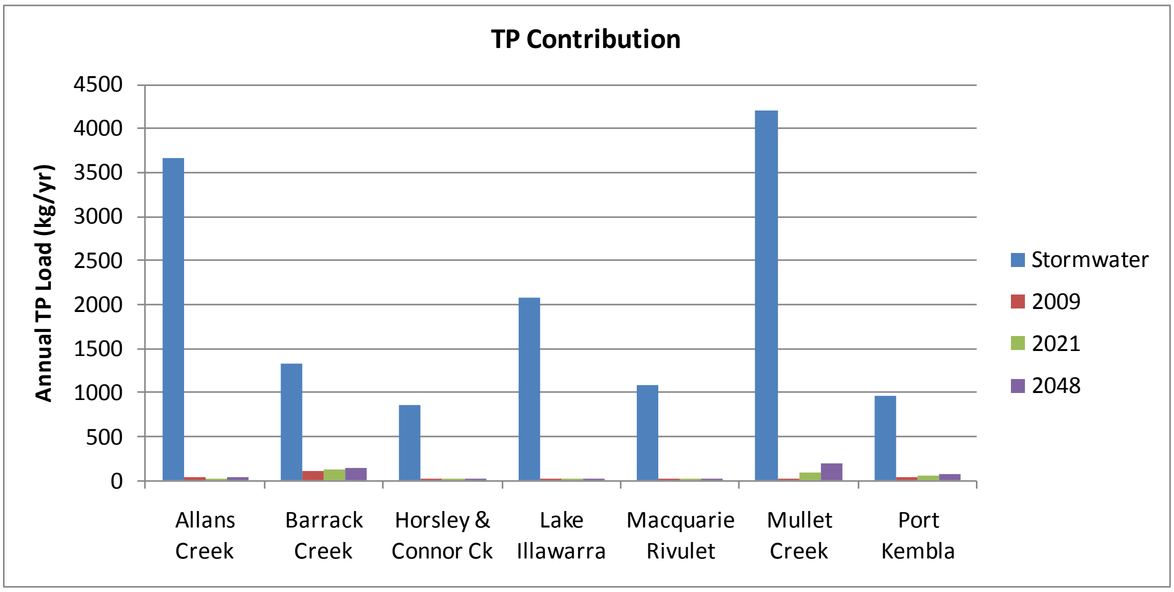
1= from directed and uncontrolled overflows identified as high and highest risk

2= for the purposes of this assessment Allan's Creek catchment contains stormwater contributions from Allan's Creek, American Creek, Branch Creek, Brandy and Water Creek and Byarong Creek which all drain to the Allan's Creek catchment.

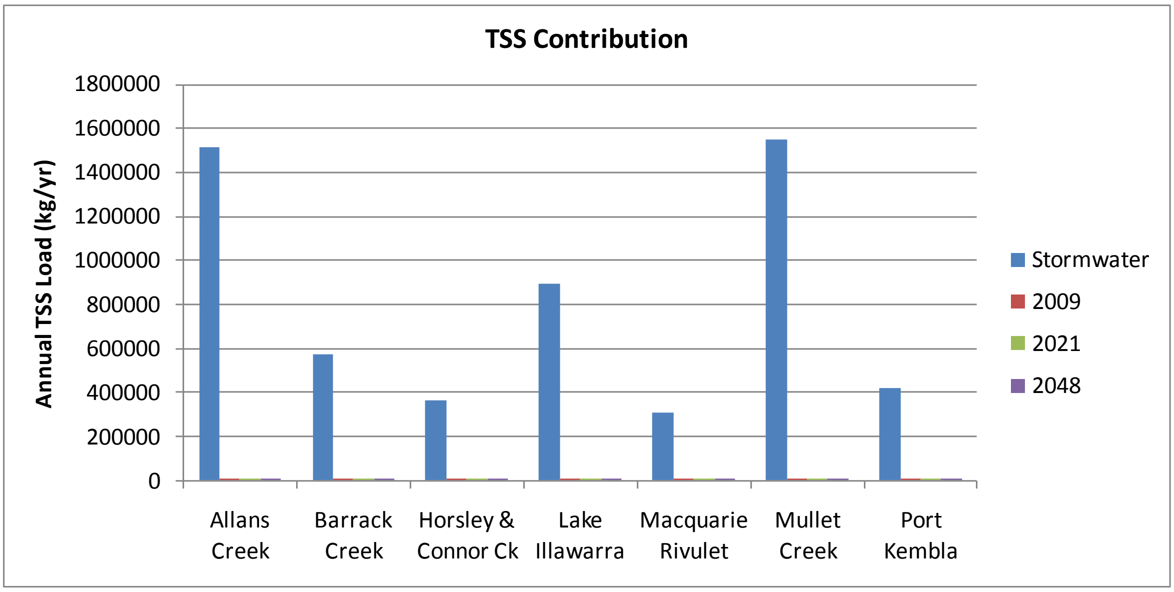
- **Figure 5-5 Total nitrogen stormwater and overflow loads**



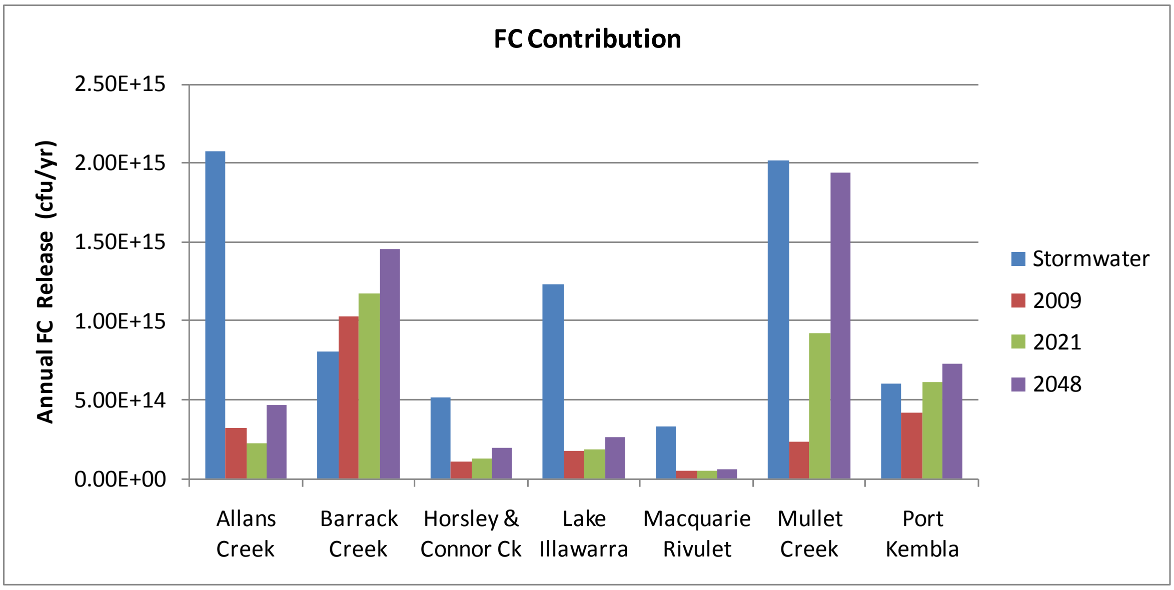
- **Figure 5-6 Total phosphorus stormwater and overflow loads**



- **Figure 5-7 Total suspended solids stormwater and overflow loads**



- **Figure 5-8 Faecal coliform stormwater and overflow loads**



Overall, the results demonstrate that stormwater contributes significantly to the annual loads of TN, TP and TSS while the relative contribution of stormwater to the FC loads varies significantly depending on the sub-catchment

The results are consistent across the catchments where by wastewater overflows comprise a very small proportion of overall pollutant load. More specifically:

- 0.05 to 0.76% of annual total suspended solid loads are derived from high and highest risk wastewater overflows during wet weather.

- 0.43 to 15.08% of annual total nitrogen loads are derived from high and highest risk wastewater overflows during wet weather.
- 0.44 to 10.87% of annual total phosphorus loads are derived from high and highest risk wastewater overflows during wet weather.

The notable exceptions to this include:

- Barrack Creek TN loads where wastewater overflows currently contribute an estimated 11% of overall annual sub-catchment loads, increasing to 12% and 15% in 2021 and 2048 respectively.
- Port Kembla TN loads where wastewater overflows are estimated to contribute 11% of overall annual sub-catchment loads by 2048.
- Barrack Creek TP loads where wastewater overflows are estimated to contribute 11% of overall annual sub-catchment loads by 2048.

The key directed overflows contributing to these results include:

- Barrack Creek – 1125705, 1122981, 1125953
- Port Kembla – 8121785

These overflows show a noticeable increase in both volume and frequency of events as a result of the Proposal. In terms of TSS, current estimates suggest that the relative contribution of wastewater overflows to overall sub-catchment loads is negligible (Table 5-34).

It is noteworthy here that while the overall annual wastewater overflow loads of TN, TP and TSS in the Mullet Creek sub-catchment are relatively high, the ratio of wastewater overflow derived pollutant loads to stormwater derived pollutant loads is relatively low. This is due to the relative size of the sub-catchment and the larger areas associated with peri-urban and grazing landuses.

In contrast, the contribution of wastewater overflows to annual FC loads, while variable, is significant particularly in the Barrack Creek sub-catchment in 2009, 2021 and 2048, Mullet Creek in 2048 and Port Kembla sub-catchment in 2021 and 2048.

6. Analysis and Conclusions

6.1. Overview

By way of an overview, the approach adopted in this assessment has included:

- Risk assessment. This assessment prioritised all directed (49) and uncontrolled (621) overflows according to the frequency and/or volume of overflow and discharge location. Prioritisation ranged from low to highest priority, with only high and highest priority overflows being subject to ongoing assessment. This resulted in 20 directed and 45 uncontrolled overflows being assessed further by way of mass balance spreadsheet modelling.
- Mass Balance Modelling. This assessment determined the pollutant loads per event in 2009 (current), 2021 and 2048 at high and highest priority overflows. Pollutant loads at each overflow location in 2021 and 2048 were compared with current pollutant loads to determine overflows with increased loads from the current situation. The results of the mass balance assessment identified increased loads on a per event basis at 10 directed and 17 uncontrolled overflows which were then subject to impact assessment.
- Impact Assessment. This assessment determined the annual pollutant loads and event concentrations at the 10 directed and 17 uncontrolled overflows to determine the potential scale of impact at a discharge location. Following this, a cumulative overflow and stormwater impact assessment was undertaken to determine the relative annual contribution of pollutants from these two sources on a sub-catchment scale. The results of the impact assessment identified three directed overflows (SCOF117, 1122981 and 1125705) where the frequency and volume of overflows requires remedial action.

The outputs from the various assessments have been used to understand directed and uncontrolled overflows that have the potential to present risks to environmental values, relative wastewater and stormwater contributions, potential impacts to key environmental values in the Proposal area and suggested mitigation measures. This information is presented in Section 6.2 to 6.8.

6.2. Directed Overflows

Whilst many of the directed overflows were defined as high and highest risk, the loads of total suspended solids, nutrients and faecal coliforms are considered relatively minor compared to stormwater contributions from the sub-catchments. The small incremental increases in nutrient loads due to the directed overflows would be readily assimilated by the receiving system. Therefore it may be more cost effective to manage and reduce diffuse source run-off from directed overflows within sub-catchments that are high and highest risk through the incorporation of effective water sensitive urban design principles.

Despite pollutant loads from stormwater having a higher contribution than wastewater overflows, there remains three directed overflows that should be further investigated due to significantly increased pollutant loads as a direct result of the Proposal. These directed overflows are SCOF117 in the Mullet Creek sub-catchment and 1122981 and 1125705 in the Barrack Creek Catchment.

Both 1122981 and 1125705 show noticeable increases (1.3-1.4 times) in pollutant loads as a result of the Proposal with these overflows discharging to the same wetlands within the Barrack Creek catchment. There is the potential that the increased loads from both these overflows may exceed the maximum pollutant load that can be received in the wetland without compromising the environmental values.

SCOF117 is clearly the largest directed overflow in the Wollongong system and as such presents considerable risk to receiving waters for all constituents of concern. Nutrient concentrations and loads will increase considerably through time and while the discharge is to Mullet Creek in the first instance, the ability of the system to assimilate these loads is questionable. The volume of wastewater is also of concern, estimated to increase from 13,500 kL per event in 2009 to 17,000 and 19,600 kL per event in 2021 and 2048 respectively. This volume of discharge to Mullet Creek and subsequently into Lake Illawarra is unlikely to be sustainable. The potential for eutrophication of Mullet Creek and Lake Illawarra would appear to be high.

6.3. Uncontrolled overflows

Whilst a number of uncontrolled overflows present high or highest risk, the increase in event loadings as a result of the Proposal in 2021 and 2048 is generally small. Whilst the loads per event at some overflows increase, the concentrations of TSS, TN and TP per event at the majority of uncontrolled overflows actually decrease. That is TSS, TN and TP concentrations are lower per event in 2021 and 2048 than current (2009) concentrations. Therefore the likelihood that these overflows will impact on environmental values is low.

6.4. Wastewater and stormwater

It is apparent from this estimation that the relative contribution of wastewater overflows and stormwater to annual loads of TN, TP and TSS in these sub-catchments is largely dominated by stormwater. Whilst the generation rates applied in the assessment (Table 3-2) are from current literature and are indicative only, these rates would need to be reduced by an order of magnitude to make a significant difference to the results. It should also be noted that wastewater loads are calculated on a worst case where all overflows in a sub-catchment occur during the same events.

In contrast, it is apparent that the relative contribution of FC loads to these systems is in many instances dominated by wastewater overflows. While faecal contamination is largely transient, a small number of overflows pose a threat to the environmental values identified for this project. The directed overflows of concern are those that discharge to popular recreational sites and include:

- SCOF107 which discharges to Lake Illawarra; and
- 1400028, 1125705 and 1122981 located in the Barrack Creek which may discharge to Little Lake.

6.5. Assessment of impacts from the Proposal on Environmental Values

Section 2.1 provided a summary of the recognised environmental values for the study area. Whilst an assessment of impacts that the proposal may have on environmental values is provided below and mitigation measures recommended where appropriate, the influence of other sources of pollutants namely stormwater needs to be recognised. According to DEC (2006), it may not be equitable to require one activity alone to restore ambient water quality for environmental values, unless it is clearly identified as the only activity affecting water quality or as having by far the greatest impact.

6.5.1. Assessment of impacts from the Proposal on Aquatic ecosystems

Water quality conditions in the project area are currently influenced by pollutant loads received from existing wastewater overflows and the stormwater system. Existing water quality data and literature presented in Section 2, indicates that the receiving waterways appear to generally meet relevant guidelines for the protection of aquatic ecosystems with respect to nutrients and total suspended solids (see Section 2). Whilst the data is limited, deterioration in water quality occurs at times following wet weather, but this appears to be short lived and may cause transient pulse impacts (such as increased turbidity and reduced light penetration), rather than a long-term press impact associated with increased total suspended solids and nutrients.

The increased pollutant loads as a direct result of the Proposal in 2021 and 2048 are expected to be readily assimilated into the receiving environment at the majority of directed and uncontrolled overflows. Impacts to matters of state or national significance including SEPP14 or directory of important wetlands are not expected impacted by the Proposal. However significant increases in loads over time at directed overflow 1122981 and 1125705 in the Barrack Creek Catchment and

SCOF117 in the Mullet Creek catchment together with stormwater loads may result in exceeding the maximum pollutant load that both Barrack Creek (including Little Lake) and Mullet Creek can assimilate to maintain this environment value. Therefore, pollutant reduction mitigation measures for both stormwater and wastewater may need to be implemented to reduce the risk of eutrophication, algal blooms, sedimentation and other impacts to aquatic ecosystems.

6.5.2. Assessment of impacts from the Proposal on primary and secondary recreation

Whilst faecal coliform densities are predicted to increase by varying amounts at all overflows the issue is most relevant at the overflows which discharge directly to areas used for recreation. These overflows include SCOF107 in the Lake Illawarra Catchment and 1400028, 1125705 and 1122981 in the Barrack Creek Catchment. Faecal coliform densities in overflow at SCOF107 and 1400028 are currently small and show little increase in 2021 and 2048, as such their impact on recreation is likely to be negligible, particularly when compared to stormwater. Whilst faecal coliform densities are predicted to show more notable increases per event at 1125705 and 1122981, it is unlikely that the impact to the recreational users will increase significantly beyond the current situation, as recreating in these waters is not recommended following rainfall.

6.5.3. Assessment of impacts from the Proposal on aesthetic quality

Whilst pollutants from existing wastewater overflows and stormwater are currently entering Lake Illawarra, the aesthetic quality of the Lake has shown continual improvement since 2005 (LIA 2010). As such it would appear that the lake is resilient and able to assimilate the impacts associated with increased pollutant loads from high and highest risk overflows which are not considered substantial enough to change the aesthetic quality of the Lake.

6.6. Mitigation Measures

In order to mitigate the potential impacts associated with increased overflows from the directed overflows of concern (SCOF117, 1122981 and 1125705), an engineering solution may be necessary. There are several options available to mitigate the issue which include:

1) Increasing the size of the transfer infrastructure (pipes) downstream of directed overflow of concern, by either upgrading existing pipe size or duplication of the pipes. Depending on the volume of overflow and the capacity of the downstream pipes between the directed overflow and the next overflow point in the system, upgrading of the infrastructure may be required for a considerable distance downstream. Each proposed change would require hydraulic

modelling to determine if this resolves the problem or just shifts the overflow issues further downstream.

2) Provision of storm storage at the directed overflow of concern. This would allow the temporary storage and controlled release of the stored wastewater downstream after the wet weather event had subsided. Again the effectiveness and required size of the storage needs to be validated by modelling.

3) A combination of options 1 and 2. If some storage was provided for the wastewater, the changes to downstream infrastructure may not be as significant.

4) Lining of the wastewater pipes upstream of directed overflow, as this would prevent stormwater from entering into the wastewater system. This could be very difficult to implement unless there is a good understanding in the locations of (discrete) wet weather infiltration hot-spots.

5) Restricting upstream and/or downstream pumping station capacity.

The contribution of faecal coliforms to the system will increase the overall load during the project and concept stages however faecal die-off following wet weather should result in a transient pulse impact on the system which is only likely to be evident for a few days. As such it is not considered effective to undertake costly mitigation measures for those directed overflows. Rather it would be advisable to ensure that recreational users are aware of the risks of using recreational waters following rainfall and perhaps extend the recommended time for avoiding recreation in areas susceptible to faecal pollution.

6.6.1. Summary

Whilst the Proposal has potential impacts on environmental values from increased nutrients, TSS and faecal coliforms, the environmental values of these catchments are compromised more by stormwater flows than by wastewater overflows. Whilst the receiving environment appears to be reasonably resilient and able to assimilate existing pollutant loads, a limited number of directed overflows associated with the Proposal appear to present potential significant risks by 2021 and beyond. These directed overflows are 1122981 and 1125705 which discharge to the same wetland in the Barrack Creek catchment and directed overflow SCOF117 located in the Mullet Creek catchment.

Mitigation measures at these locations may be required through time, however stormwater management should not be overlooked considering the significant contribution in pollutant loads that stormwater generates in each of the catchments.

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8. Abbreviations and Glossary

AGA	Adjacent Growth Areas
ANZECC	Australian & New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
cfu	Colony forming units (of faecal coliforms)
Cfu/100mL	Colony forming units per 100ml of sample analysed
DECCW	Department of Environment, Climate Change and Water (now OEH)
DO	Dissolved oxygen
EA	Environmental Assessment
EPL	Environment Protection Licence
FRP	Filterable Reactive Phosphorus
Ha	Hectare
KL	Kilolitre = 1,000L
KL/year	Kilolitres per year
km	Kilometres = 1,000m
km^2	Square kilometres
LIA	Lake Illawarra Authority
mg/L	Milligrams per litre (of water)
ML	Megalitres
ML/day	Megalitres per day = 1,000,000L/day
NHMRC	National Health and Medical Research Council
NOx	Oxidised Nitrogen
OEH	Office of Environment and Heritage
SEPP	State Environmental Planning Policy
SS	Suspended solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
µg/L	Micrograms per litre
WDURA	West Dapto Urban Release Area
WRP	Water Recycling Plan
WWTP	Wastewater Treatment Plant

Ammonia (NH_4^+)	Represents the most reduced form of inorganic nitrogen available, and is preferentially utilised by plants and aquatic micro-organisms. The main sources of ammonia in aquatic ecosystems are found to be from human and animal wastes and also by release during the decomposition of organic material by bacteria
Assimilate	The ability of a water body to purify itself of pollutants
ANZECC/ARMCANZ guidelines	Australian Water Quality Guidelines for Fresh and Marine Waters published by ANZECC in 2000. These guidelines provide reference levels for comparison with water quality results
Assimilative Capacity	The capacity of natural body of water to receive and dilute wastewaters or toxic materials without damage to aquatic life or humans who consume the water
Catchment	The area drained by a stream or body of water or the area of land from which water, stormwater or wastewater is collected
Choke	Full or partial blockage in wastewater pipe. May be caused by tree roots, debris, or structural collapse
Concept Approval Area	Area covered by the application for Concept Plan Approval for the overall Proposal to provide water and wastewater services to the WDURA and AGAs. This is synonymous with the Proposal Area
Dilution ratio	The ratio of the concentration of a substance or contaminant before dilution to that after dilution
Directed Overflow	A structure designed in the reticulation system that operates as channel excess volume into the adjacent stormwater system or through constructed environmental discharge location
Dissolved Oxygen	The amount of oxygen that is dissolved in water. Dissolved oxygen is vital for many forms of riverine and estuarine biota including native fish and is also vital for the functioning of healthy aquatic ecosystems
Ecosystem	A community of organisms, interacting with one another, and the environment in which they live
Enterococci	Faecal organisms used as an indicator of wastewater contamination in the environment
Environmental Impact	Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organisation's activities, products and services
Environment Protection Licence	A licence that allows pollution of the environment under controlled conditions regulated by the EPA, as outlined in the Protection of the Environment Operations Act, 1997
Environmental Value	Environmental values are those values or uses of water that the community believes are important for a healthy ecosystem or for public benefit, welfare, safety or health and that require protection from the effects of pollution, waste discharges and deposits

	(ANZECC/ARMCANZ 2000)
Estuarine Waters	Tidal habitats and wetlands that are usually enclosed by land by have access to the ocean ad are at least occasionally diluted by freshwater such as bays, river mouths and lagoons
Eutrophic	Having a large or excessive supply of plant nutrients (nitrates and phosphates)
Eutrophication	Abundance of nutrients resulting in excessive algal growth and decay and often low dissolved oxygen in waterways
Event	An overflow occurrence either for the entire wastewater system or at a single overflow location. Each systems has a number events (otherwise referred to as targets) stipulated in the EPL
Faecal coliforms	The portion of the coliform bacteria group which is present in the intestinal tracts and faeces of warm blooded animals. A common pollutant in water
Gravity Main	A wastewater main in which wastewater travels under the effects of gravity
Infiltration	Groundwater entering the wastewater system through cracked pipes or faulty joints
Macrophyte	A large plant living in water, either emergent, submergent or floating
Median	A median values lies where 50 percent of results will be below this value, and 50 percent will be above it
Nitrogen	A naturally occurring element that can enter the water from the catchments. Often added to soils in fertiliser. Plants use nitrogen as a nutrient for growth and high levels in water may result in excessive growth of algae and aquatic weeds
Nutrients	Substances required for growth by plants and other organisms. Major plant nutrients are phosphorus and nitrogen
Nutrient Loading	The total amount of nitrogen or phosphorus entering the water during a given time such as kilograms of nitrogen per year. Nutrients may enter the water from runoff, groundwater or wastewater overflows
OEH	Office of the Environment and Heritage (previously DEC, DECC and DECCW) the primary NSW public sector organisation responsible for protecting the environment
Overflow	A discharge of untreated or partially treated wastewater from the wastewater treatment system. Overflows may occur as directed overflows or uncontrolled overflows
25th Percentile	The value that 25% of samples are not expected to exceed
75th Percentile	The value that 75% of samples are not expected to exceed

Pathogen	A micro-organism capable of causing diseases in humans, animals or plants. They may be bacteria, virus or parasites found in wastewater or stormwater
pH	Is a measure of the acidity or alkalinity of an aqueous solution. Values of pH range from 0 (highly acidic) to 14 (highly alkaline)
Phosphorus (P)	An element that is essential for all living organisms. It is a nutrient and a common ingredient in fertilisers and washing detergents. The Australian environment is adapted to very low levels of P in soils and water
Pollutants	contaminants in water that, in sufficient quantities, can cause environmental degradation
Primary contact Recreation	Where the body can be fully immersed and there is the potential to swallow water and there is a direct contact with the water. It includes activities such as swimming, diving and water skiing
Project Approval Area	Area covered by the application for Project Approval for components of the Proposal required to service the early release Precincts (Kembla Grange, Sheaffes/Wongawilli).
Proposal	To construct and operate water and wastewater infrastructure required to service the new development in West Dapto Urban Release Area (WDURA) and Adjacent Growth Areas (AGAs) in the Illawarra region
Proposal Area	That area comprising the WDURA and AGA. This is synonymous with the Concept Approval area
Receiving water/environment	A stream, river, pond, lake, harbour or ocean into which discharges flow
Risk Assessment	the process by which scientific data are analysed to describe the form and characteristics of risk that is, the likelihood of harm to humans or the environment
Runoff	water that flows across the land surface and does not soak into the ground
Secondary Contact Recreation	Includes activities such as paddling, wading, boating and fishing in which there is some direct contact with water but there the probability of swallowing water is unlikely
Stormwater	Rainwater which runs off urban and agricultural lands frequently carrying various forms of pollution such as litter and detritus, animal droppings, wastewater overflows and dissolved chemicals. This untreated water is carried in stormwater channels and discharges into creeks, rivers, the harbour and ocean
Stormwater system	The system of pipes, canals and other channels used to carry stormwater to bodies of water such as rivers or ocean. The System

	does not usually involve any treatment
Total Nitrogen	A measure of all forms of nitrogen found in the water sample including nitrate, nitrite, ammonia-N and organic forms of nitrogen
Total Phosphorus	Total concentrations of all forms of phosphorus found in the water
Total suspended solids	A measure of the concentration of those particles in water which will not pass through a standard filter
Trigger Value	ANZECC/ARMCANZ (2000) state that these are concentrations (or loads) of the key performance indicators measured for the ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur. They indicate a risk of impact if exceeded and should 'trigger' some action
Turbidity	A measure of fine suspended material or particles in water
Uncontrolled overflow	An overflow that can occur along any part of the reticulation system during normally large wet weather events that is not a directed overflow. They occur when the design of the gravity system can no longer support the required volume
Wastewater	untreated or partially treated liquid waste received in the reticulation system
Wastewater System	The system of pipes and pumping stations through which wastewater flows
Wastewater Treatment Plant (WWTP)	A facility to improve wastewater quality before discharge to receiving waters which applies to the facilities at Shellharbour.
Water quality	The biological, chemical and physical properties of water.
West Dapto Urban Release Area	Refers to development of West Dapto within both Wollongong and Shellharbour LGA
Wet weather overflow	Is an overflow which occurs due to inflow and infiltration of stormwater during a rainfall event in the reticulation system caused by wet weather, as determined by hydraulic modelling of the wastewater system model
Wetlands	Low-lying area often covered by shallow water, such as marshes, mangroves, swamps, bogs or billabongs. Rich in biodiversity, they store and filter water and replenish underground water supplies. Also effective in cleaning polluted water by reducing aquatic plant nutrients, suspended solids and oxygen demand.
Wrack	Detached macrophytes (seagrass and macroalgae) that accumulate along shorelines

Appendix A Statutory Framework

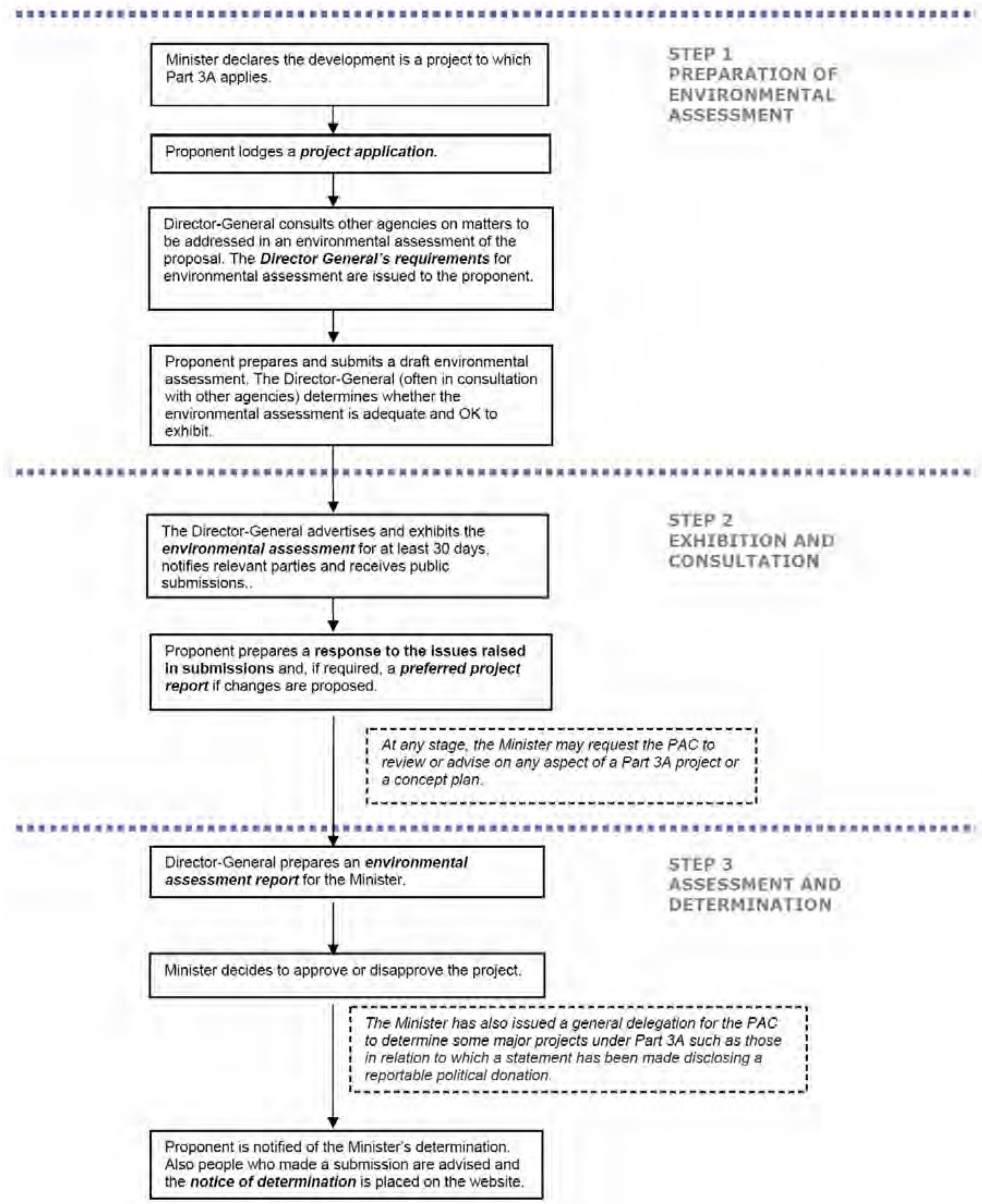
The following chapter provides consideration of the relevant applicable State and Commonwealth legislation, environmental planning instruments, including the relevant planning approval process applicable to the project.

> ***The Director-General's Requirements***
>
> *The Environmental Assessment shall include an assessment of the water quality impacts arising from operation of the project taking into account applicable NSW Government Policies.*

A.1 Planning Approval

The Environmental Assessment (EA) for the Water and Wastewater Servicing of the West Dapto Urban Release Area and Adjacent Growth Areas Project will be assessed under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act). By order of the Minister, the West Dapto Urban Release Area and Adjacent Growth Areas Project was declared to be a project to which Part 3A of the EP&A applies, due to its State and regional planning significance, on 7 September 2009. The project requires the approval of the Minister for Planning.

The steps in the assessment and approval process under Part 3A of the EP&A Act are summarised below and illustrated in Figure 3. Further detail on the Part 3A process can be found on the Department of Planning website at www.planning.nsw.gov.au.



- **Figure A-1 Approvals process under Part 3A of the EP&A Act**

A.2 Statutory planning framework

A.2.1 NSW Legislation

Environmental Planning and Assessment Act 1979

Development in NSW is subject to the requirements of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and its associated regulation. Environmental planning instruments prepared pursuant to the Act set the framework for approvals under the Act.

Section 75R of the EP&A Act excludes the application of the provisions of environmental planning instruments (other than State Environmental Plans-SEPPs) to approved projects, including approved critical infrastructure projects. The SEPPS that are applicable to this project include:

- State Environmental Planning Policy (Infrastructure) 2007.
- State Environmental Planning Policy (Major Development) 2005.
- State Environmental Planning Policy No 14 – Coastal Wetlands.
- State Environmental Planning Policy No 71 – Coastal Protection.
- State Environmental Planning Policy (Rural Lands) 2008.
- Illawarra Regional Environmental Plan No 1. This is now a deemed SEPP.

However, in deciding whether or not to approve the carrying out of a project, the Minister for Planning may (but is not required to) take into account the provisions of relevant environmental planning instruments (EPIs) that would not (because of Section 75R) apply to the project if approved. Such EPIs include:

- Wollongong Local Environmental Plan (West Dapto) 2010.
- Wollongong Local Environmental Plan 2009.
- Shellharbour Local Environment Plan 2000.
- Shellharbour Rural Local Environmental Plan 2004.

Fisheries Management Act 1994

The *Fisheries Management Act 1994* protects aquatic species such as fish and marine vegetation.

Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) is administered by the Department of Environment, Climate Change and Water (DECCW). The POEO Act regulates air and water pollution, noise control and waste management. The provision of environmental pollution licences are a core strategy under the PEOA. However, applications for environmental protection licences cannot be refused if they are required for carrying out a Part 3A approved project.

National Parks and Wildlife Act 1974

The National Parks and Wildlife Act 1974 (NPW Act) is administered by the DECCW and provides for:

- Protection of flora and fauna, including threatened species;
- Protection of Aboriginal sites or remains; and
- Protection of land designated as National Park.

Section 118A of the NPW Act prohibits the harming or picking of threatened species, endangered populations or endangered ecological communities without appropriate approval or authorisation.

Part 6 of the NPW Act contains provisions for the protection of Aboriginal heritage, and specifies the permit and approval requirements for impacts on Aboriginal objects and places. Under Section 90(1) of the NPW Act, a person who "without first obtaining the consent of the Director-General, knowingly destroys, defaces or damages, or knowingly causes or permits the destruction or defacement of or damage to, an Aboriginal object or Aboriginal place" is guilty of an offence.

Threatened Species Conservation Act 1995

The Threatened Species Conservation Act 1995 (TSC Act) is administered by the Department of Environment, Climate Change and Water (DECCW) (formerly the Department of Environment and Climate Change) and provides for the protection of threatened species, populations, ecological communities, and their habitats (with the exception of fish and marine plants). In relation to development assessment, the provisions of the TSC Act are linked to the EP&A Act. Specifically, Section 5A of the EP&A Act identifies the factors that must be taken into account in deciding whether there is likely to be a significant impact on threatened species, populations or ecological communities or their habitats. It establishes seven factors on which this assessment must be based (the 'Seven Part Test'). Where a significant impact is considered likely, a Species Impact Statement (SIS) must be prepared. Under Section 91 of the Act, the Director-General may grant a licence to harm or pick threatened species, populations or ecological communities or damage habitat.

Coastal Protection Act 1979

The *Coastal Protection Act 1979* (CP Act) provides for the protection of the coastal environment of NSW for the benefit of both present and future generations. Section 38(1) of the CP Act requires that the concurrence of the Minister for the Environment, Climate Change and Water be obtained for any development occurring in the coastal zone. Section 75U(1a) of the EP&A Act, however, states that concurrence under Part 3 of the CP Act is not required for an approved project.

A.2.2 Commonwealth legislation

Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is administered by the Commonwealth Department of Sustainability, Environment, Water Population and Communities (DSEWPC). Under the EPBC Act, approval is required for actions that are likely to have a significant impact on a matter of national environmental significance (NES) or Commonwealth land. The EPBC Act identifies seven matters of NES:

- World Heritage properties;
- National heritage places;
- Ramsar wetlands of international significance;
- Threatened species and ecological communities;
- Migratory species;
- Commonwealth marine areas; and
- Nuclear actions (including uranium mining).

The EPBC Act also requires assessment and approval for actions that are likely to have a significant impact on the environment of Commonwealth land, even if the subject action is taken outside Commonwealth land. When a person proposes to take an action that they believe may need approval under the EPBC Act, they must refer the proposal to the DSEWPC for assessment.

A.2.3 Other guidelines and policies

Water quality guidelines used in this project are provided in the following table. A summary of the policies associated with the water quality component of the project are also provided below.

Ecosystem Type	Indicator										
	Chl-a (µg/L)	TP (µg/L)	FRP (µg/L)	TN (µg/L)	NOx (µg/L)	NH4+ (µg/L)	DO (% sat)	DO (mg/L)	pH	Salinity (µS/cm)	Turbidity (NTU)
Lowland River[1]	3 (5[2])	25	20	350	40	20	85-110	>6[4]	6.5-8.5	125-2200	6-50
Estuaries[1]	4	30	5	300	15	15	80-110	>6[4]	7-8.5	N/A	0.5-10
Marine[1]	1	25	10	120	25	20	90-110	>6[4]	8-8.4	N/A	0.5-10
Lake Illawarra[3]	7.01	120	68	720	40	60	NA	NA	NA	NA	<6.11

Source: [1]ANZECC/ARMCANZ (2000) and DECCW (2006)

[2] DECCW (2006)

[3]Lake Illawarra Authority (2010)

[4]ANZECC (1992)

Guidelines for Managing Risks in Recreational Water (NHMRC, 2008)

The Guidelines for Managing Risks in Recreational Water (NHMRC, 2008) aim to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters.

Category	Microbial water quality assessment category (95th percentile – intestinal enterococci/ 100mL)	Estimates of Probability
A	<40	Gastrointestinal illness risk <1%
B	41-200	Gastrointestinal illness risk 1-5%
C	201-500	Gastrointestinal illness risk 5-10%
D	>500	Gastrointestinal illness risk >10%

The guidelines have been applied to understand the current recreational water quality and threat to public health of waterways that have the potential to be impacted by overflows due to the development of the West Dapto Urban Release Area and Adjacent Growth Areas.

Riparian Corridor Management Study (DIPNR, 2004)

The *Riparian Corridor Management Study* (DIPNR, 2004) was undertaken by DIPNR for Wollongong City Council. It outlines management measures for zones of riparian habitat occurring along watercourses.

The study will consider the potential impacts that water quality will have upon riparian areas within the study area.

Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000)

The Australian and New Zealand Environment Conservation Council water quality guidelines (2000) provide a framework for conserving ambient water quality in rivers, lakes, estuaries and marine waters.

The ANZECC/ARMCANZ (2000) *National Water Quality Guidelines for Fresh and Marine Water Quality* have been applied to understand the current health of the waterways in the study area and the ability to support nominated environmental values, particularly the protection of aquatic ecosystems. The Guidelines provide recommended trigger values which have been applied to understand the existing water quality and key indicators of concern.

Lake Illawarra Estuary Management Study and Strategic Plan (LIA 2006)

The Lake Illawarra Estuary Management Study and Plan was developed in accordance with Part 4 of the NSW Government's Estuary Management Program. It outlines key management issues for the Lake, present management objectives, and considers management options. The management objectives are focussed on entrance condition (entrance management), algal blooms, water quality, organic wrack accumulation and ooze formation, erosion and sedimentation, catchment inputs (catchment management), ecology and the fishery, waterway use, riparian zones, foreshore enhancement, flooding, visual amenity, community involvement, culture and heritage, commercial opportunities, funding (revenue)

This assessment has been undertaken with consideration of the key management objectives and issues that have been identified within the Lake.

Appendix B Mass Balance Results

B.1 Directed Overflows

Lake Illawarra Catchment

Six directed overflow sites SCOF106, SCOF108 SCOF107, 1400000, 1119924 and 1121017 located in the Lake Illawarra catchment were identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-1 and described below.

- **Table B-1 Mass balance results for risk prioritised directed overflows in the Lake Illawarra Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
SCOF106	3.3	0.6	0.1	$1.09x10^{12}$	2.15	0.4	0.07	$7.19x10^{11}$	2.8	0.5	0.09	$9.26 x10^{11}$
SCOF108	47.2	8.7	1.6	$1.57x10^{13}$	29.4	5.4	0.98	$9.81x10^{12}$	33.3	6.1	1.1	$1.11 x10^{13}$
SCOF107	43.7	8.02	1.5	$1.46x10^{13}$	70.3	12.9	2.3	$2.34x10^{13}$	77.2	14.2	2.6	$2.57 x10^{13}$
1400000	46.5	8.5	1.6	$1.55x10^{13}$	38.4	7.1	1.3	$1.28x10^{13}$	39.6	7.3	1.32	$1.32 x10^{13}$
1119924	25.5	4.7	0.9	$8.49x10^{12}$	20.2	3.7	0.7	$6.73x10^{12}$	21.2	3.9	0.71	$7.05 x10^{12}$
1121017	53.2	9.7	1.8	$1.77x10^{13}$	43.4	7.9	1.4	$1.45x10^{13}$	46.7	8.6	1.6	$1.56 x10^{13}$

Current (2009) pollutant loads per event at SCOF106 are 3.3 kg/event of TSS, 0.6 kg/event of TN, 0.1 kg/event of TP and $1.09x10^{12}$ cfu/event of FC. In 2021, the loads per event decrease for all indicators. By 2048, loads of all indicators increase slightly but remain less than the current (2009) situation. Whilst the frequency and volume of overflow increase slightly overtime, the increase in system capacity results in similar or reduced loads per event from SCOF106.

Similarly at SCOF108, although the volume and frequency of overflows increase, the loads of key indicators decrease per event between 2009 and 2021 but increase between 2021 and 2048. Loads per event in 2048 however are still less than is currently being observed in 2009.

Despite upgrades to system capacity, in 2021 and 2048 the increases in frequency and volume of overflows at SCOF107 result in increased loads per event for all indicators. The most noticeable increase in loads per event occurs between 2009 and 2021, when loads increase by 1.5 to 2 times, with increases between 2021 and 2048 less significant.

Pollutant loads per event for all key indicators at 1400000, 1119924 and 1121017 decrease between 2009 and 2021. Between 2021 and 2048, pollutant loads per event increase for all indicators but remain less than the current (2009) situation.

Mullet Creek Catchment

One directed overflow site (SCOF117) located in the Mullet Creek catchment was identified to be carried forward to the impact assessment. The mass balance results at the site for current (2009), 2021 and 2048 are summarised in Table B-2 and described below.

- **Table B-2 Mass balance results for risk prioritised directed overflows for the Mullet Creek Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
SCOF117	405	74	14	1.35×10^{14}	1,196	219	40	3.99×10^{14}	1,381	253	46	4.60×10^{14}

Pollutant loads per overflow event at SCOF117 dramatically increase between 2009 and 2021 for all key indicators, with loads per event in 2021 approximately 2.8-2.9 times greater than in 2009. Pollutant loads per event continue to increase between 2021 and 2048, but the magnitude of increase is significantly less.

Barrack Creek Catchment

Six directed overflow sites (CMSP343, 1400028, 1123473, 1125705, 1122981 and 1125953) located in the Barrack Creek catchment were identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-3 and described below.

- **Table B-3 Mass balance results for risk prioritised directed overflows for the Barrack Creek Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)

CMSP343	4.4	0.8	0.15	1.45x10^{12}	3.8	0.7	0.13	1.27x10^{12}	3.7	0.69	0.12	1.25x10^{12}
1400028	25	4.7	0.86	8.62x10^{12}	27	4.95	0.9	9.00x10^{12}	29	5.3	0.96	9.64x10^{12}
1123473	50	9.2	1.68	1.68x10^{13}	47	8.75	1.6	1.59x10^{13}	48	8.79	1.6	1.60x10^{13}
1125705	137	25.2	4.6	4.58x10^{13}	199	36.5	6.6	6.64x10^{13}	222	40.8	7.4	7.42x10^{13}
1122981	221	40.6	7.4	7.39x10^{13}	285	52.3	9.5	9.50x10^{13}	284	52.1	9.4	9.48x10^{13}
1125953	420	77	14	1.40x10^{14}	353	64.8	11.7	1.18x10^{14}	347	63.6	11.6	1.16x10^{14}

Pollutant loads per overflow event at CMSP343 and 1125953 decrease between 2009 and 2021 and 2021 and 2048 for all indicators. Pollutant loads also decrease per event between 2009 and 2021 at 1123473, but then increase slightly in 2048.

At 1400028 minor increases in loads per event of all pollutants are observed between 2009 and 2021 and between 2021 and 2048. At directed overflows 1125705 and 1122981 most significant increases in pollutant loads are expected per event between 2009 and 2021, with slightly less significant increases between 2021 and 2048.

Horsley and Connor Creek Catchment

One directed overflow site (1120960) located in the Horsley and Connor Creek catchment was identified to be carried forward to the impact assessment. The mass balance results of the site for current (2009), 2021 and 2048 are summarised in Table B-4 and described below.

- **Table B-4 Mass balance results for risk prioritised directed overflows for the Horsley and Connor Creek Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
1120960	142	26	4.7	4.73x10^{13}	137	25	4.56	4.56x10^{13}	154	28	5.1	5.13 x10^{13}

Pollutant loads per event decrease between 2009 and 2021 at 1120960 for all key indicators but loads increase per event in 2048.

Allan's Creek Catchment

Five directed overflow sites (1131051, 1129001, 1130399, 1128785 and 1128317) located in the Allan's Creek catchment were identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-5 and described below.

- **Table B-5 Mass balance results for risk prioritised directed overflows for the Allan's Creek Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
1131051	6.4	1.7	0.21	2.13×10^{12}	5.5	1	0.18	1.84×10^{12}	5.5	1	0.18	1.84×10^{12}
1129001	11	2.03	0.37	3.68×10^{12}	10.6	1.94	0.35	3.53×10^{12}	10.6	1.94	0.35	3.53×10^{12}
1130399	78	14	2.6	2.60×10^{13}	111	20.5	3.7	3.73×10^{13}	111	20.5	3.7	3.73×10^{13}
1128785	117	21	3.9	3.89×10^{13}	153	28.1	5.1	5.10×10^{13}	153	28.1	5.1	5.10×10^{13}
1128317	93	17	3.09	3.09×10^{13}	133	24.4	4.45	4.45×10^{13}	133	24.4	4.45	4.45×10^{13}

Pollutant loads per event for directed overflows 1131051 and 1129001 decrease between 2009 and 2021, but at 1130399, 1128785, and 1128317, pollutant loads increase by 1.3 to 1.4 times. Pollutant loads per event in 2048 are similar to 2021 at the five directed overflows.

Port Kembla Catchment

One directed overflow (8121785) located in the Port Kembla catchment was identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-6 and described below.

- **Table B-6 Mass balance results for risk prioritised directed overflows for the Port Kembla Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
8121785	524	96	17	1.75×10^{14}	624	114	21	2.08×10^{14}	624	114	21	2.08×10^{14}

Pollutant loads at 8121785 increases per event between 2009 and 2021 for all key indicators however there is no change in event loads between 2021 and 2048.

B.2 Uncontrolled Overflows

Lake Illawarra Catchment

Seven uncontrolled overflow sites (1141135, 1141999, 1142022, 1139143, 1139339, 1396642 and 1118692) located in the Lake Illawarra catchment forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-7 and described below.

- **Table B-7 Mass balance results for loads per event for risk prioritised uncontrolled overflows for the Lake Illawarra Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
1141135	10.8	2	0.36	$3.61x10^{12}$	8	1.47	0.27	$2.67x10^{12}$	9.4	1.7	0.3	$3.13 x10^{12}$
1141999	4.67	0.86	0.16	$1.56x10^{12}$	4.77	0.87	0.16	$1.59x10^{12}$	5.4	0.99	0.18	$1.79 x10^{12}$
1142022	7.1	1.29	0.24	$2.35x10^{12}$	7.3	1.33	0.24	$2.43x10^{12}$	7.8	1.44	0.26	$2.62 x10^{12}$
1139143	7.4	1.3	0.25	$2.45x10^{12}$	6.1	1.1	0.2	$2.03x10^{12}$	6.8	1.2	0.23	$2.27 x10^{12}$
1139339	22	4.1	0.74	$7.40x10^{12}$	19.3	3.5	0.64	$6.42x10^{12}$	21.4	3.9	0.7	$7.13 x10^{12}$
1396642	27	5	0.9	$9.08x10^{12}$	21	3.7	0.7	$6.86x10^{12}$	20	3.68	0.67	$6.70 x10^{12}$
1118692	19	3.5	0.6	$6.43x10^{12}$	17	3.1	0.6	$5.67x10^{12}$	19	3.5	0.64	$6.37 x10^{12}$

Pollutant loads per event at uncontrolled overflows 1141135, 1139143 and 1139339 decrease between 2009 and 2021 and then increase between 2021 and 2048. Despite increases from 2021 to 2048, loads per event remain less than the current situation. Pollutant loads per event at 1141999 and 1142022 increase between 2009 and 2021 and between 2021 and 2048. Uncontrolled overflows 1396642 and 1118692 have a reduction in pollutant loads per event between 2009 and 2021. Pollutant loads per event continue to decrease by a small about at 1396642 between 2021 and 2048, but increase at 1118692 for that same period.

Mullet Creek Catchment

Six uncontrolled overflow sites (1135796, 1133545, 1142018, 1136273, 1135500 and 1132832) located in the Mullet Creek catchment were identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-8 and described below.

- **Table B-8 Mass balance results for loads per event for risk prioritised uncontrolled overflows for the Mullet Creek Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
1135796	5	0.97	0.18	$1.76x10^{12}$	10	1.92	0.35	$3.50\ x10^{12}$	16	3	0.54	$5.41\ x10^{12}$
1133545	16	2.94	0.53	$5.34x10^{12}$	15	2.75	0.50	$5.00\ x10^{12}$	18	3.3	0.6	$6.01\ x10^{12}$
1142018	10	1.75	0.32	$3.18x10^{12}$	10	1.88	0.34	$3.41\ x10^{12}$	13	2.38	0.4	$4.34\ x10^{12}$
1136273	40	7.30	1.33	$1.33x10^{13}$	33	6.13	1.11	$1.11\ x10^{13}$	35	6.49	1.18	$1.18\ x10^{13}$
1135500	21	3.90	0.71	$7.08x10^{12}$	57	10.47	1.90	$1.90\ x10^{13}$	77	14.1	2.56	$2.56\ x10^{13}$
1132832	81	14.9	2.71	$2.71x10^{13}$	69	12.73	2.31	$2.31\ x10^{13}$	76	14	2.6	$2.55\ x10^{13}$

Three uncontrolled overflows, 1133545, 1136273 and 1132832 have a reduction in pollutant loads per event between 2009 and 2021 for all key indicators. Pollutant loads per event between 2021 and 2048 for these overflows increased slightly, however despite increases, pollutant loads per event at 1136273 remain less than current (2009) loads.

Pollutant loads per event at 1142018 increased slightly between 2009 and 2021 between 2021 and 2048.

Overflows 1135796 and 1135500 have the most significant increase in pollutant loads per event between 2009 and 2021, whereby loads per event generally increase by two fold or more. Between 2021 and 2048 pollutant loads continue to increase per event however the magnitude of change is not as large between 2021 and 2048.

Ocean Outfalls

One uncontrolled overflow site (1140820) from ocean outfalls was identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-9 and described below.

Table B-9 Mass balance results for loads per event for risk prioritised uncontrolled overflows from ocean outfalls

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
1140820	38	6.9	1.26	$1.26x10^{13}$	28	5.2	0.95	$9.46x10^{12}$	31	5.7	1.04	$1.04\ x10^{13}$

Pollutant loads on an event basis at 1140820 decreased between 2009 and 2021 for all indicators. Pollutant loads per event increase between 2021 and 2048 however event loads in 2048 are still less than is currently being observed in 2009.

Barrack Creek Catchment

Two uncontrolled overflow sites (1123653 and 1127548) located in the Barrack Creek catchment were identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-10 and described below.

Table B-10 Mass balance results for loads per event for uncontrolled overflows for the Barrack Creek Catchment

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
1123653	4	0.82	0.15	$1.50x10^{12}$	5	0.85	0.15	$1.54\ x10^{12}$	5	0.92	0.16	$1.67x10^{12}$
1127548	91	16	3	$3.03x10^{13}$	72	13.3	2.4	$2.41\ x10^{13}$	75	13.7	2.5	$2.49x10^{13}$

Pollutant loads per event increase slightly at 1123653 between 2009 and 2021 and between 2021 and 2048.

Uncontrolled overflow 1127548 has a reduction in pollutant loads per event between 2009 and 2021 for all key indicators. Pollutant loads per event between 2021 and 2048 increase slightly but despite increases, pollutant loads per event at 1127548 remain less than current (2009) loads.

Horsley and Connor Creek Catchment

Two uncontrolled overflow sites (1119176 and 1121644) located in the Horsley and Connor Creek catchment were identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-11 and described below.

- **Table B-11 Mass balance results for loads per event for risk prioritised uncontrolled overflows for the Horsley and Connor Creek Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
1119176	7.67	1.41	0.26	$2.56x10^{12}$	5.52	1.01	0.18	$1.84x10^{12}$	4.60	0.84	0.15	$1.53 x10^{12}$
1121644	7.95	1.46	0.27	$2.65x10^{12}$	7.31	1.34	0.24	$2.44x10^{12}$	9.34	1.71	0.31	$3.11 x10^{12}$

At uncontrolled overflows 1119176 and 1121644, pollutant loads decrease per event between 2009 and 2021. In 2048, pollutant loads per event at 1119176 are less than 2021 however at 1121644 loads increase per event between 2021 and 2048.

Macquarie Rivulet Catchment

Ten uncontrolled overflow sites (1551095, 1117919, 1117911, 1395591, 1121559, 1117699, 1117799, 1119031, 1121555 and 1121635) located in the Macquarie Rivulet catchment were identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-12 and described below.

- **Table B-12 Mass balance results for loads per event for risk prioritised uncontrolled overflows for the Macquarie Rivulet Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
1551095	2.24	0.41	0.07	$7.47x10^{12}$	1.91	0.35	0.06	$6.38x10^{12}$	1.96	0.36	0.07	$6.52x10^{12}$
1117919	3.73	0.68	0.12	$1.24x10^{12}$	3.59	0.66	0.12	$1.20x10^{12}$	3.50	0.64	0.12	$1.17x10^{12}$
1117911	4.75	0.87	0.16	$1.58x10^{12}$	4.96	0.91	0.17	$1.65x10^{12}$	5.21	0.96	0.17	$1.74x10^{12}$
1395591	8.83	1.62	0.29	$2.94x10^{12}$	8.93	1.64	0.30	$2.98x10^{12}$	8.51	1.56	0.28	$2.84x10^{12}$
1121559	7.74	1.42	0.26	$2.58x10^{12}$	6.24	1.14	0.21	$2.08x10^{12}$	5.72	1.05	0.19	$1.91x10^{12}$

Overflow ID	2009 TSS (kg/event)	2009 TN (kg/event)	2009 TP (kg/event)	2009 FC (cfu/event)	2021 (project approval) TSS (kg/event)	2021 (project approval) TN (kg/event)	2021 (project approval) TP (kg/event)	2021 (project approval) FC (cfu/event)	2048 (concept approval) TSS (kg/event)	2048 (concept approval) TN (kg/event)	2048 (concept approval) TP (kg/event)	2048 (concept approval) FC (cfu/event)
1117699	11.14	2.04	0.37	$3.71x10^{12}$	9.65	1.77	0.32	$3.22x10^{12}$	10.21	1.87	0.34	$3.40x10^{12}$
1117799	10.88	1.99	0.36	$3.63x10^{12}$	10.20	1.87	0.34	$3.40x10^{12}$	9.91	1.82	0.33	$3.30x10^{12}$
1119031	19.21	3.52	0.64	$6.40x10^{12}$	13.78	2.53	0.46	$4.59x10^{12}$	11.31	2.07	0.38	$3.77x10^{12}$
1121555	18.58	3.41	0.62	$6.19x10^{12}$	15.43	2.83	0.51	$5.14x10^{12}$	14.69	2.69	0.49	$4.90x10^{12}$
1121635	54.14	9.92	1.80	$1.80x10^{13}$	43.22	7.92	1.44	$1.44x10^{13}$	38.99	7.15	1.30	$1.30x10^{13}$

Overflow pollutant loads per event for all indicators decrease between 2009 and 2021 at 8 of the 10 uncontrolled overflows with 1117911 and 1395591 both predicted to have increased pollutant loads per event between 2009 and 2021. Between 2021 and 2048, pollutant loads per event continue to decrease at 7 of the uncontrolled overflows. Pollutant loads per event increase at 1117911 and 1395591 and 1117699 between 2021 and 2048.

Allan's Creek Catchment

Fourteen uncontrolled overflow sites (1130679, 1136262, 1129143, 1128713, 1131717, 1128997, 1129135, 1129893, 1130584, 1129697, 1128841, 1128668, 1129389 and 1131184) located in the Allan's Creek catchment were identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-13 and described below.

- **Table B-13 Mass balance results for loads per event for risk prioritised uncontrolled overflows for the Allan's Creek Catchment**

Overflow ID	2009 TSS (kg/event)	2009 TN (kg/event)	2009 TP (kg/event)	2009 FC (cfu/event)	2021 (project approval) TSS (kg/event)	2021 (project approval) TN (kg/event)	2021 (project approval) TP (kg/event)	2021 (project approval) FC (cfu/event)	2048 (concept approval) TSS (kg/event)	2048 (concept approval) TN (kg/event)	2048 (concept approval) TP (kg/event)	2048 (concept approval) FC (cfu/event)
1130679	0.94	0.17	0.03	$3.14x10^{11}$	1.76	0.32	0.06	$5.87x10^{11}$	3.2	0.59	0.11	$1.07x10^{12}$
1136262	1.88	0.35	0.06	$6.28x10^{11}$	1.9	0.35	0.06	$6.35x10^{11}$	2.21	0.4	0.07	$7.36x10^{11}$
1129143	3.09	0.57	0.1	$1.03x10^{12}$	3.07	0.56	0.10	$1.02x10^{12}$	3.49	0.64	0.12	$1.16x10^{12}$
1128713	1.78	0.33	0.06	$5.94x10^{11}$	1.82	0.33	0.06	$6.06x10^{11}$	2.21	0.41	0.07	$7.37x10^{11}$
1131717	2.2	0.4	0.07	$7.32x10^{11}$	2.36	0.43	0.08	$7.87x10^{11}$	2.93	0.54	0.1	$9.78x10^{11}$

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
1128997	4.86	0.89	0.16	$1.62x10^{12}$	0.78	0.14	0.03	$2.60x10^{11}$	0.78	0.14	0.03	$2.60x10^{11}$
1129135	3.9.	0.72	0.13	$1.31x10^{12}$	4.27	0.78	0.14	$1.42x10^{12}$	4.71	0.86	0.16	$1.57x10^{12}$
1129893	3.83	0.7	0.13	$1.28x10^{12}$	4.02	0.74	0.13	$1.34x10^{12}$	4.31	0.79	0.14	$1.44x10^{12}$
1130584	8.02	1.47	0.07	$2.67x10^{12}$	32	6	1	$1.08x10^{13}$	16.41	3.01	0.55	$5.47x10^{12}$
1129697	8.11	1.49	0.27	$2.70x10^{12}$	5.1	0.93	0.17	$1.70x10^{12}$	5.07	0.93	0.17	$1.69x10^{12}$
1128841	4.91	0.9	0.16	$1.64x10^{12}$	4.94	0.91	0.16	$1.65x10^{12}$	5.71	1.05	0.19	$1.90x10^{12}$
1128668	27.2	5	0.91	$9.09x10^{12}$	33.9	6.21	1.13	$1.13x10^{13}$	43.3	7.94	1.44	$1.44x10^{13}$
1129389	7.36	1.35	0.25	$2.45x10^{12}$	7.42	1.36	0.25	$2.47x10^{12}$	8.11	1.49	0.27	$2.70x10^{12}$
1131184	55.2	10.1	1.84	$1.84x10^{13}$	52	9.48	1.72	$1.72x10^{13}$	54.75	10	1.83	$1.83x10^{13}$

Pollutant loads per event increase at 10 of the 14 uncontrolled overflow sites between 2009 and 2021. Deceases are predicted at 1129143, 2238997, 1129697 and 1128841 during this same period. Pollutant loads per event between 2021 and 2048 increase at all sites except 1128997 which remains unchanged and at 1129697 which decreases slightly.

Port Kembla Catchment

Three uncontrolled overflow sites (1134082, 1377705 and 1133831) located in the Port Kembla catchment were identified to be carried forward to the impact assessment. The mass balance results of the sites for current (2009), 2021 and 2048 are summarised in Table B-14 and described below.

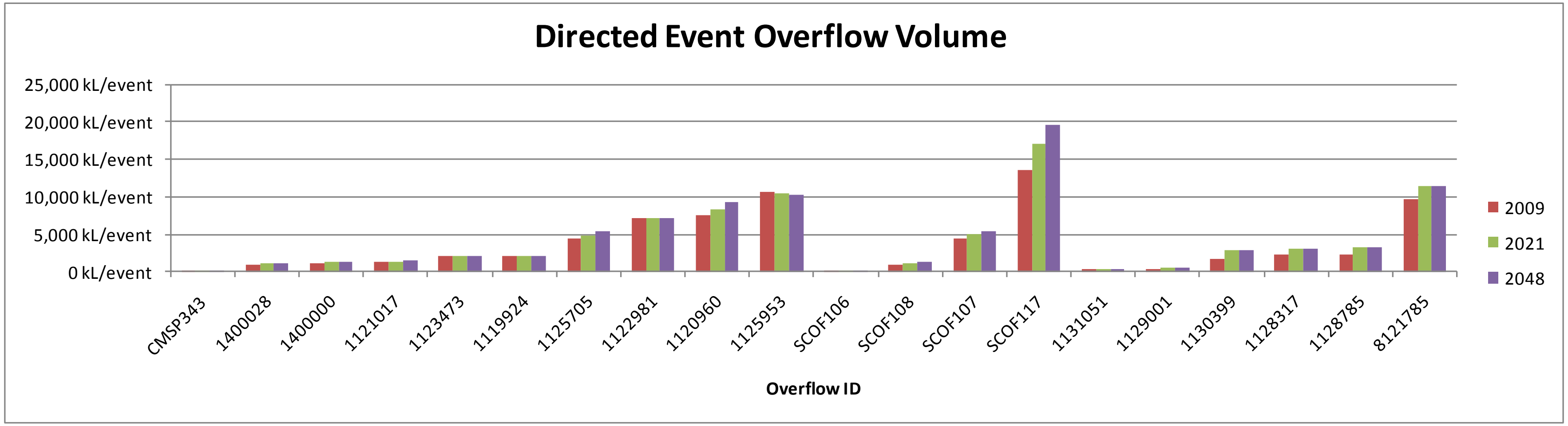
- **Table B-14 Mass balance results for loads per event for risk prioritised uncontrolled overflows for the Port Kembla Catchment**

Overflow ID	2009				2021 (project approval)				2048 (concept approval)			
	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)	TSS (kg/event)	TN (kg/event)	TP (kg/event)	FC (cfu/event)
1134082	9.46	1.73	0.32	$3.15x10^{12}$	8.52	1.56	0.28	$2.84x10^{12}$	9.04	1.66	0.3	$3.01 x10^{12}$
1377705	4.2	0.77	0.14	$1.40x10^{12}$	2.1	0.38	0.07	$6.99x10^{11}$	2.1	0.38	0.07	$6.99 x10^{11}$
1133831	10.7	1.95	0.35	$3.55x10^{12}$	10	1.83	0.33	$3.33x10^{12}$	10	1.83	0.33	$3.33 x10^{12}$

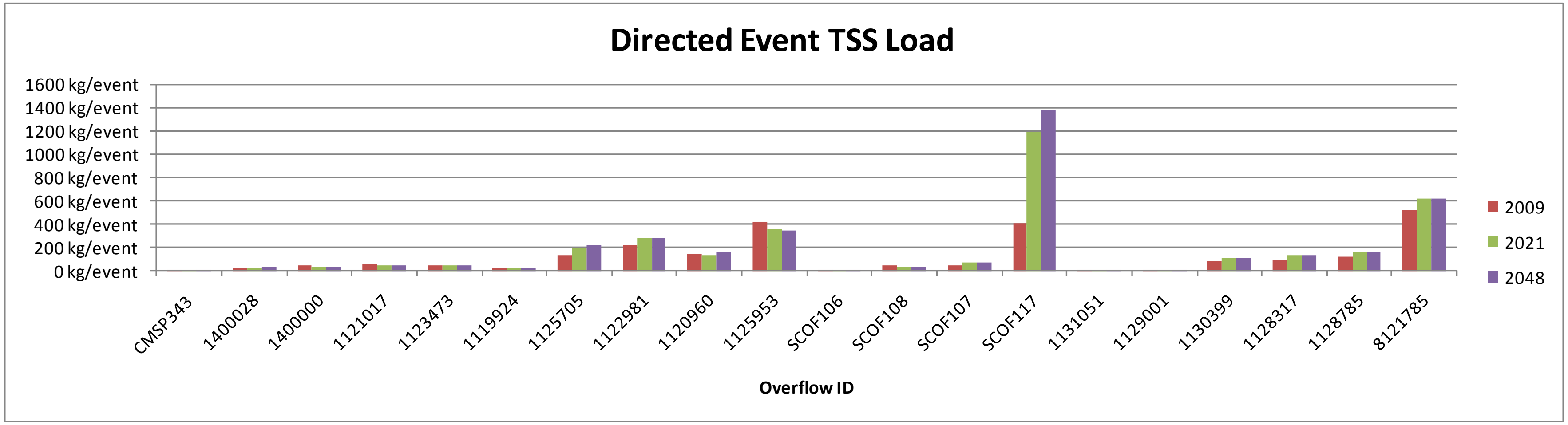
Pollutant loads at the three uncontrolled overflows, decrease per event between 2009 and 2021. Between 2021 and 2048 pollutant loads per event remain unchanged at 1377705 and 1133831, but increase slightly at 1134082. Despite increases, pollutant loads per event in 2048 remain less than 2009.

Appendix C Directed Overflow Load Comparisons per Event

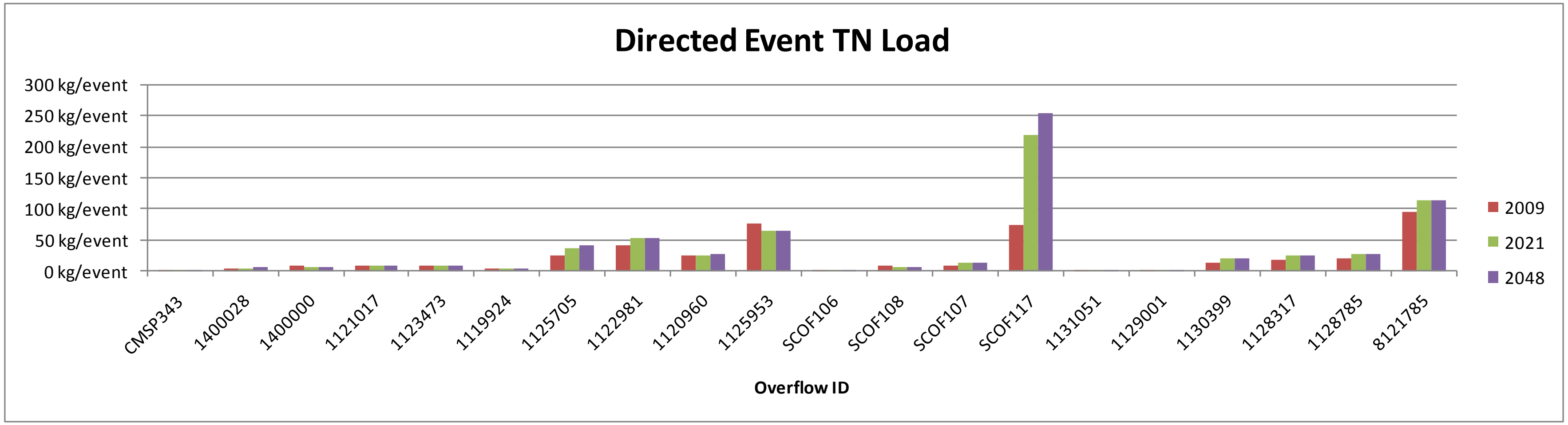
Appendix C provides a visual comparison of the increases in overflows volumes, TSS, TN, TP, and faecal coliform loads per event in 2009, 2021 and 2048 for high and highest priority overflows. As shown in Figures C-1 to C-5, SCOF117 has the highest overflow volume per event and subsequently the highest event pollutant loads, followed by 8121785 and 1125953.



- **Figure C-1: Volume of overflow per event at high and highest priority directed overflows**



■ **Figure C-2: TSS loads per event at high and highest priority directed overflows**



■ **Figure C-3: TN loads per event at high and highest priority directed overflows**

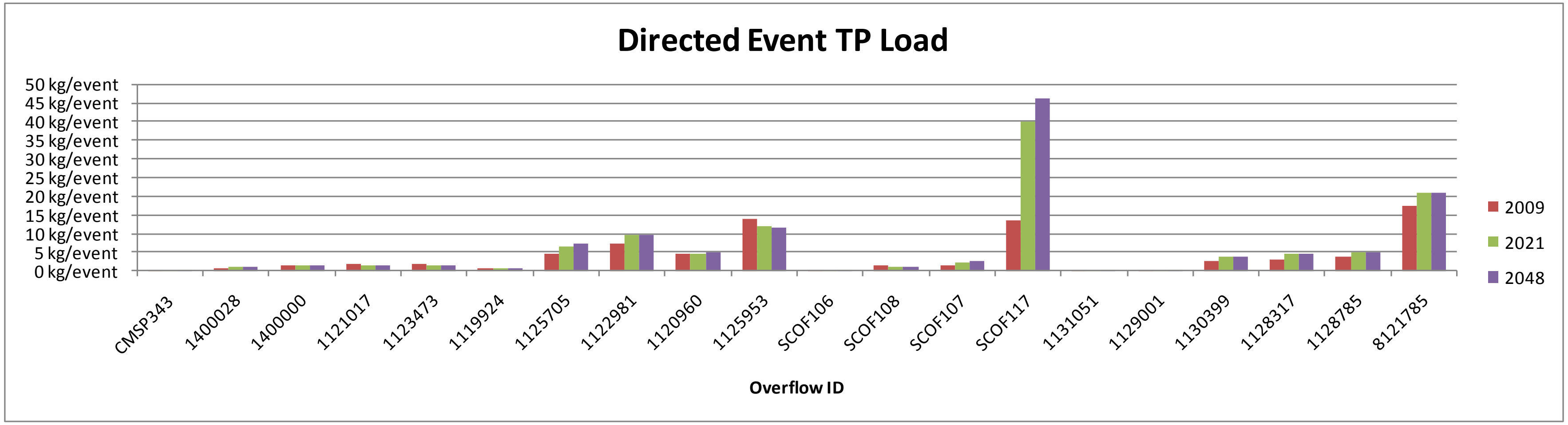


Figure C-4: TP loads per event at high and highest priority directed overflows

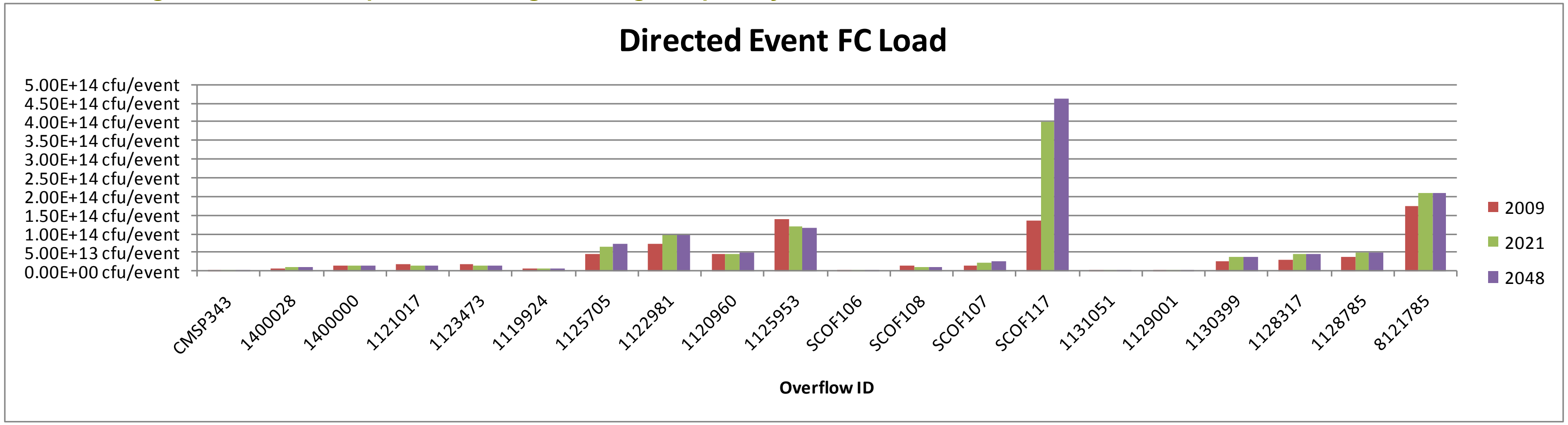
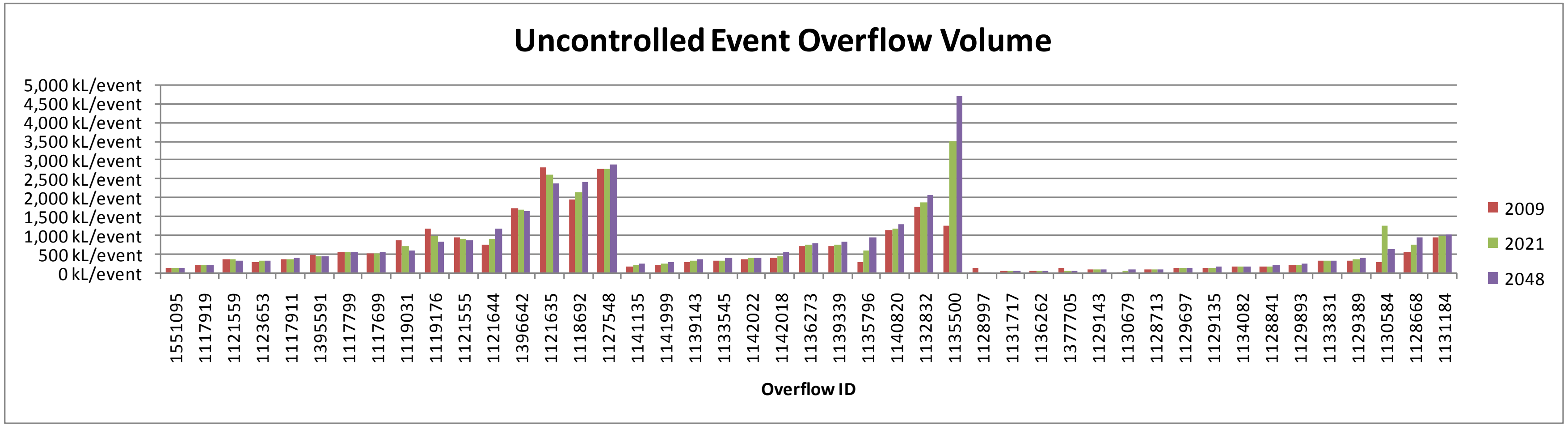


Figure C-5: FC loads per event at high and highest priority directed overflows

Appendix D Uncontrolled Overflow Load Comparisons per Event

Appendix D provides a visual comparison of the increases in overflows volumes, TSS, TN, TP, and faecal coliform loads per event in 2009, 2021 and 2048 for high and highest priority uncontrolled overflows. As shown in Figures D-1 to D-5, 113550 has the highest overflow volume per event and subsequently the highest event pollutant loads, followed by 1127458 and 1118692. There are also a number of uncontrolled overflows that show a decrease in overflow volume and pollutant loads per event between 2009, 2021 and 2048 including 1119176 and 1119031.



- **Figure D-1: Volume of overflow per event at high and highest priority uncontrolled overflows**

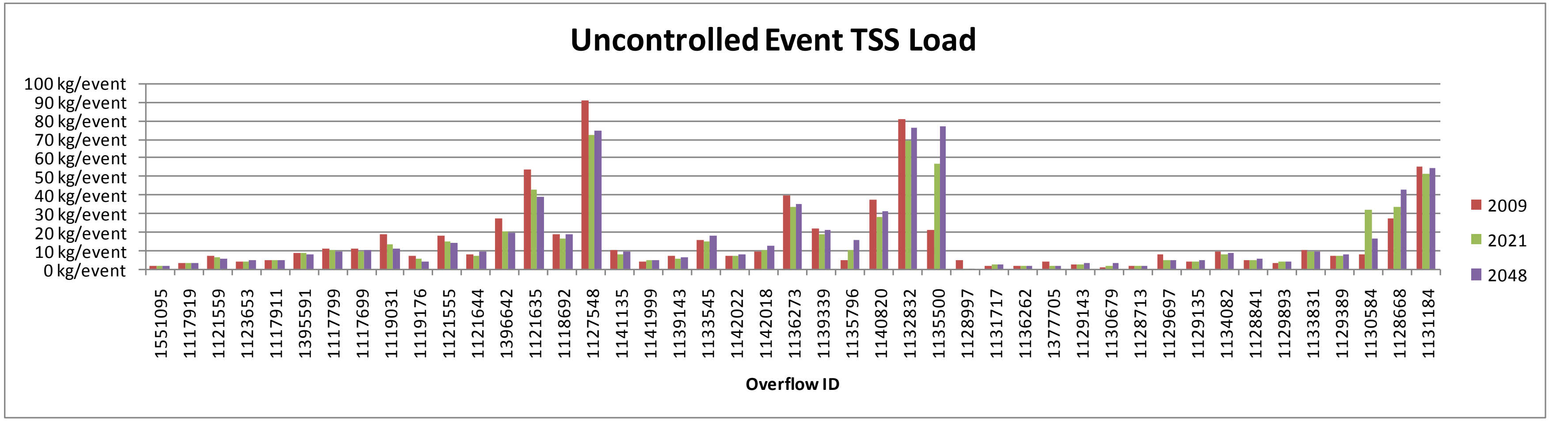


Figure D-2: TSS loads per event at high and highest priority uncontrolled overflows

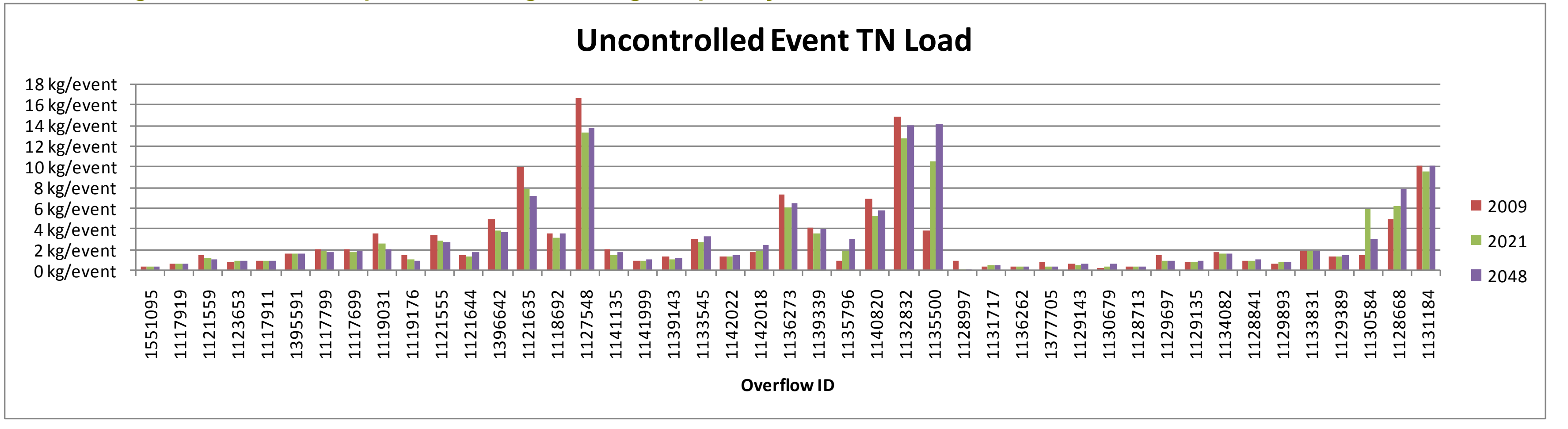
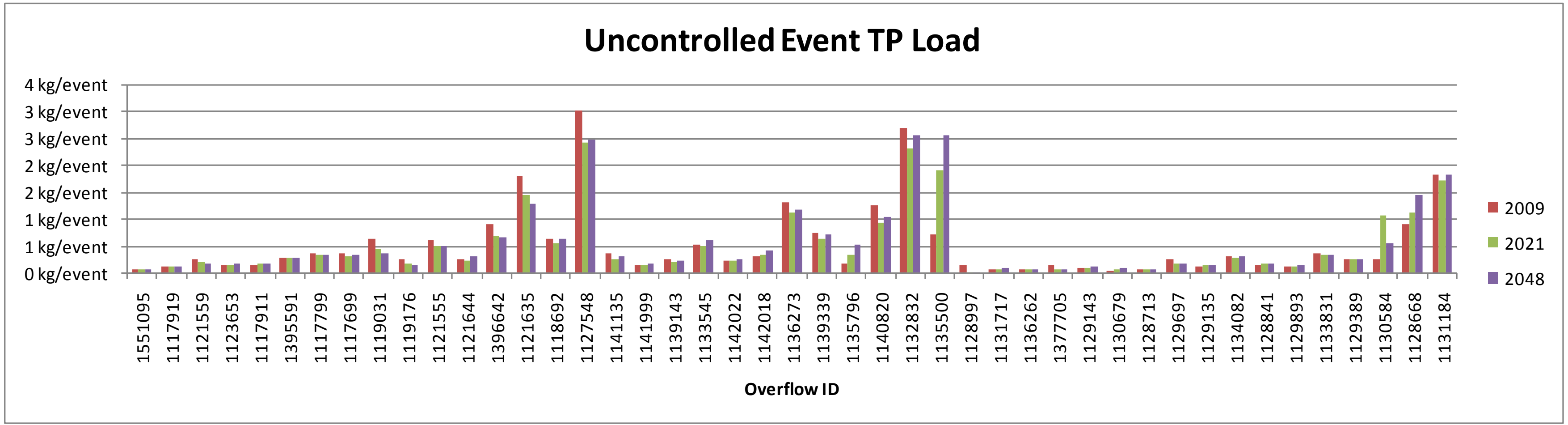
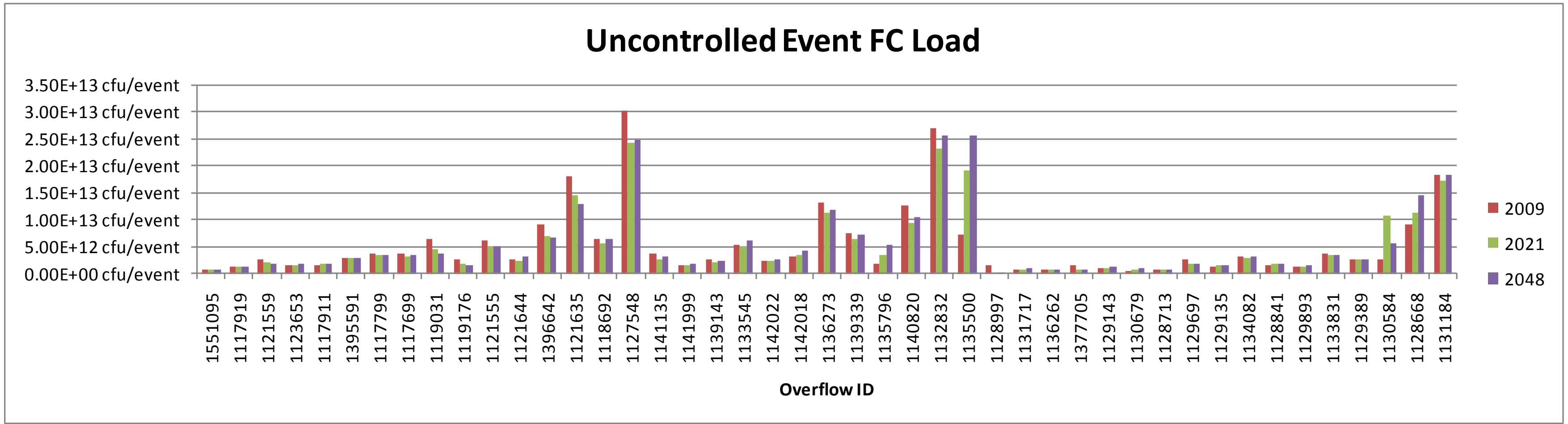


Figure D-3: TN loads per event at high and highest priority uncontrolled overflows



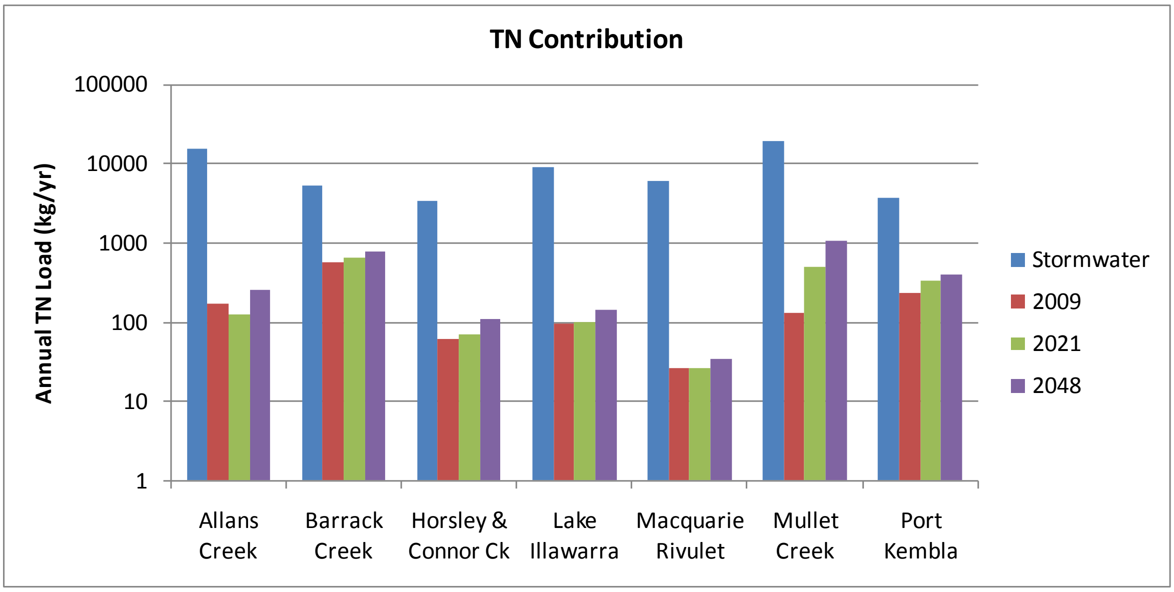
■ **Figure D-4: TP loads per event at high and highest priority uncontrolled overflows**



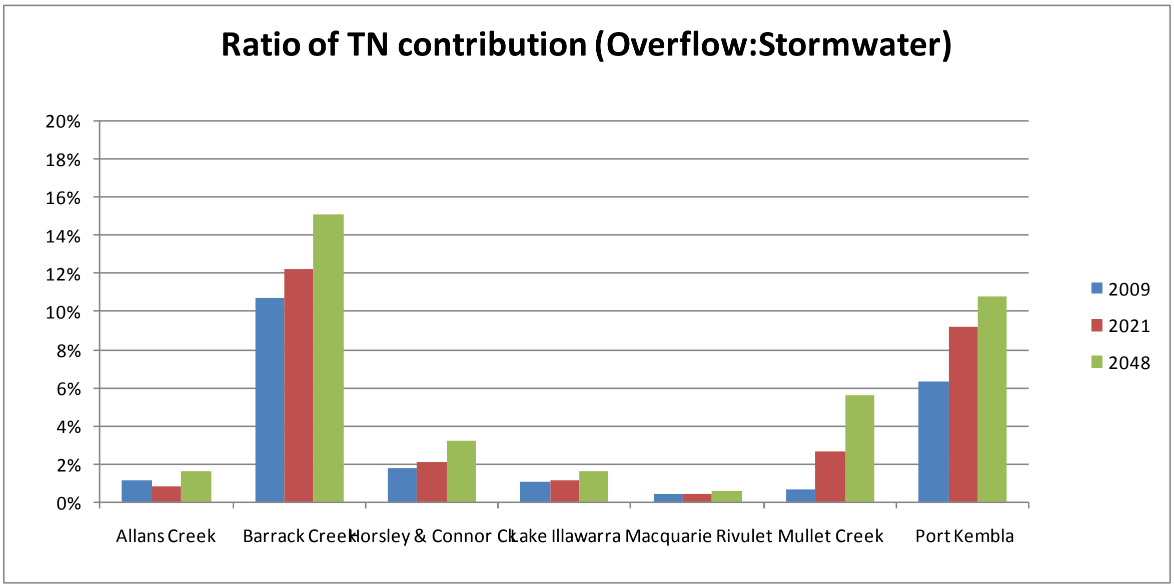
■ **Figure D-5: FC loads per event at high and highest priority uncontrolled overflows**

Appendix E Pollutant Contribution

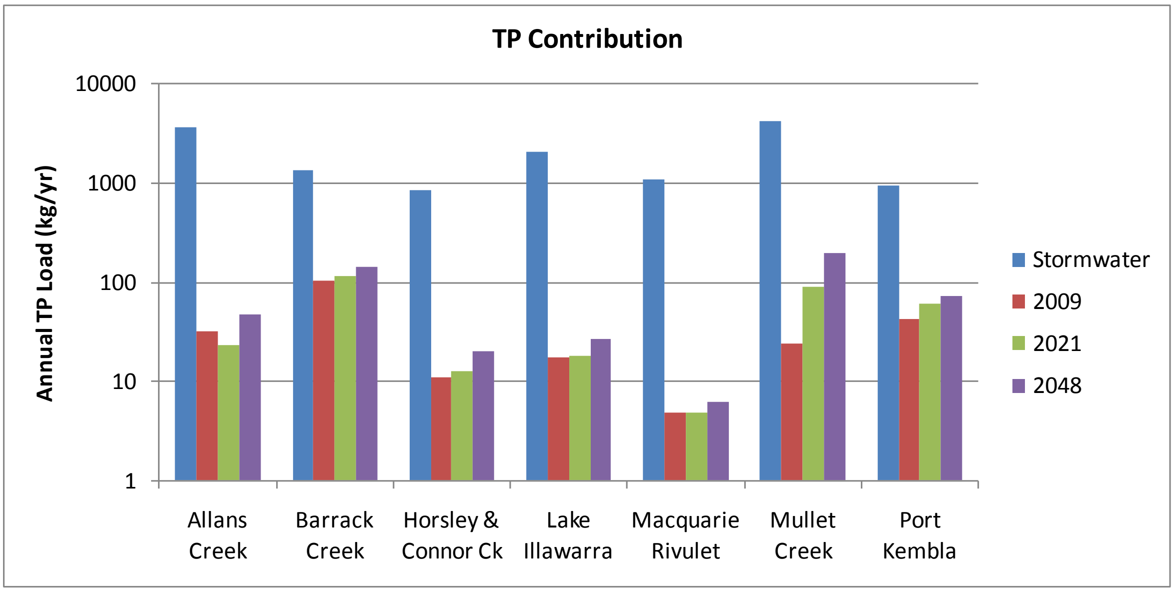
Appendix E graphically presents the pollutant contribution in kilograms per year generated from both stormwater and high and highest priority wastewater overflows on a sub-catchment scale. This information is presented in Figure E-1 for TN, Figure E-3 for TP, Figure E-5 for TSS and Figure E7 for FC. Generally the greatest contributor of pollutants is stormwater, although annual FC releases from wastewater and stormwater are similar. Also displayed (Figure E-2, Figure E-4, Figure E-6 and Figure E-8) is the ratio of pollutant contribution on a sub-catchment scale. Generally contribution of pollutants from wastewater overflows is very low with the exception of faecal coliforms, when the contribution from stormwater and overflows similar. The graphs also show that some sub-catchments have higher pollutant loads than others, such as Barrack Creek and Mullet Creek. These sub-catchments contain those overflows that were identified as potentially impacting on environmental values due to their volume and frequency of overflows in 2021 and 2048.



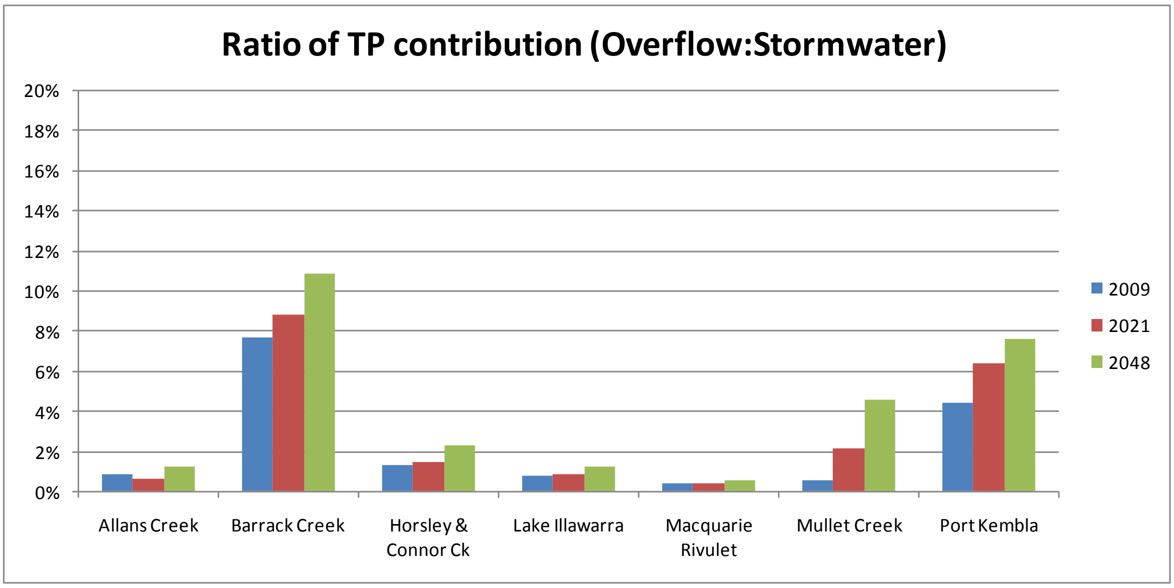
- **Figure E-1: Contribution of annual TN loads from stormwater and overflows in 2009, 2021 and 2048 per sub-catchment.**



- **Figure E-2: Ratio of TN contrition from overflows and stormwater in 2009, 2021 and 2048**



- **Figure E-3: Contribution of annual TP loads from stormwater and overflows in 2009, 2021 and 2048 per sub-catchment.**



- **Figure E-4: Ratio of TP contrition from overflows and stormwater in 2009, 2021 and 2048**

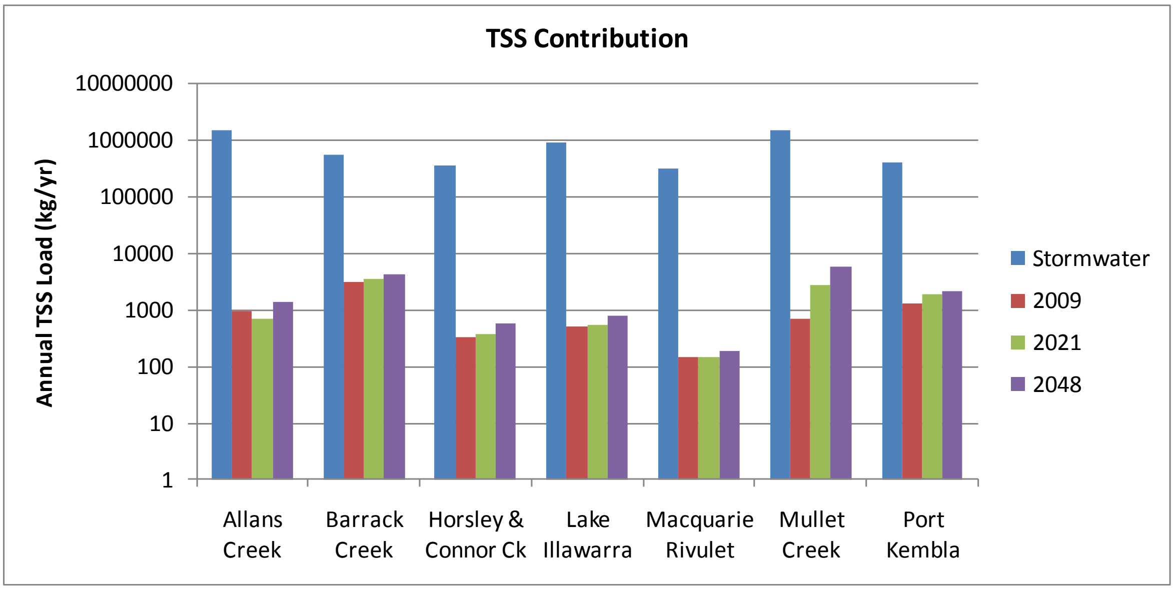


Figure E-5: Contribution of annual TSS loads from stormwater and overflows in 2009, 2021 and 2048 per sub-catchment.

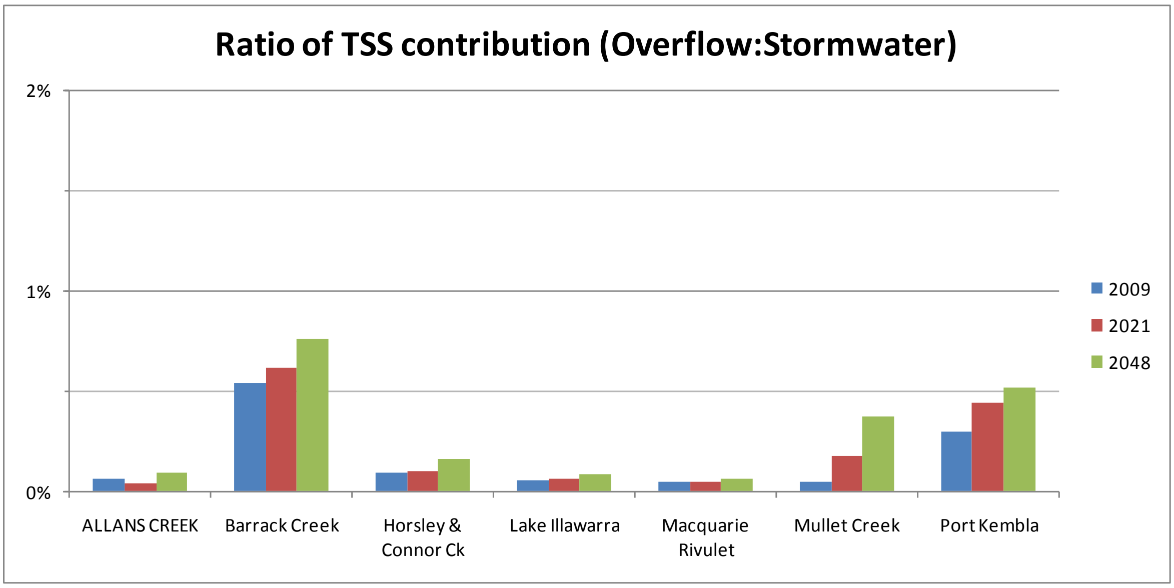
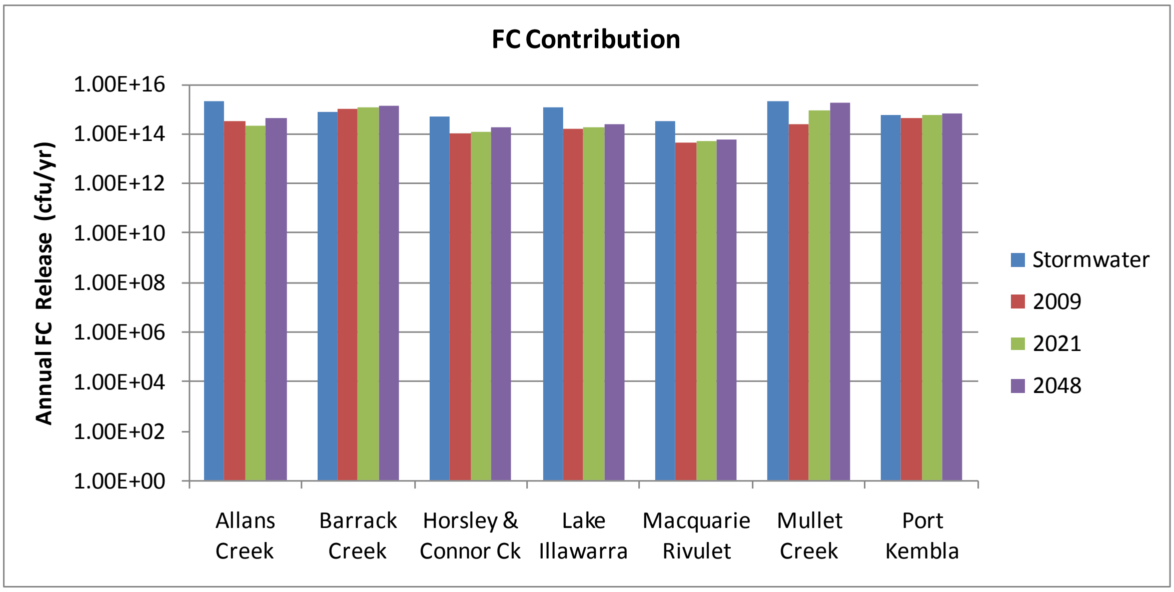
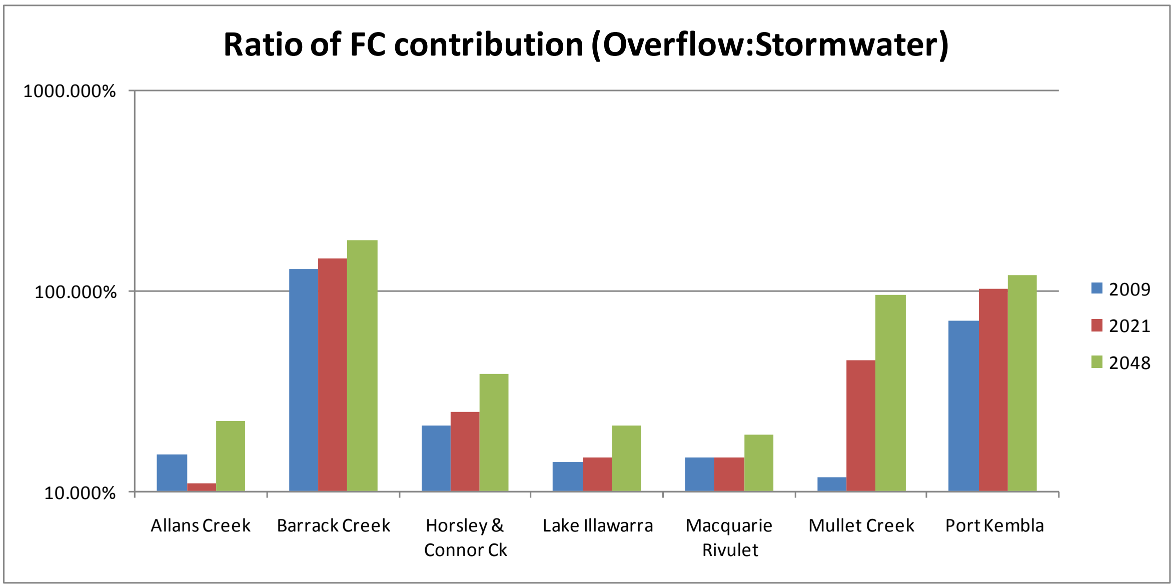


Figure E-6: Ratio of TSS contrition from overflows and stormwater in 2009, 2021 and 2048



- **Figure E-7: Contribution of annual FC release from stormwater and overflows in 2009, 2021 and 2048 per sub-catchment.**



- **Figure E-8: Ratio of FC contrition from overflows and stormwater in 2009, 2021 and 2048**

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