Appendix A

Declaration

Department of Planning

ENVIRONMENTAL PLANNING AND ASSESSMENT ACT 1979

Order Declaring Development to be a Project Under Part 3A of the Environmental Planning and Assessment Act 1979 Amendment

I, the Executive Director, Major Projects Assessment, as delegate of the Minister for Planning and Infrastructure, pursuant to section 75B (5) of the Environmental Planning and Assessment Act 1979 (the Act), amend the project declaration made under section 75B of the Act on 7 September 2009 (GG No. 146 of 16 October 2009, p5426), by amending the developments described in Schedule 1 to that order, by replacing it with the developments described in Schedule 1 to this order.

In my opinion, the development referred to in Schedule 1 of this order is of State and regional environmental planning significance.

Dated: 29 February 2012.

CHRISTOPHER WILSON,
Executive Director,
Major Projects Assessment

SCHEDULE 1

A proposal for the water and wastewater servicing of the West Dapto Urban Release Area and Adjacent Growth Areas comprising:

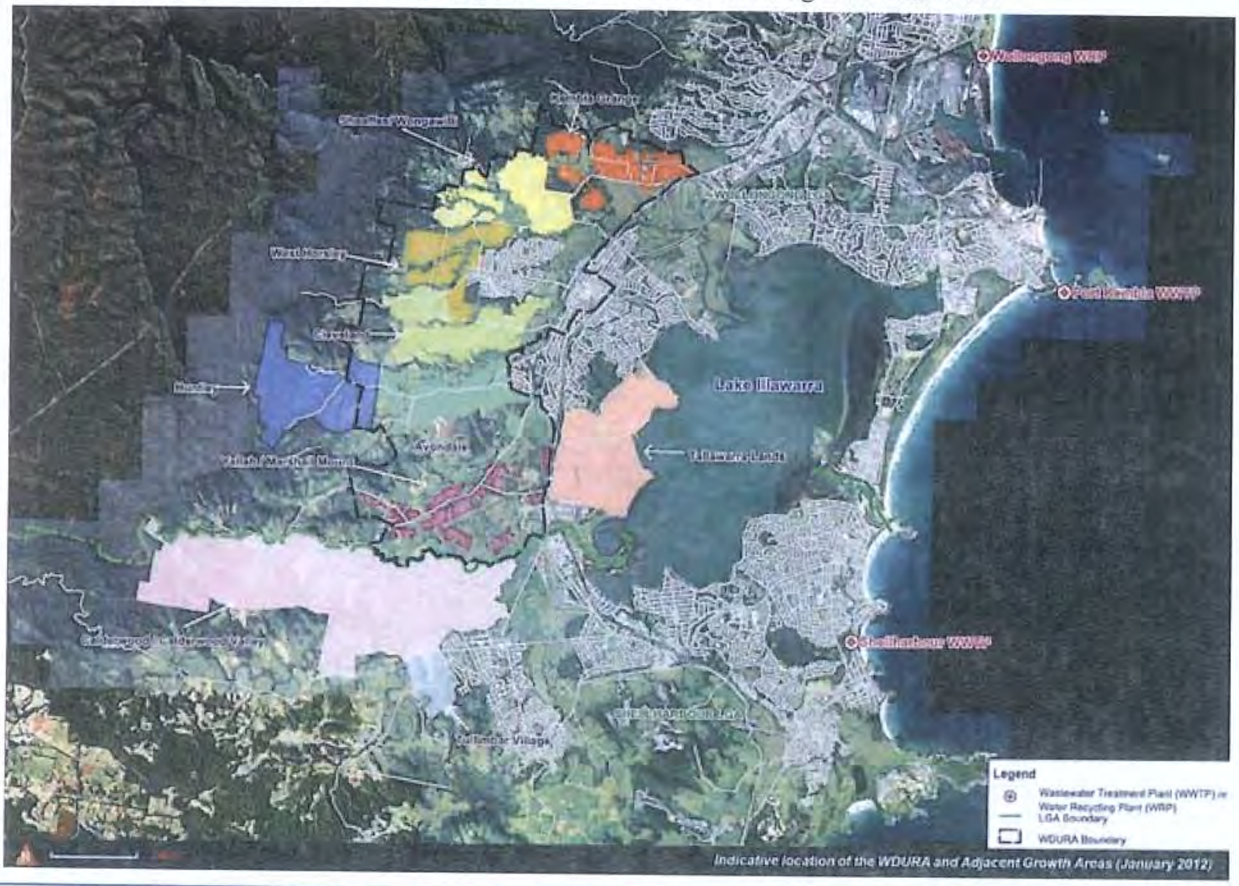
- the construction and operation of drinking water and wastewater pipelines, pumping stations, drinking water reservoirs and associated infrastructure; and
- upgrades to the Wollongong and Shellharbour sewage treatment plants.

The West Dapto Urban Release Area is generally defined as the suburbs of Kembla Grange, Sheaffes/Wongawilli, West Horsley, East Horsley, Cleveland, a portion of Huntley, Avondale, Yallah/Marshall Mount and the Dapto Sub Regional Centre.

The Adjacent Growth Areas are generally defined as a portion of Huntley, Tallawarra lands, Calderwood and Tullimbar Village.

As generally shown on the indicative map prepared by Sydney Water dated 23 January 2012 and titled Indicative location of WDURA and Adjacent Growth Areas (January 2012).

Note: The assessment of the project under Part 3A will include the consideration of one or more options for the alignment of the drinking water and wastewater pipelines and location of drinking water reservoirs.



Indicative location of the WDURA and Adjacent Growth Areas (January 2012)

Appendix B

Director-General's requirements

Planning & Infrastructure

Contact: Belinda Scott
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Email: Belinda.Scott@planning.nsw.gov.au

Our ref.: MP 09_0189

Dr Judy Hansen
General Manager, Sustainability Division
Sydney Water Corporation
Parramatta NSW 2124

Attention: Murray Johnson

Dear Dr Hansen

Subject: Director-General's Requirements for Water and Wastewater Servicing for the West Dapto Urban Release Area and Adjacent Growth Areas (MP 09_0189)

In reference to your request, to amend the Director General's Requirements (DGRs) made at the meeting held on the 6 June 2011, the DGRs have been amended.

I have attached a copy of the amended Director-General's Requirements (DGRs) for the preparation of an Environmental Assessment for the project.

The DGRs have been prepared based on the information you have provided to date. Please note that under section 75F(3) of the *Environmental Planning and Assessment Act 1979*, the Director-General may alter these requirements at any time. If you do not submit an Environmental Assessment for the project within 2 years, the DGRs will expire.

Prior to exhibiting the Environmental Assessment that you submit for the project, the Department will review the document to determine if it adequately addresses the DGRs. The Department may consult with other relevant government authorities in making this decision. Please provide 5 hard copies and 5 electronic copies [1] of the Environmental Assessment to assist this review.

If the Director-General considers that the Environmental Assessment does not adequately address the DGRs, the Director-General may require you to revise the Environmental Assessment. Once the Director-General is satisfied that the DGRs have been adequately addressed, the Environmental Assessment will be made publicly available for at least 30 days.

Your contact officer for this proposal, Belinda Scott, can be contacted on (02) 9228 6472 or via email at Belinda.Scott@planning.nsw.gov.au. Please mark all correspondence regarding the proposal to the attention of the contact officer.

Yours sincerely,

SHaddad
Sam Haddad
Director General 4/7/2011

[1] File parts must be no greater than 5Mb each. File parts should be logically named and divided.

ATTACHMENT 1
Director-General's Requirements
Section 75F of the *Environmental Planning and Assessment Act 1979*

Director-General's Requirements

Section 75F of the *Environmental Planning and Assessment Act 1979*

Application number	MP09_0189
Project	Concept Plan Application: construction, operation and maintenance of drinking water, and wastewater infrastructure to service the West Dapto Urban Release Area and adjacent growth areas, including the following key components: ▪ new trunk pipelines for drinking water and wastewater; ▪ new pumping stations for drinking water and wastewater and upgrades to existing pumping stations; ▪ transfer of wastewater flows from the new growth areas to Wollongong or Shellharbour Sewage Treatment Plants for treatment and either reuse or ocean discharge; ▪ potential amplification and / or upgrades to Wollongong and Shellharbour Sewage Treatment Plants; and ▪ at least one and potentially two new water reservoirs. Project Application: to construct infrastructure related to the initial release Precincts (e.g. Kembla Grange, Sheaffes/Wongawilli) to be identified in the Environmental Assessment.
Location	The West Dapto Release Area is located wholly in the Wollongong LGA, however some components of the project are located in the Shellharbour LGA to the South.
Proponent	Sydney Water Corporation
Date issued	4 July 2011
Expiry date	4 July 2013
General requirements	The Environmental Assessment (EA) must include: ▪ an **executive summary**; ▪ a **detailed description** of the project including construction methods, location and alignment of project components, operation details including treatment technology and water quality standards to be applied, means of minimising wet weather infiltration, water demand management measures and interfaces with existing sewage treatment infrastructure, energy requirements and any staging. This should include a discussion on the uncommitted capacity of the Wollongong and Shellharbour Sewage Treatment Plants and their capacity to serve the proposed development;

	▪ consideration of any **relevant statutory provisions** including the consistency of the project with the objects of the *Environmental Planning and Assessment Act 1979* and permissibility*;* ▪ an assessment of the **environmental impacts** of the project, with particular focus on the key assessment requirements specified below; ▪ a **draft Statement of Commitments** detailing measures for environmental mitigation, management and monitoring for the project; ▪ **justification** for undertaking the project with consideration of the environmental, social and economic benefits and impacts of the proposal; and ▪ **certification by the author** of the Environmental Assessment that the information contained in the Assessment is neither false nor misleading.
Key issues	▪ **Strategic and Project Justification –** the Environmental Assessment shall clearly outline the strategic context of the project, having regard to existing and future development of West Dapto. Discuss how the project relates to relevant strategic and statutory planning documents including the following: the *Illawarra Regional Strategy* (2007); the *West Dapto Release Area Review Planning and Infrastructure Report* (Growth Centres Commission, 2008); the *Sydney Water Integrated Servicing Strategy*, the *Lake Illawarra Estuary Management Study and Strategic Plan* (March 2006) the *Illawarra Regional Environmental Plan No. 1*, and relevant local environmental plans including *draft Wollongong Local Environmental Plan (West Dapto) 2009*. The Environmental Assessment must describe the need for and objectives of the project; alternatives considered (including an assessment of the environmental costs and benefits of the project relative to alternatives) and provide justification for the preferred project. ▪ **Water Quality, Hydrology and Soils** – the Environmental Assessment shall include an assessment of water quality impacts arising from the construction and operation of the project taking into account applicable NSW Government policies. With respect to construction, risks associated with laying pipelines, including across watercourses, acid sulphate soils, salinity, erosion and sedimentation controls and management of any discharges from the project to prevent impacts to nearby watercourses, groundwater and water bodies should be addressed. ▪ Potential impacts to riparian areas should consider the *Riparian Corridor Management Study* (DIPNR 2004). The EA should include an assessment of the potential flood risks associated with the project including a risk screening of proposed water infrastructure development areas against the benchmarks identified in the *Draft NSW Coastal Planning Guideline: Adapting to Sea Level Rise* (DOP,

	2009). The assessment should include the full range of flood events including probable maximum flood and proposed mitigation measures with respect to operation. ▪ 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); • the quality of the treated wastewater in dry and wet weather; • impacts from effluent discharge from Wollongong and or the Shellharbour Sewage Treatment Plants, particularly beyond currently approved levels; and • identification of wet weather effluent storage requirements. ▪ Assess appropriate wastewater treatment technology for the removal/reduction of key pollutants and consider options to reduce readily bio-available forms of nutrients. Demonstrate how treated wastewater discharged to waterways will meet *ANZECC 2000* water quality criteria for relevant chemical and no-chemical parameters. ▪ Measures to prevent or minimise sewage discharge or overflows and subsequent impacts to nearby watercourses, groundwater and water bodies shall be addressed. ▪ **Human Health** – the Environmental Assessment should address 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). ▪ **Flora and Fauna -** The Environmental Assessment should include a flora and fauna impact assessment taking into consideration impacts on any threatened species, populations, ecological communities and/or critical habitat and any relevant recovery plan in accordance with the *Guidelines for Threatened Species Assessment* (DEC & DPI, 2005) and with consideration to the *Illawarra Escarpment and Coastal Plain - Bioregional Assessment* (DEC July 2003). This assessment shall include a description of actions to avoid impact in the first instance and then mitigate impacts or compensate for unavoidable impacts. The EA should address key threatening processes, justify the need for clearing any vegetation and/ or habitat features and include an evaluation of potential impacts on waterways, aquatic ecosystems or riparian zones, including any in stream stormwater basins, potential for weed infestation and impacts to fish passage. Offsets should be considered for clearing of native vegetation consistent with “improve or maintain principles”. Sufficient details must be provided to demonstrate the availability of viable and achievable options to offset the impacts of the project. Where the

	proposal would be located adjacent to DECCW estate, the EA must identify management implications on DECCW estate from edge effects such as weed and pest management consistent with the *Guidelines for Developments Adjoining DEC Land* and identify all reasonable and feasible measures to minimise impact. ▪ **Aboriginal and Non-Aboriginal Cultural Heritage Impacts** – the Environmental Assessment shall include an assessment of Aboriginal and non-Aboriginal heritage values that may be impacted by the project with details on any subsurface archaeological investigations undertaken for potential archaeological deposits. Consideration should be given to the significance of the impacts of the project and any mitigation measures. The assessment must address the information and consultation requirements of the draft *Guidelines for Aboriginal Cultural Heritage Assessment and Community Consultation* (DEC, 2005). ▪ **Air Quality**– the Environmental Assessment shall include an assessment of the air quality impacts associated with the operation of the project, particularly where operation is required beyond currently approved levels at the Wollongong and Shellharbour Sewage Treatment Plants, with specific reference to odour impacts. The analysis should be prepared in accordance with the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (DEC, 2005), *Assessment and Management of Odour from Stationary Sources in NSW* (DEC, 2001) and *Technical Notes: Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW* (DEC, 2001). ▪ **Noise and Vibration –** the Environmental Assessment shall include an assessment of noise and vibration impacts during construction and operation and in a cumulative context with existing development. Construction traffic noise must also be addressed. The assessment must take into account the following guidelines, as relevant: *Interim Noise Construction Guidelines (DECC 2009)*, *Environmental Criteria for Road Traffic Noise* (EPA, 1999), *Industrial Noise Policy* (EPA, 2000) and *Assessing Vibration: A Technical Guideline* (DECC, 2006). ▪ **Hazards and Risk** – the Environmental Assessment shall include an assessment of the hazards and risk associated with the project including details of hazardous materials used or kept on the premises during the construction and operation phases, particularly any additional risk at the Wollongong or Shellharbour Sewage Treatment Plants. The assessment must refer to the Department's Guideline *Applying SEPP 33* (DUAP, 1994). If relevant, a *Preliminary Hazard Analysis* in accordance with the Department's Hazardous Industry Planning Advisory Paper No.6, *Guidelines for Hazard Analysis* must be included as part of the Environmental Assessment. ▪ **Environmental Risk Analysis–** notwithstanding the above key assessment requirements, the Environmental Assessment shall include an environmental risk analysis to identify potential environmental impacts associated with the project (construction and

	operation), proposed mitigation measures and potentially significant residual environmental impacts after the application of proposed mitigation measures. Where additional key environmental impacts are identified through this environmental risk analysis, an appropriately detailed impact assessment of this additional key environmental impact must be included in the Environmental Assessment.
Consultation	You should undertake an appropriate and justified level of consultation with relevant parties during the preparation of the Environmental Assessment, including: ▪ local, State or Commonwealth government authorities and service providers such as the Department of Health, the NSW Office of Water, the Department of Environment, Climate Change and Water, the Lake Illawarra Authority, the Department of Industry and Investment, the Southern Rivers Catchment Management Authority, Roads and Traffic Authority, and Shellharbour and Wollongong City Councils. ▪ specialist interest groups, including local Aboriginal land councils; and ▪ the local community, including affected landowners. The Environmental Assessment must describe the consultation process, document all community consultation undertaken to date and identify the issues raised (including where these have been addressed in the Environmental Assessment).

Appendix C

Marine water quality assessment

West Dapto Urban Release Area and Adjacent Growth Areas

Prediction of Marine Impacts

Peter M Tate

October 2011

Contents

Figures

Tables

Executive summary

This report addresses the Director-General's Requirements (DGRs) and comments from DECCW for discharges to the marine environment resulting from the proposed West Dapto Urban Release Area and Adjacent Growth Area developments. Three main areas of potential impact are examined: water quality, public health and marine aquatic ecology.

Numerical modelling is the primary tool for assessing potential impacts on water quality and public health. The model uses results from 2009 as a base against which scenarios for 2016, 2021, 2031 and 2048 (the ultimate development timeline) are compared. Potential impacts on aquatic ecology are assessed by analysing existing data and reviewing results from the Marine Monitoring Program undertaken as part of the Illawarra Waste Water Strategy (IWWS).

Under dry weather conditions, discharge of wastewater is through the Wollongong or Shellharbour outfalls only. Under wet weather conditions most of the wastewater is also discharged through these two outfalls. However, under heavy and persistent wet weather, discharge of wastewater to the marine environment may also occur through the Port Kembla outfall and through stormwater drains.

Model results apply at the edge of the outfall initial mixing zones. These mixing zones are defined differently at Wollongong and Shellharbour because of differences in the residual buoyant energy of the wastewater at the sea surface. At Wollongong, the edge of the initial mixing zone is approximately 100 m from the outfall. This distance is an explicit output from the model. Shellharbour wastewaters discharge into shallow waters and, when the wastewater reaches the sea surface, mixing of the wastewater and the receiving water is incomplete. The distance from the outfall to the edge of the initial mixing zone is approximately 1,000 m. The volumes of these two initial mixing zones are in proportion with the volumes of wastewater discharged through the Wollongong and Shellharbour outfalls.

The concentrations of most substances are either below the limit of reading or less than the relevant guideline at the edge of the initial mixing zone. Results from dry weather modelling indicate that concentrations of indicator bacteria are well within the relevant public health guidelines for all scenarios examined. Concentrations of most nutrients lie below the guideline values. Most substances that have the potential to bioaccumulate are not detected in the wastewater.

Under wet weather conditions wastewater may discharge through the Port Kembla outfall and through stormwater drains, as well as through the Wollongong and Shellharbour outfalls. At Shellharbour, total phosphorus exceeds the ANZECC (2000) guidelines less than 50% of the time during wet weather only. The Port Kembla outfall is a single port discharge at the cliff base and is relatively inefficient, resulting in very low dilutions. Faecal coliforms, enterococci, ammonia, total nitrogen, total phosphorus, aluminium, cobalt, copper, iron, manganese, lead, zinc and total suspended solids all exceed the ANZECC (2000) guidelines during wet weather. All other variables, for which we have emission factors, remain within their respective ANZECC (2000) guidelines. Discharges from stormwater drains to the receiving water will, similarly, exceed the ANZECC (2000) guidelines for the above substances. Discharges from stormwater drains to sand near the outlet will likely exceed the public health guidelines. Such events will occur infrequently and studies undertaken as part of the IWWS show rapid recovery after the cessation of the discharge.

Field investigations (undertaken between 2002 and 2007) associated with the early operation of the new / upgraded outfalls at Wollongong and Shellharbour could not detect statistically significant changes in the aquatic communities that could attributed to these outfalls.

Combined results from the numerical modelling, data from wastewater samples and marine monitoring programs all indicate that the proposed developments will not significantly affect the public health, water quality or the aquatic ecology of the marine communities.

The combination of very high levels of wastewater treatment, the lack of impacts observed in the marine monitoring programs and incremental change to the volume of wastewater over the years suggests that field monitoring programs will struggle to detect statistically significant change. Therefore, it is recommended that the existing monitoring program, comprising monitoring for a range of substances and toxicity testing, be continued.

1 Introduction

1.1 Background

The West Dapto Urban Release Area (WDURA) and Adjacent Growth Areas (AGA) are major growth sites identified to meet future housing requirements in the Illawarra region over the next 40 years. It is proposed that the new area accommodates up to 35,000 new dwellings by 2048.

The WDURA and AGA wastewater servicing strategy identifies the need to connect the servicing areas to downstream and existing sewerage networks that transport flows to the Wollongong Water Recycling Plant (WRP) or the Shellharbour Wastewater Treatment Plant (WWTP). A number of new assets and infrastructure (including trunk mains, carriers, storage structures and pumping stations) will be constructed to service these growth areas. The non-potable water strategy aims to collect rainwater for residential non-potable water requirements, thereby reducing the average daily demand for potable water. However, no reduction in wastewater loading following implementation of rainwater tank options is anticipated and no allowance has been made for reducing the size of future assets.

Under most flow conditions, wastewater will be transported to either the Wollongong WRP or the Shellharbour WWTP for treatment. The treated wastewater will be either reused or discharged through the existing ocean outfalls. It is anticipated that the capacity of the Wollongong WRP will be reached by 2034 (59 ML/day), while that of the Shellharbour WWTP will be reached just prior to 2048 (20 ML/day).

The location of the WDURA and AGA development and the outfalls through which the treated wastewater will be discharged are shown in Figure 1.

Numerical modelling carried out as part of this study focuses on base conditions using flows from 2009 and estimated flows for 2016, 2021, 2031 and 2048 (ultimate flow). It is noted that the 2048 scenario is beyond the approved discharge levels. Therefore, the 2048 modelling scenarios will not be strictly applicable. In the absence of 2048 approved discharge levels, modelling results are compared with existing approved discharge levels. Using the model results, concentrations of contaminants are estimated at the edge of the initial mixing zones and the results compared with the relevant ANZECC (2000) or NHMRC (2008) guidelines. The guidelines are obtained from the following references.

References from the ANZECC (2000) guidelines, Volume 1, Chapters 3, 4 and 5

- Tables 3.3.2 and 3.3.3 – Default trigger values for marine water quality in south-east Australia
- Table 3.4.1 – Trigger values for toxicants at alternative levels of protection
- Table 4.4.2 – Physico-chemical stressor guidelines for aquaculture species
- Table 4.4.3 – Toxicant guidelines for aquaculture species
- Table 4.4.5 – Chemical compounds for tainting of flesh
- Table 5.2.2 – Summary of water quality guidelines for recreational waters
- Table 5.2.3 – Summary of water quality guidelines for recreational purposes – general chemicals
- Table 5.2.4 – Summary of water quality guidelines for recreational purposes – pesticides.

Reference from the NHMRC (2008) guidelines

- Table 5.7 – Microbial water quality assessment categories.

The Director-General's Requirements state "The Environmental Assessment shall include an assessment of water quality impacts arising from operation of the project taking into account applicable NSW Government Policies". In addition to the ANZECC (2000) and NHMRC (2008) guidelines, the following documents form the applicable NSW Government Policies and references.

- Marine Water Quality Objectives for NSW Ocean Waters – South Coast (DEC, 2005)
- Lake Illawarra Authority Condition Assessment of Lake Illawarra (LIA, 2010), and
- Information obtained from the Lake Illawarra Estuary Management Study and Strategic Plan (WBM, 2006).

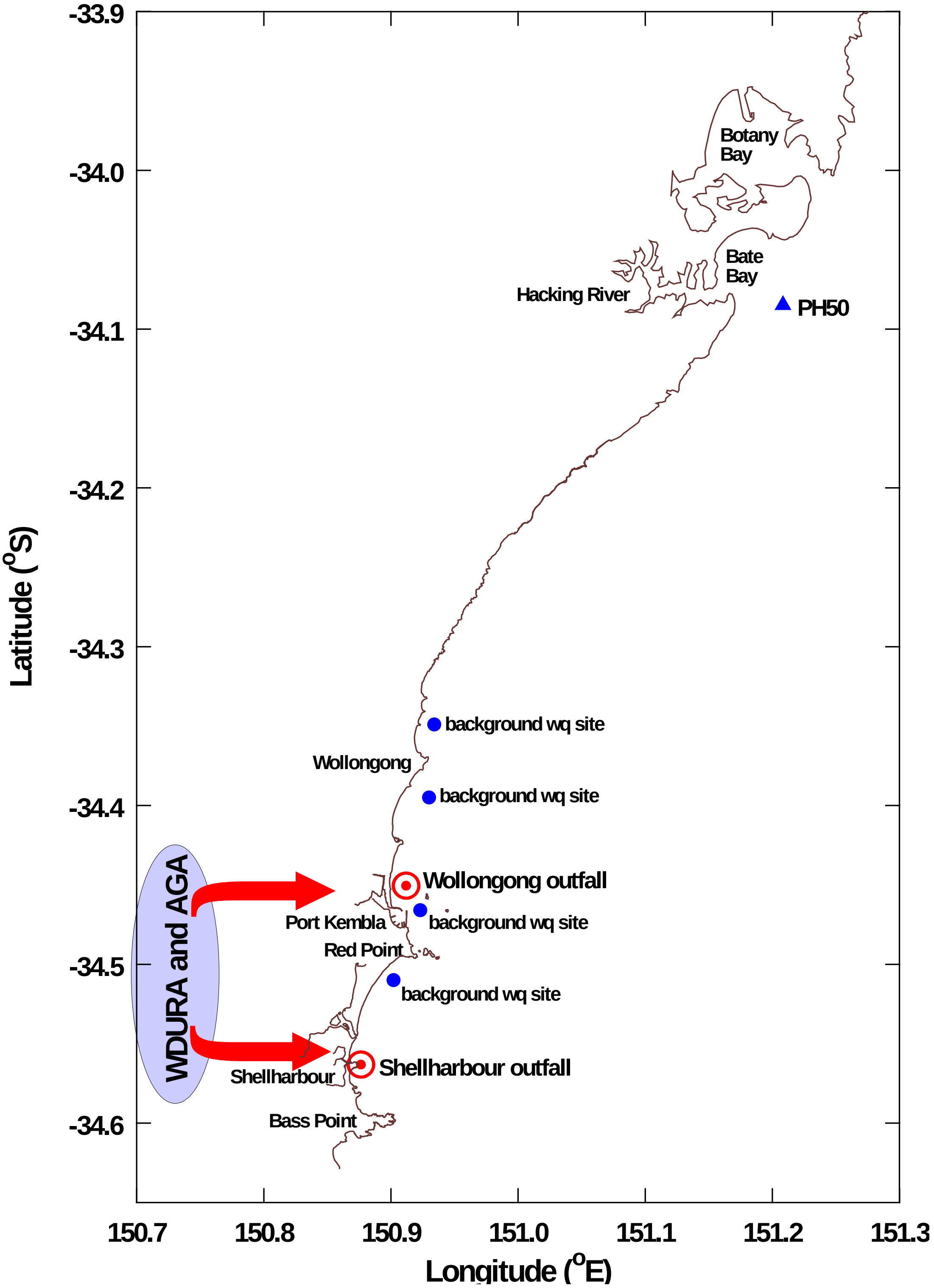

Figure 1. Location of the proposed West Dapto development, Wollongong WRP and Shellharbour WWTP and the water quality sampling locations used to establish background conditions.

Meeting the ANZECC (2000) and NHMRC (2008) guidelines will automatically ensure that the guidelines associated with these water quality objectives are met. Therefore, this study focuses on the ANZECC (2000) and NHMRC (2008) guidelines.

1.2 Objectives

The overall objectives of the study outlined in this report are to:

- assess any impacts from discharges to the marine environment resulting from the WDURA and AGA development, and
- respond to the Director-General's Requirements (DGRs) issued under Part 3A of the EP&A Act and comments from the Department of Environment, Climate Change and Water (DECCW) pertaining to the marine environment.

The assessment is presented as a combination of numerical model predictions of water quality and public health conditions with comparisons against relevant guidelines and reviews of recently conducted marine environmental monitoring programs.

Numerical modelling of existing and future wastewater flows through the Wollongong and Shellharbour outfalls is presented using results from the CORMIX model (Jirka, et al, 1996). This modelling is conducted via a series of scenarios based around the anticipated increase in wastewater flows associated with the WDURA and AGA.

The primary objective of the modelling is to estimate concentrations of water quality and public health parameters after discharge from the respective outfalls and compare these concentrations with relevant guidelines at the edge of the initial mixing zone.

1.3 Report Structure

This report is formatted around addressing the DGR and comments on the DGRs provided by the former DECCW (now Office of Environment and Heritage, OEH). Some of these requirements and recommendations and comments include multiple components each of which may be addressed in different sections of the report.

This report is structured as follows:

Section 2 outlines the methods used to obtain data for input to the numerical model. The model itself is also briefly described. The guidelines against which we assess the potential impacts of future scenarios are detailed. An assessment of the background data is made.

Section 3 details the results from the modelling and comparisons with relevant water quality and public health guidelines.

Section 4 provides an overall environmental assessment of the potential impacts of the development on marine waters. This includes the overall health of the marine ecosystem, recreation activities and visual amenity.

Section 5 summarises the main findings of this assessment.

Section 6 details the references to which this report refers.

Appendix 1 is a glossary of terms. This provides an explanation of some of the technical terms used in this report.

The DGRs and DECCW comments are summarised in Table 1, together with a reference to the section in which they are addressed.

Table 1. Summary of the DGRs and comments from DECCW and where they are addressed in this section.

DGR / DECCW comment	Section
Director Generals Requirements: • Address the human health impacts arising from the wastewater infrastructure and processes including wastewater disposal. The assessment should be undertaken in accordance with the Guidelines for Managing Risks in Recreational Water (NHMRC, 2008).	4.4 Summary of Human Health Impacts
• The Environmental Assessment shall include an assessment of water quality impacts arising from operation of the project taking into account applicable NSW Government Policies.	1.1 Background
• Details on the impacts and management of wastewater and infrastructure must be addressed, including:	
(a) Frequency and volume of overflow for dry and wet weather and pollutant load.	2.8 Annual Loads
(b) Quality of treated wastewater in dry and wet weather.	2.4.2 Wastewater Flow and Quality and 3.4 Wet Weather
(c) Impacts from effluent discharge from Wollongong and or Shellharbour sewage treatment plants particularly beyond currently approved levels.	3 Model Results
(d) Not addressed in this report.	
(e) Not addressed in this report.	
(f) Demonstrate how treated wastewater discharged to waterways will meet ANZECC (2000) water quality criteria for relevant chemical and non-chemical parameters.	4.4 Summary of Human Health Impacts
DECCW Comments: • The proposal should demonstrate how wastewater discharged to the waterways will ensure the ANZECC 2000 water quality criteria for relevant chemical and non-chemical parameters are met at the edge of the initial mixing zone and that any impacts in the initial mixing zone are reversible.	4.4 Summary of Human Health Impacts and 3.5 Reversibility of Effects

DGR / DECCW comment	Section
• DECCW recommends that the project demonstrates the mixing zone will not contain:	
(a) Contaminants in concentrations that cause acute toxicity to aquatic life.	4.5 Toxicity Testing
(b) Substances that can bioaccumulate.	4.6 Bioaccumulation
(c) Contaminants in concentrations that settle to form harmful deposits (also in the far field).	4.2 Deposition and Visual Amenity
(d) Substances in concentrations that produce problematic colour, odour, turbidity or undesirable aesthetic impacts (also in the far field)	4.2 Deposition and Visual Amenity
(e) Substances in concentrations that encourage undesirable aquatic life or result in the dominance of nuisance species.	4.2 Deposition and Visual Amenity
• Any assumptions used in the assessment should be explicitly stated, particularly where there is a significant influence on environmental outcomes.	2.9 Model Assumptions
• A monitoring program should be developed to enable an understanding of the potential impacts of treated wastewater discharge on the aquatic environment.	4.7 Environmental Monitoring
• The Environmental Assessment will need to assess the potential impact of the proposal against the relevant aquatic environmental values of each discharge location. • The proposal should demonstrate that the discharge of readily bio-available forms of nitrogen are minimised	4.3 Summary of Aquatic Environmental Values
• The proposal should demonstrate how the discharge of treated wastewater will contribute to moving towards achievement of water quality objectives for the Illawarra catchments over time.	4.3 Summary of Aquatic Environmental Values

2 Modelling Methods

2.1 Overview

This study uses a statistical approach to the modelling. The plume dispersion model is run using environmental data obtained from the waters near each of the outfalls (current speed and direction and density of the water column) over periods of approximately 12 months. Wastewater flow and quality data are obtained from the Wollongong WRP and Shellharbour WWTP. Wastewater flow data estimates for 2009, 2016, 2021, 2031 and 2048 are provided from Sydney Water, Asset Planning. Wastewater quality data are available for the period mid-2007 to 2010. Wastewater quality data obtained prior to 2007 are not representative of the present levels of treatment.

Input data are randomly selected and the model is run for each data selection. The model outputs the size of the initial mixing zone and the plume dilution at the edge of the initial mixing zone. Repetition of this process results in many estimates of these outputs, from which robust statistics can be derived. This approach ensures that the important time scales that affect the wastewater plume movement are covered in the model simulations, including: diurnal variations in wastewater flow, the effects of tides and seasonal variations resulting in changes to the water density stratification.

Model results are compared with the ANZECC (2000) water quality guidelines and, for enterococci, with the NHMRC (2008) guidelines. Wastewater quality variables are randomly selected and combined with the model results giving concentrations of the wastewater variables at the edge of the Wollongong and Shellharbour initial mixing zones. These estimated concentrations are then directly compared with the relevant guideline.

2.2 ANZECC and NHMRC Guidelines

The primary guidelines for assessing impacts to the environment (water quality and aquatic ecology) are ANZECC (2000) and, for assessing public health, both the ANZECC (2000) and NHMRC (2008) guidelines. The Marine Water Quality Objectives (DEC, 2005) provide the basis for the environmental values adopted in this study.

In the absence of site-specific data, ANZECC (2000) provide default trigger values, which, if exceeded, should prompt further investigations. For example, the default trigger values for nutrients in marine waters in New South Wales are listed in Table 2. However, ANZECC (2000) does acknowledge that it is “not possible to develop a universal set of specific guidelines …. (and that) guidelines can be refined according to local environmental conditions” (ANZECC, 2000, p.8).

Table 2. ANZECC (2000) default trigger values for marine and estuarine waters in New South Wales and Lake Illawarra Authority trigger values for Lake Illawarra.

Variable	Unit	ANZECC (2000) - marine	LIA (2010)
Chlorophyll-a	µg/L	1	7.01
Total phosphorus	µg/L	25	120
Filterable reactive phosphorus	µg/L	10	68
Total nitrogen	µg/L	120	720
Oxidised nitrogen	µg/L	25	40
Un-ionised ammonia	µg/L	20	

Historical data show that the median concentrations of some variables in marine waters off Sydney and Wollongong already exceed the ANZECC (2000) default trigger values. Therefore, it is suggested that, in these waters, some of the ANZECC (2000) default trigger values may not be appropriate. This is described in detail in Section 2.3.

ANZECC (2000) also outlines public health indicators. Median faecal coliform concentrations should not exceed 150 cfu/100mL (from a minimum of five samples taken at regular intervals not exceeding one month). In addition, four out of five of these samples should be less than 600 cfu/100mL. Median enterococci concentrations should not exceed 35 cfu/100mL, with a maximum level of 60-100 cfu/100mL. The NHMRC (2008) guidelines state that, for class A waters, the 95%ile concentrations should be less than 40 cfu/100mL. The modelling results produced as part of this study are compared with both guidelines.

A detailed list of contaminants measured in the wastewater produced at the Wollongong WRP and the Shellharbour WWTP and corresponding ANZECC (2000) water quality guidelines are shown in Table 5 and Table 6, respectively.

In the past a large array of substances were monitored in the Wollongong and Shellharbour wastewaters. However, analyses over many years resulted in most of these substances having concentrations below the limit of reading. The ongoing analyses of such substances were replaced by whole-of-wastewater toxicity testing. An advantage of this new approach is that an adverse toxic response from any substance (in addition to those substances previously monitored) would be detected. Toxic responses at critical wastewater concentrations would be a trigger for a more detailed assessment of the wastewater.

2.3 Background Data

Contaminants are discharged to the marine environment from sources such as ocean and industrial outfalls. In addition, some of these substances are naturally occurring: for example, concentrations of nutrients may increase as a result of oceanic upwellings. Two data sources are used to examine background concentrations of nutrients and to compare these concentrations with the ANZECC (2000) default trigger values: the Port Hacking data and data collected from four reference locations as part of the Illawarra Waste Water Strategy (IWWS). These data sources are labelled “PH50” and “background wq site”, respectively in Figure 1.

CSIRO (and more recently, OEH) have maintained a monitoring station offshore from Port Hacking (34^{o}05.0’S, 151^{o}12.5’E, in waters approximately 65m deep) since 1942. This monitoring station is designated PH50. Variables measured include surface phosphate and nitrate, both of which are plotted as functions of time (from 1960 to 2007) in Figure 2. Preceding 1985 data were obtained weekly and since that time data have been collected monthly. Superimposed on the plots are the ANZECC (2000) default trigger values for filterable reactive phosphorus and oxidised nitrogen. These trigger values represent, in the absence of specific information, the default values at which investigations into the cause of these observations should take place.

It is noted that phosphate is a subset of filterable reactive phosphorus and that nitrate is a subset of oxidised nitrogen. Therefore, these species of nutrients will underestimate the number of times the ANZECC (2000) default trigger values are exceeded. Based on these data, the ANZECC (2000) default trigger values for oxidised nitrogen are exceeded for 26% of the readings and filterable reactive phosphorus are exceeded for 20% of readings. These percentages are consistent through time, which implies that the relative contributions of anthropogenic inputs at this location are small.

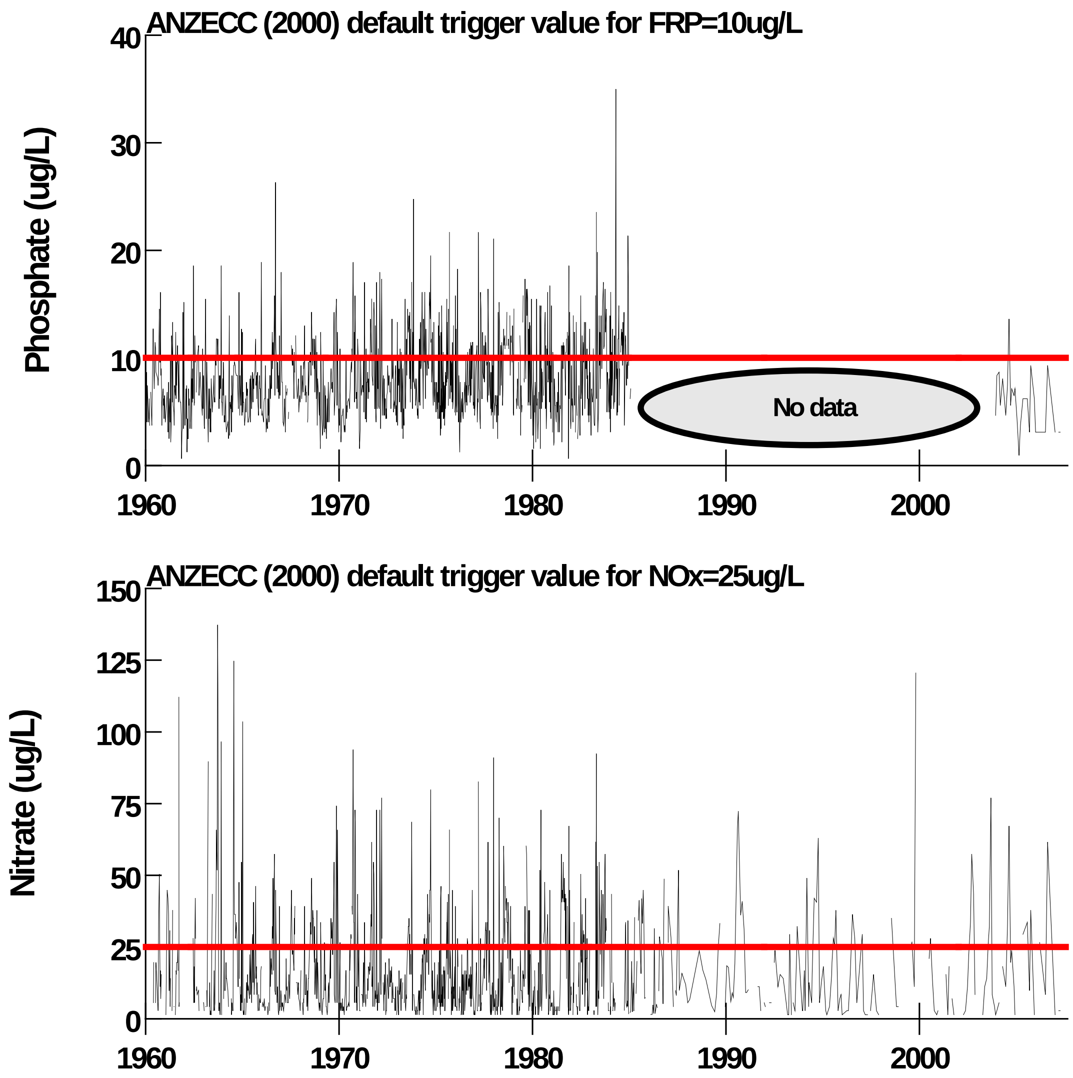

Figure 2. Concentrations of phosphate and nitrate at the monitoring station designated PH50. The horizontal lines represent the ANZECC default trigger values.

Concentrations of nutrients collected from the water surface as part of the IWWS are plotted in Figure 3. These data were collected for 12 months prior to commissioning of the Wollongong outfall and for 12 months after commissioning. Only data from four reference locations are included in the above plots. Further, any data that included concentrations of faecal coliforms or enterococci in excess of 10 cfu/100mL were omitted. Therefore only data records that are un-impacted by wastewater are included.

Results indicate the following percentages of nutrient readings exceed the ANZECC (2000) default trigger values: total nitrogen (93%), oxidised nitrogen (24%), ammonia (22%), filterable reactive phosphorus (8%) and total phosphorus (6%). The nitrogen-based nutrients exceed the ANZECC (2000) default trigger values for a substantial proportion of samples, while the phosphorus-based nutrients exceed the guidelines in a relatively small proportion of samples. These oxidised nitrogen percentages are similar to those resulting from the PH50 site monitoring data, while the filterable reactive phosphorus percentages are approximately half of those obtained from the PH50 site monitoring data.

In both the southern Sydney and Illawarra regions, the background concentrations of nutrients already exceed the ANZECC (2000) default trigger values for a substantial proportion of the time.

In a three-year study identifying contributions to high concentrations of nutrients to the coastal waters between Port Stephens and Jervis Bay, Pritchard et al (2003) identified upwelling as the “principal driver for major algal blooms”. Similarly, Dela-Cruz et al (2002) stated that the “predominant underlying mechanism regulating population growth of *Noctiluca scintillans* (the dinoflagellate mainly responsible for red tides) along the southeast coast of Australia is the uplifting of nutrient-rich slope water". Results from both studies infer that the relatively high background concentrations of nutrients in the coastal waters near southern Sydney and Wollongong / Shellharbour mainly result from natural oceanic processes (viz. upwelling).

Therefore, it is suggested that some ANZECC (2000) default trigger values may not be appropriate for the Sydney and Illawarra regions. Despite this potential problem and in the absence of any obvious alternative values, the ANZECC (2000) default trigger values are used in this study.

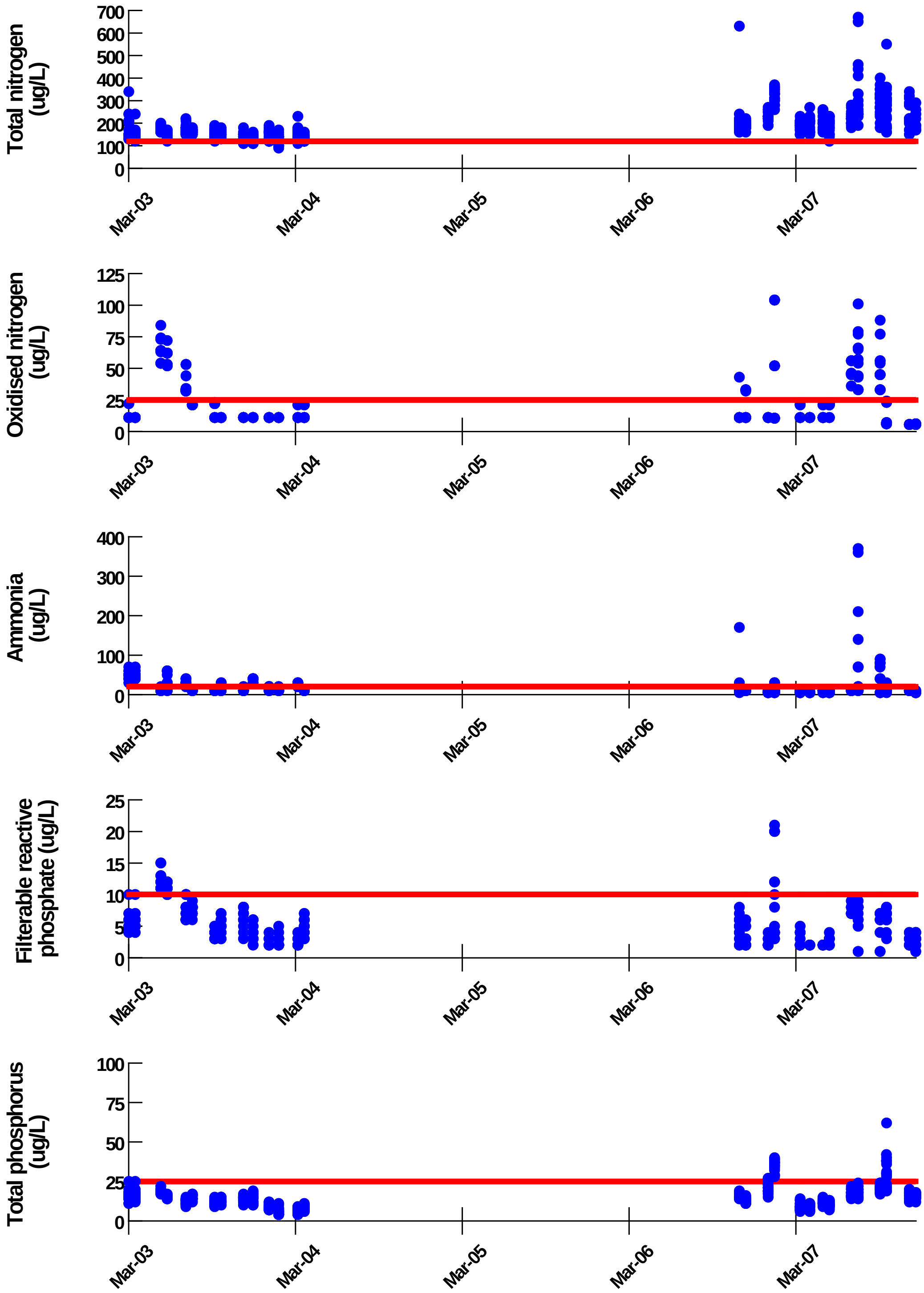

Figure 3. Concentrations of nutrients at reference locations collected as part of the IWWS. The horizontal line represents the ANZECC default trigger values.

2.4 Model Input Data

Data required to run any plume dispersion model include: configuration of the outfall, wastewater flow, current speed and direction and density profiles of the water column. A summary of these data for both Wollongong and Shellharbour outfalls follows.

2.4.1 Outfall Configuration

The Wollongong outfall comprises twin pipelines (2 m apart) discharging wastewater approximately 1 km offshore into waters 20 m deep. The offshore-most 300 m of each pipeline form the diffuser, comprising 50 T-shaped outlet nozzles (100 outlet nozzles per pipeline). Each outlet nozzle is 150 mm in diameter and is fitted with a non-return check valve to prevent the intrusion of seawater into the pipeline under low flow conditions. The two pipelines can operate either separately or simultaneously. Presently they operate separately, alternating every few days or so. As part of this study, it is assumed that only one pipeline will operate for flows less than 40 ML/day and that both pipelines will operate simultaneously for flows exceeding 40 ML/day.

Some wet weather flows may be discharged through the Port Kembla outfall. This outfall discharges wastewater at the base of a cliff, approximately 8 m below the sea surface. The diameter of the outlet is approximately 1 m.

The Shellharbour outfall lies approximately 120 m offshore from Barrack Point in waters 8 m deep. Treated wastewater is discharged through a diffuser comprising 24 T-shaped outlet nozzles (48 outlet nozzles in total). As for the Wollongong outfall, each outlet nozzle is 150 mm in diameter and is fitted with a non-return check valve.

2.4.2 Wastewater Flow and Quality

Wastewater flow data were obtained from both the Wollongong WRP and the Shellharbour WWTP from 2009. To produce a dry weather data set, days on which rain occurred were identified and the corresponding wastewater flow removed from the data set. Flows for the scenarios were scaled from the 2009 dry weather flows using the estimated average dry weather flows provided in Table 3. Two levels of wastewater reuse were assumed at the Wollongong WWTP – 20 ML/day and 30 ML/day. It was assumed that all flow from the Shellharbour WWTP passes through the outfall.

Table 3. Dry weather wastewater flow for each of the modelled scenarios.

Year (Scenario)	Wollongong average dry weather flow (ML/day)	Discharge to outfall: Reuse = 20 ML/day	Discharge to outfall: Reuse = 30 ML/day	Shellharbour average dry weather flow – Discharge to outfall (ML/day)
2009	43.00	23.00	13.00	14.00
2016	46.18	26.18	16.18	15.07
2021	49.66	29.66	19.66	16.15
2031	53.50	33.50	23.50	17.94
2048	62.20	42.20	32.20	22.08

For each model run, the wastewater flow data was randomly selected from the available data.

A list of substances measured in the Wollongong and Shellharbour wastewater between July 2007 and June 2010 are provided in Table 5 and Table 6. Note: substantial changes were made to both systems prior to July 2007 and earlier data will not reflect the present level of treatment. The tables also include:

(a) the limit of reading (LOR) associated with each substance, number of samples collected during this period and the number of samples with readings greater than the LOR

(b) ANZECC (2000) water quality guidelines for each substance (where they exist)

(c) comments of the suitability of data for analysis in this study.

Some 73 substances have been identified from the Wollongong wastewater of which 13 have both readings above the LOR and have a relevant ANZECC (2000) water quality guideline. For the Shellharbour wastewater these numbers are 20 and eight, respectively. Virtually all readings for organics lie below the LOR.

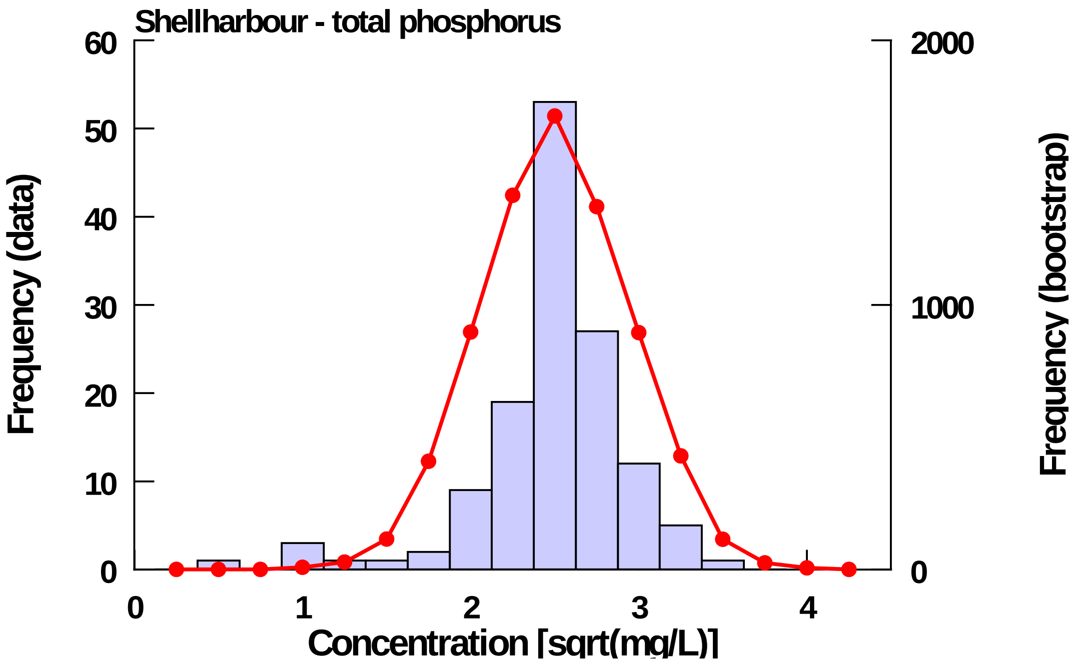

Figure 4. Example of the shapes of the probability distributions obtained from the data (bars) and from the bootstrap (red line) samples.

A relatively small amount of wastewater quality data is available (as few as six data points may be available). To increase this sample size, bootstrapping techniques are employed. Available data are transformed (using a square root transform for most data and a log10 transform for indicator bacteria). Samples are randomly extracted from the respective probability distributions, a process that is repeated many times. Selected data are compared with the original distribution. An example (for total phosphorus at Shellharbour) is given in Figure 4, which shows a similar distribution for both the data and the bootstrap samples.

When combined with the model outputs, the results are directly compared with the ANZECC (2000) default trigger values.

2.4.3 Currents and Water Density

At each outfall approximately 12 months of ocean current and density stratification data are available. The density stratification is approximated by a temperature profile (assuming constant salinity throughout the water column) at the Wollongong outfall. The shallow waters at the Shellharbour outfall (approximately 8 m deep) coupled with the winds, effectively prevent the growth of substantial thermal stratification. The water column near the Shellharbour outfall is assumed isothermal with constant salinity, and temperature values obtained from the temperature sensor located in the current meter. Water column profiling carried out as part of the IWWS indicated that this assumption is valid in shallow waters (Tate, 2007).

At the Wollongong outfall current speed and direction data were obtained from a bottom-mounted Acoustic Doppler Current Profiler (ADCP) between 9 November 2006 and 28 November 2007. Data were recorded at 5-minute intervals, every 1 m throughout the water column. At the Shellharbour outfall current speed and direction data were obtained from a bottom-mounted ADCP between 4 September 2001 and 22 January 2002 and again between 12 March 2005 and 31 August 2005. Data were recorded at 15-minute intervals every 0.25 m throughout the water column.

Water level and temperature data were also obtained from both locations. All data were averaged into 60-minute time bins and 5-metres depth bins for input to the plume dispersion model.

2.5 The CORMIX Model

The CORMIX model was selected as the plume dispersion model for use on this project. The model has been critically reviewed in the scientific literature (e.g. Jirka and Akar 1991; Jirka and Doneker 1991) and is a preferred model for estimating plume trajectories and dilutions of the United States Environment Protection Agency (USEPA) and OEH. Jirka and Akar (1991) and Jirka and Doneker (1991) outline a set of extensive laboratory calibration experiments to which the models have been subjected, resulting in a robust, calibrated model. Further, the results from the near-field model component of CORMIX compare well with results from other near-field models including; IMPULSE (Chu, 1976), JETLAG (Lee and Cheung, 1990), and PLUME (Tate and Middleton, 2000).

CORMIX includes both a near-field model (CORJET) and a far-field model (FFLOCATR). These two models are applicable to different phases of the movement of the wastewater and reflect the different physical processes responsible for the dilution of the wastewater plume.

Both the Wollongong and Shellharbour outfalls include outlet nozzles that are fitted with non-return check valves (also known as duckbill valves). These valves help prevent the intrusion of seawater into the outfall pipeline, which reduces the efficiency of the outfall. Without the duckbill valves, the cross-sectional shape of the outlet nozzles is circular. However, duckbill valves change the shape of the outlet from circular to (approximately) elliptical (e.g. Tate and Middleton, 2004). Further, the shape of the duckbill valve changes with volume flow through the outlet (Lee et al, 1998). CORMIX cannot model discharges from non-circular outlet shapes. To overcome this problem, estimates of the open area of the shape of the duckbill valve were translated to an equivalent circular shape (using the expression in Lee et al. 1998), which were then used in the CORMIX model. Tate and Middleton (2004) showed that the dilution achieved using duckbill valves can, in theory, be up to 25% greater than that achieved for discharges through a nozzle not fitted with duckbill valves. Therefore, the dilution results presented in this report will be conservative.

Wastewater from the outfalls is discharged as a positively buoyant jet (also known as a forced plume) – “positively buoyant” because the density of the wastewater is less than that of the receiving waters and “as a jet” because the speed of discharge is substantially greater than the speed of the receiving waters. The positive buoyancy of the wastewater results in it rising through the water column entraining the ambient receiving water. Plume rise continues until either the plume reaches the sea surface or (if stratification of the water column is sufficiently large) the density of the wastewater/seawater mixture (i.e. the wastefield) reaches or exceeds the density of the surrounding water. The distance from the outfall at which this occurs is referred to as the distance to the edge of the initial dilution zone (the CORJET model applies in this zone). By definition, near-field models terminate when they reach the edge of the initial dilution zone. Additional dilution of the wastefield may occur beyond the edge of the initial dilution zone, which is modelled using FFLOCATR.

A series of outfall dilution studies was undertaken in 2007 to validate the model configuration used for the new Wollongong outfall and for the upgraded Shellharbour outfall. The exercises were carried out under a range of wastewater flow and environmental conditions. Agreement between the model output and the field studies was good and the model is regarded as validated for those outfalls. Results from these studies are presented in PRP 004[1] (Tate and Pera, 2008).

[1] PRP 004 is Pollution Reduction Program No. 004 for the IWWS. It includes effluent characterisation, toxicity testing and a series of outfall dilution studies to validate the numerical models used in the IWWS study.

2.6 Wastewater Mixing and Mixing Zones

Wastewater discharges from ocean outfalls undergo two types of mixing each of which are the focus of two different models. In the first type of mixing the difference in buoyancy (or energy) between the wastewater and the receiving waters dominates the mixing. This type of mixing occurs in the near-field and is modelled using CORJET. The distance to the end of the near-field model is defined as the distance to the edge of the initial dilution zone. This distance is not fixed and varies according to the outfall configuration, wastewater flow, current speed and stratification. Beyond the near-field (in the far-field) oceanic turbulence dominates the mixing process. In the far-field, the model FFLOCATR is applicable. CORJET and FFLOCATR combine to form the CORMIX model.

On exit from the outlet ports, wastewater mixes with the surrounding seawater. Mixing continues until the density (or salinity) of the wastewater / seawater mixture equals that of the surrounding seawater. The distance from the outlet port to this point is referred to as the distance to the edge of the initial mixing zone. In the Illawarra region the average seawater salinity is approximately 35.5 psu, with a standard deviation of approximately 0.25 psu. When the salinity of the wastewater / seawater mixture lies in the range 35.5 +/- 0.25 psu, the mixing process is essentially complete. The edge of the initial mixing zone has been reached.

For the Wollongong outfall, the initial dilution zone and the initial mixing zone are approximately the same. The distance to the edge of the initial mixing zone for the Wollongong outfall is generally less than 100 m and is shown schematically in Figure 5.

At Shellharbour, buoyant mixing is not complete when the diluted wastewater reaches the edge of the initial dilution zone (usually the sea surface). When the diluted wastewater reaches the sea surface there is still a substantial difference in salinity between it and the receiving waters. Therefore, there remains a large potential for mixing due to buoyancy well beyond the initial dilution zone. The salinity of the diluted Shellharbour wastewater approaches that of the surrounding seawater at a distance of approximately 1,000 m downstream from the Shellharbour outfall and is shown schematically in Figure 6. This distance defines the distance from the Shellharbour outfall to the edge of the initial mixing zone.

A schematic of the mixing zones is shown in Figure 7.

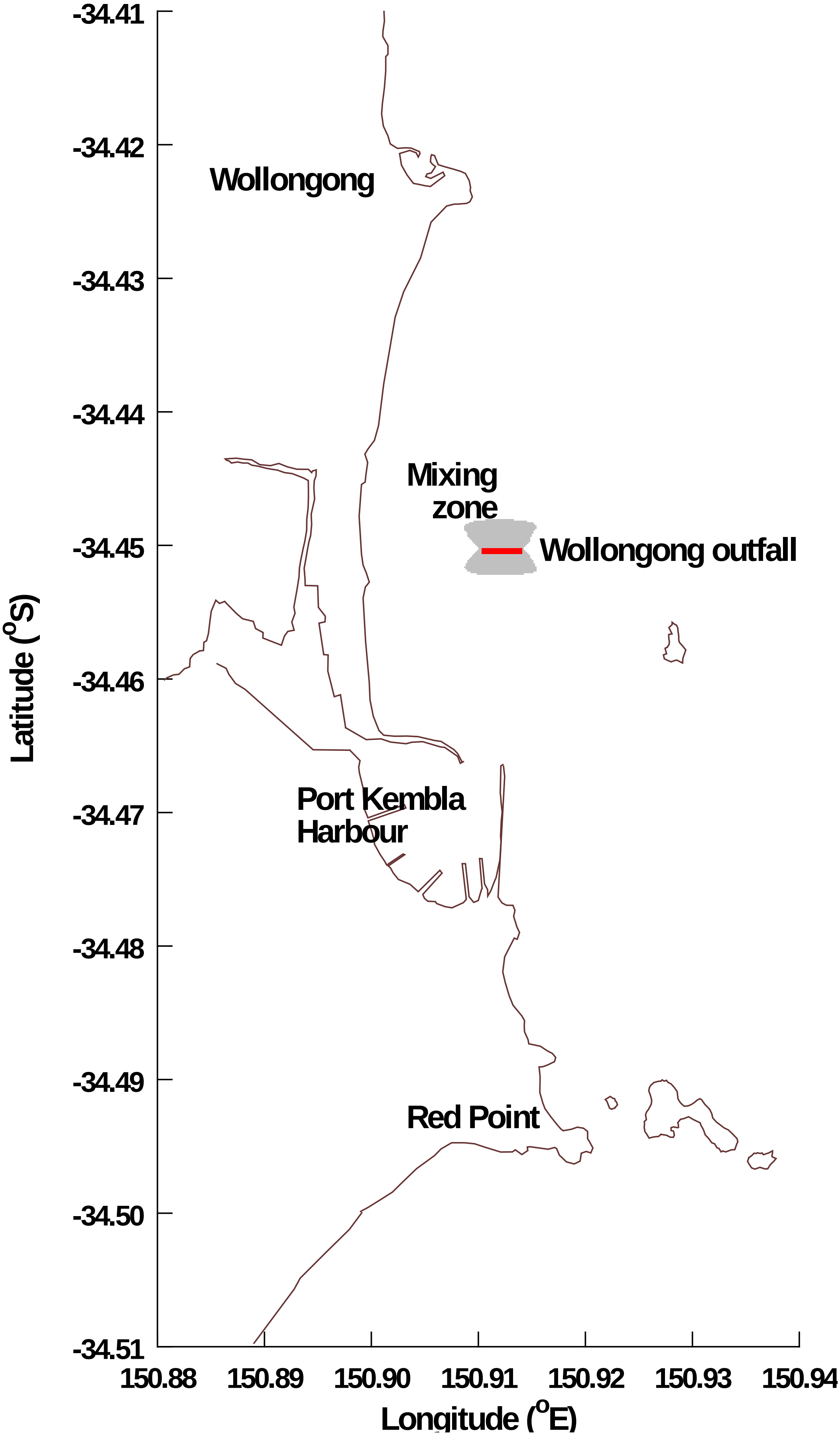

Figure 5. Approximate size of the initial mixing zone for Wollongong.

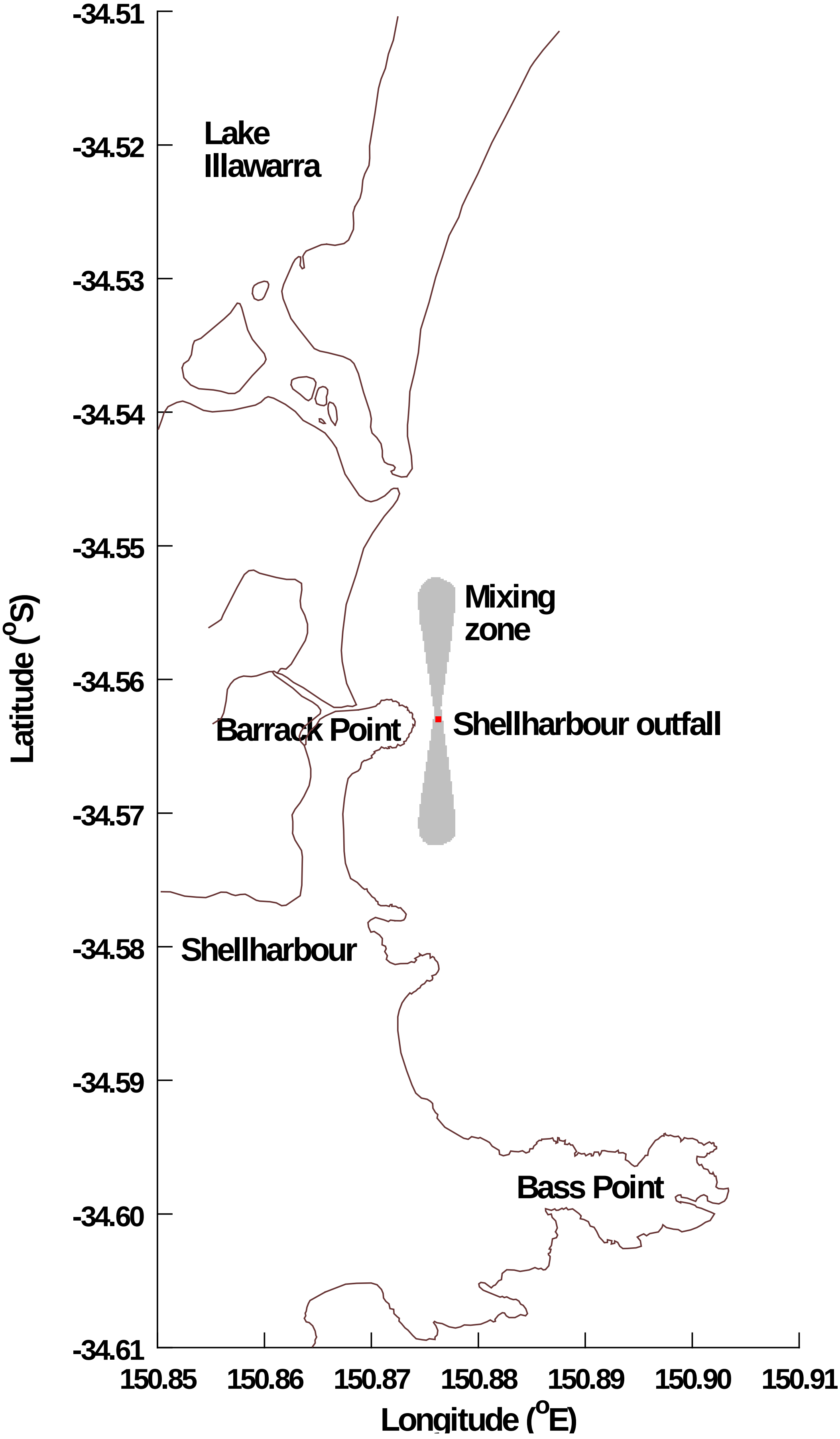

Figure 6. Approximate size of the initial mixing zone for Shellharbour.

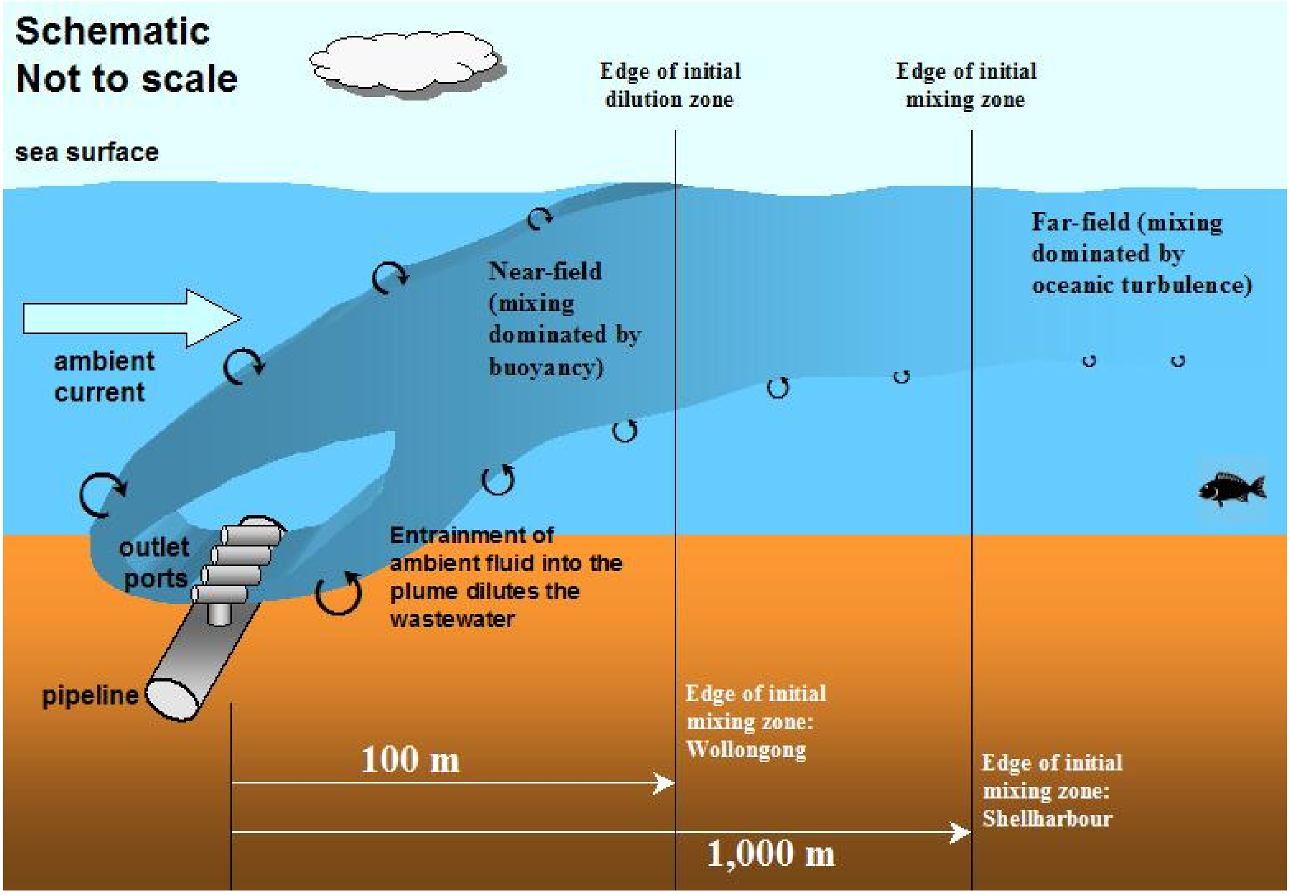

Figure 7. Schematic of the mixing of the wastewater plumes for discharges through the ocean outfalls at Wollongong and Shellharbour.

2.7 Wet Weather Discharges

Under high wastewater flows (usually associated with wet weather or storm conditions), some elements of the wastewater treatment process at Wollongong WRP and Shellharbour WWTP may be circumvented. When flow is sufficiently large, discharge may occur through the old Port Kembla outfall and, at Shellharbour, to Barrack Swamp. In addition, wet weather discharges may occur through stormwater drains discharging directly to the beach or nearshore waters.

There is a limit to the rate at which wastewater can be pumped to the Wollongong WRP. Under some wet weather conditions the limit of the pump is reached and surplus wastewater is diverted to storage facilities at Port Kembla. When storage is exceeded, wastewater is discharged through the Port Kembla outfall. Wastewater discharge through the Port Kembla outfall during 2009 represents 1.4% of the total discharge to the ocean of the Wollongong and Port Kembla plants. The CORMIX model can be used to estimate the dilution of wastewater discharged through the Port Kembla outfall.

At the Shellharbour WWTP, excess wastewater is discharged, via the tidal drain outfall, to Barrack Swamp. During 2009 the total volume discharged to the tidal drain was 0.8 ML, representing less than 0.0004% of the flow to the environment from the Shellharbour WWTP.

Stormwater drains discharge either directly to the receiving waters or to the beaches adjacent to the drains. For discharges to the receiving waters, the CORMIX model can be used to estimate dilutions. For discharges to the beaches, there will be no dilution with receiving waters and the stormwater will dissipate through the sand. In such cases, Darcy's Law can be used to estimate the time taken for the discharges to dissipate (e.g. Freeze and Cherry, 1979).

For discharges of stormwater onto the sand it is assumed that the stormwater pools near the discharge outlet prior to seeping into the sand. Further, during each rainfall event it is assumed that the flow is continuous and non-varying. For flow that is angled vertically downwards, Darcy's Law can be simplified as:

$$Q = A_z.K$$

Where Q is the discharge rate (m^3/sec) of the stormwater, A_z is area (m^2) of contact between the sand and the stormwater and K is the hydraulic conductivity (m/sec) of the sand. K can vary by several orders of magnitude (10^{-2} to 10^{-6} m/sec), e.g. Freeze and Cherry, 1979.

2.8 Annual Loads

Each of the treatments plants has annual load limits placed on a range of contaminants. The existing licence limits are detailed in Table 4 for both Wollongong WRP and Shellharbour WWTP. The calculated annual load is essentially the measured concentration of a substance multiplied by the annual flow of wastewater.

Depending of the site of wet weather events, excess wastewater may flow through the Bellambi and Port Kembla outfalls as well as through the Wollongong outfall. Similarly, excess wastewater in wet weather may discharge through the Shellharbour emergency storm bypass as well as through the Shellharbour outfall. For the purpose of estimating loads, wet weather emission factors may be used. Emission factors are estimated concentrations of variables that may be used in the absence of actual data. In general, they are more conservative than the measured data.

To estimate loads under future scenarios, measured concentration data were applied to wastewater discharged through the Wollongong WRP and Shellharbour WWTP. Emission factors were applied to flows through the Port Kembla outfall and to flows through the storm bypass and tidal drain at Shellharbour. Flow data from 2009 were obtained for all discharges and scaled to estimate flows for the future scenarios. It was assumed that the load of a contaminant discharged through the Wollongong outfall was independent of the volume of reuse from Wollongong WRP.

Climate change models predict an increase in rainfall in the Illawarra region of the next 40 years (DECCW, 2010). However, in the absence of quantifiable figures, existing rainfall patterns were used for these load calculations.

Results of the estimated loads discharged for each scenario are presented in Table 4. Examination of these results shows the loads always remain less than the existing annual load limits.

Table 4. Load limits and estimated loads for each scenario

Wollongong	kg/year					
Variable	**Licence**	**2009**	**2016**	**2021**	**2031**	**2048**
CBOD	198,535	47,725	108,435	117,077	126,612	148,216
Oil and grease	123,915	6,737	24,319	24,954	25,655	27,243
Total phosphorus	74,319	29,871	42,170	47,501	53,384	66,712
Total nitrogen	743,076	264,026	309,106	348,318	391,586	489,617
Total suspended solids	198,594	36,237	105,580	108,069	110,817	117,041
Shellharbour	**kg/year**					
Variable	**Licence**	**2009**	**2016**	**2021**	**2031**	**2048**
CBOD	116,070	31,020	31,962	33,811	36,836	43,894
Oil and grease	35,953	200	10,215	10,743	11,608	13,625
Total phosphorus	63,364	26,299	34,440	36,927	40,995	50,487
Total nitrogen	254,770	91,230	102,698	110,024	122,011	149,981
Total suspended solids	150,380	42,249	47,437	49,933	54,018	63,550

2.9 Model Assumptions

Below is outlined the main assumptions associated with the numerical modelling. Assumptions in other components of this study are explicitly stated in the relevant sections.

Several assumptions are made in running the CORMIX model. These include:

- flow through the outfall is uniform[2],
- the Wollongong outfall comprises two pipelines, which can be operated singly or in parallel[3],
- density stratification of the water column can be approximated by its temperature structure (i.e. salinity has little effect compared with temperature on density variations),
- currents and stratification data obtained from the 2001-02, 2005 and 2006-07 deployments are applicable for all scenarios,
- there is no temporal change in the concentration of contaminants in the wastewater unless explicitly stated,
- there is no temporal change in the background concentration of contaminants[4],

[2] Outlet nozzles fitted with duckbill valves require energy for them to open. Energy reduces with distance from the wastewater treatment plant. In practical terms this means that duckbill valves closer to the wastewater treatment plant will open in preference to those further offshore. The modelling assumes that all duckbill valves open uniformly for a given flow.

[3] There are no rules governing when both pipelines operate simultaneously. It is assumed that a single pipeline is open for scenarios up to and including flows of 40 ML/day and that both pipelines operate when the flow exceeds 40 ML/day.

- the proportion of treated water allocated for reuse from the Wollongong outfall remains constant for all scenarios unless specifically stated,
- no bacteria die-off was used[5],
- Darcy's Law can be used to estimate the flow of wet weather discharges through the sand,
- model estimates are based on 'normal operations' of the treatment plants.

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[4] An analysis of variance undertaken of the PH50 monitoring site data (combined into decadal bins) indicates no statistically significant difference among data from different decades at the 5% level of significance and statistical power of 95%.

[5] Indicator bacteria die off (also referred to as inactivation) as a result of discharge into a saltwater environment and with time spent in the water and exposure to sunlight. The assumption of no bacteria die-off is conservative and the model will predict higher concentrations of bacteria than actually observed.

3 Model Results

The base cases for both the Wollongong and Shellharbour outfalls use wastewater flow data from 2009. Wastewater quality data for each outfall are obtained for the period July 2009 to June 2010.

Oceanographic data needed to drive the CORMIX model includes current speed and direction and stratification of the water column. For the Wollongong system these data are obtained from an oceanographic mooring covering the period 9 November 2006 to 8 November 2007. Oceanographic data for the Shellharbour outfall are obtained from two mooring deployments: 4 September 2001 to 22 January 2002 and from 12 March 2005 to 31 August 2005.

The ANZECC (2000) water quality guidelines include a large array of substances. Many of these substances are below their limit of reading (as monitored in the treatment plants), are not relevant to this study or are covered through the whole-of-effluent toxicity testing program and are not monitored in the wastewaters. Further, some of the variables that are measured in the wastewater do not have relevant guidelines. Table 5 (Wollongong) and Table 6 (Shellharbour) detail those substances that are measured in the wastewater for licence purposes and/or for which at least one ANZECC (2000) guideline is available.

As described in Section 2.4.2, the quantity of available wastewater quality data is relatively small and a bootstrap technique is used to generate a set of data for incorporating with the model results.

The Shellharbour outfall lies in relatively shallow waters (approximately 8 m deep) and there is incomplete mixing of the wastewater plume at the end of the near-field model. Mixing of the wastewater from the Shellharbour outfall with the surrounding seawater is complete at a distance of approximately 1,000 m from the outfall (Figure 6).

3.1 Wollongong Outfall Model Results

Results are presented as “probability of exceedance curves” at the edge of the initial mixing zone – in Figure 8 for total nitrogen, Figure 9 for total phosphorus, Figure 10 for faecal coliforms and Figure 11 for enterococci. Each figure includes plots for the base case (2009) and for the projected scenarios (2016, 2021, 2031 and 2048). The solid lines indicate results assuming reuse of 20 ML/day while the dashed lines indicate results assuming reuse of 30 ML/day. The model results indicate little difference in the concentrations using the two different values for reuse.

Superimposed on Figure 8 and Figure 9 are the relevant ANZECC (2000) default trigger values (the horizontal red, dashed lines) and the 50%ile values for the background data (the horizontal blue, solid lines). Background concentrations of faecal coliforms and enterococci are assumed to be zero for all scenarios. Superimposed on the faecal coliform and enterococci plots (Figure 10 and Figure 11) are the ANZECC (2000) 50%ile levels (150 cfu/100mL and 35 cfu/100mL, respectively), the latter being very close to the NHMRC (2008) 95%ile guidelines (40 cfu/100mL for class A waters, the most restrictive class). It is noted that the previous version of the NHMRC guidelines for enterococci are identical to those in ANZECC (2000). For clarity, the NHMRC (2008) 95%ile levels are equivalent to the (upper) 5%ile probability of exceedance.

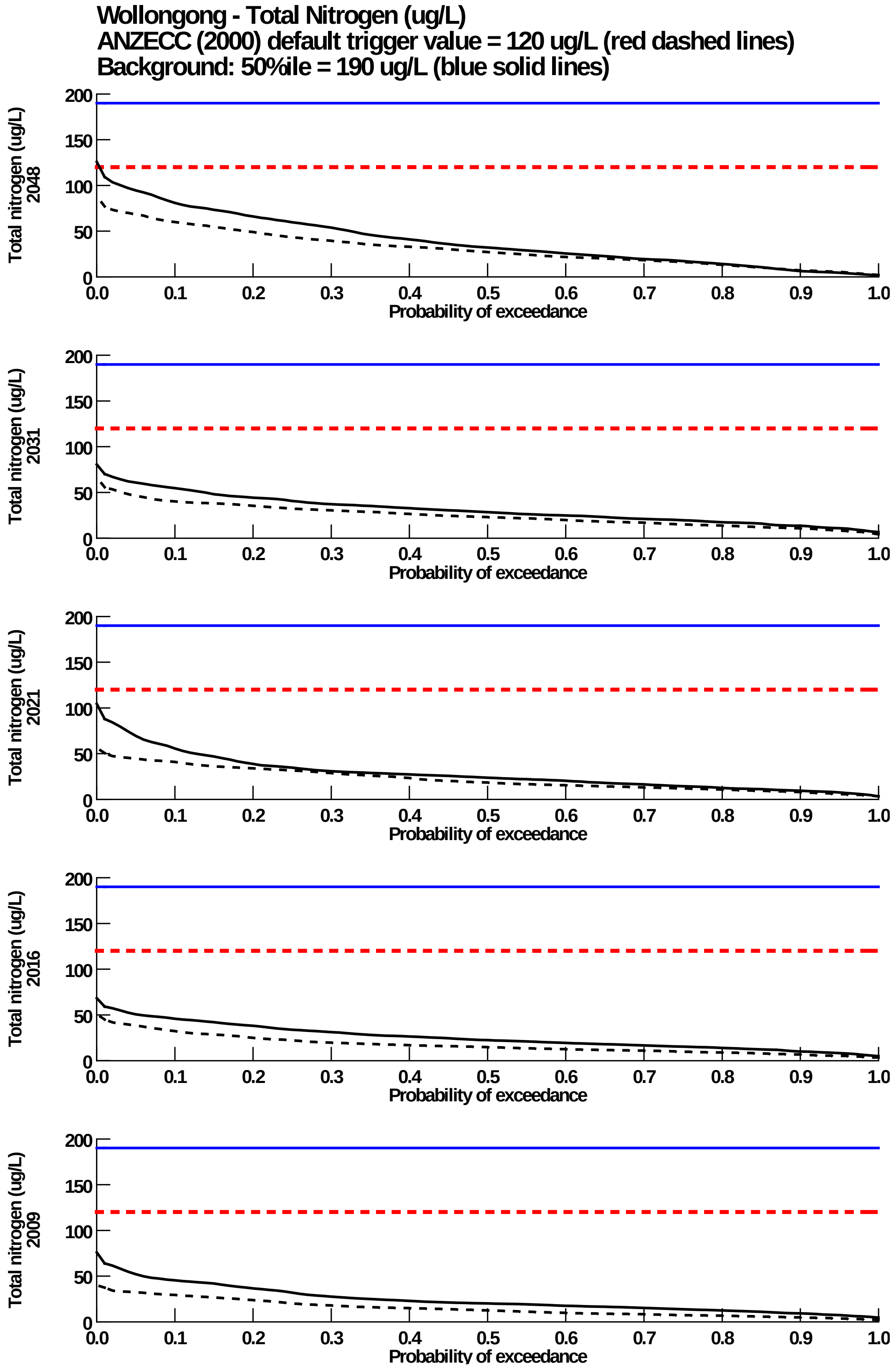

Figure 8. Probability of exceedance plots for Wollongong total nitrogen at the edge of the initial mixing zone (solid line = 20 ML/day reuse, dashed line = 30 ML/day reuse). (ug/L = micrograms per litre).

From Figure 8 it is observed that the 50%ile background level for total nitrogen (190 µg/L) already lies substantially above the ANZECC (2000) default trigger level (120 µg/L). For all scenarios examined, the modelled concentration of total nitrogen is always below the ANZECC (2000) default trigger level.

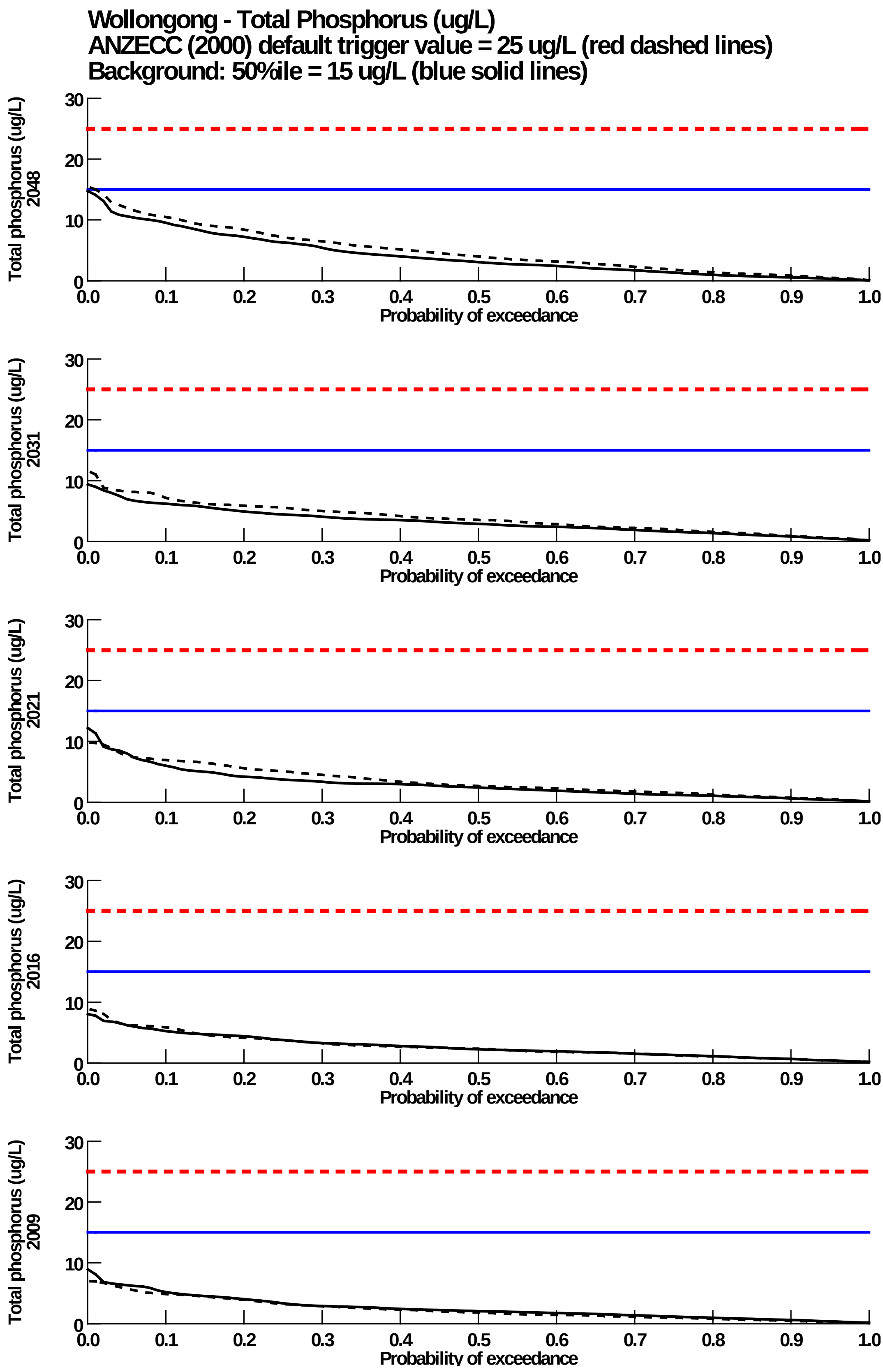

Figure 9. Probability of exceedance plots for Wollongong total phosphorus at the edge of the initial mixing zone (solid line = 20 ML/day reuse, dashed line = 30 ML/day reuse). (ug/L = micrograms per litre).

Background concentrations (50%ile levels are 15 µg/L) of total phosphorus (Figure 9) are less than, but close to, the ANZECC (2000) default trigger values (25 µg/L). Concentrations of total phosphorus always lie below the ANZECC (2000) default trigger level.

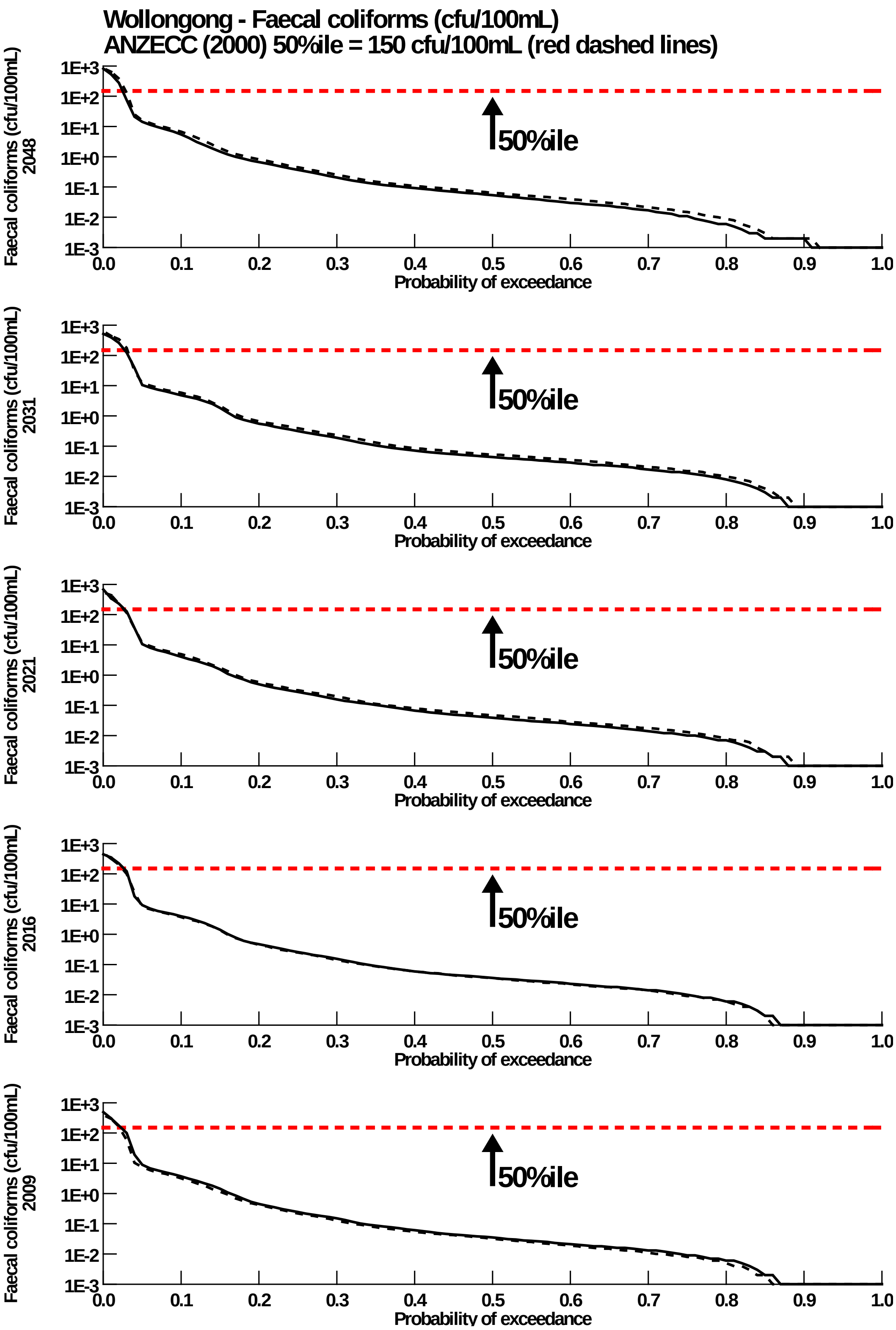

Figure 10. Probability of exceedance plots for Wollongong faecal coliforms at the edge of the initial mixing zone (solid line = 20 ML/day reuse, dashed line = 30 ML/day reuse). The arrows indicate where the guideline applies. (cfu/100mL = colony forming units per 100 millilitres).

Concentrations of faecal coliforms (Figure 10) and enterococci (Figure 11) at the edge of the initial mixing zone lie well below the ANZECC (2000) and NHMRC (2008) guidelines for all scenarios examined.

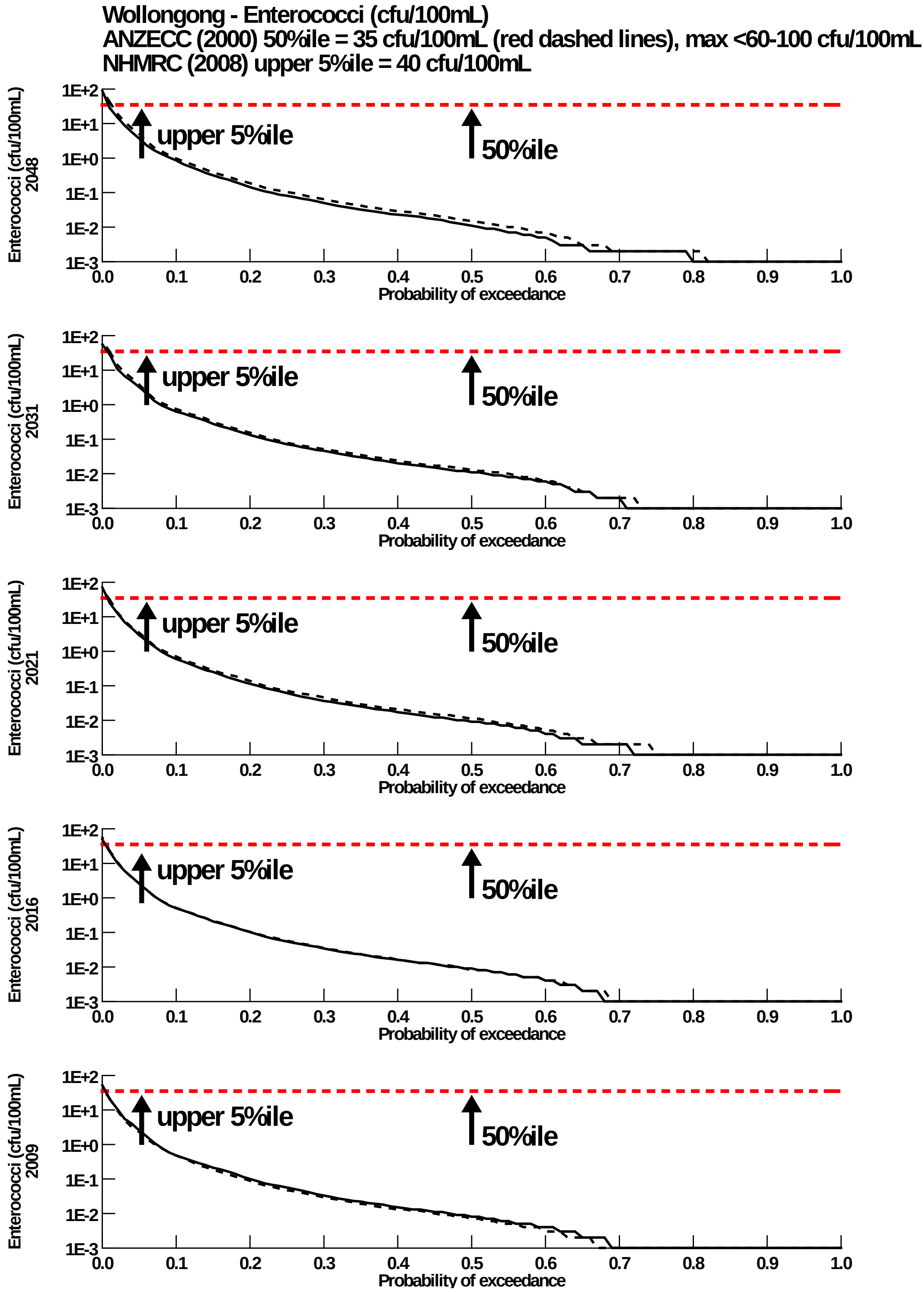

Figure 11. Probability of exceedance plots for Wollongong enterococci at the edge of the initial mixing zone (solid line = 20 ML/day reuse, dashed line = 30 ML/day reuse). The arrows indicate where the guidelines apply. (cfu/100mL = colony forming units per 100 millilitres).

Table 5. Concentrations of contaminants in the normally treated Wollongong wastewater and corresponding ANZECC (2000) water quality guidelines.

			Data 2007-2010				ANZECC (2000) water quality guidelines								
Substance	units	LOR					Marine	Species protection (marine)				aqua-	tainting	recreation	COMMENTS
			#	#>LOR*	Median	Max.	waters	99%	95%	90%	80%	culture			
^ aluminium	µg/L	5	77	77	89	681						10		200	
arsenic	µg/L	1	6	2	1	3						30		50	Observed maximum at, or below, ANZECC
barium	µg/L	1	6	6	9	22								1000	Observed maximum at, or below, ANZECC
beryllium	µg/L	1	3	0	1	1									Data at, or below, limit of reading (LOR)
boron	µg/L	5	6	6	118	206								1000	Observed maximum at, or below, ANZECC
^ cadmium	µg/L	0.1	13	0	0.1	0.1		0.7	5.5	14	36	0.5		5	Data at, or below, limit of reading (LOR), LOR<ANZECC
^ chromium	µg/L	1	13	10	2	3		7.7	27.4	48.6	90.6	20		50	Observed maximum at, or below, ANZECC
cobalt	µg/L	0.1	6	6	1.1	1.6		0.005	1	14	150				
^ copper	µg/L	1	37	37	6	14		0.3	1.3	3	8	5	1	1000	
iron	µg/L	10	6	6	113	359						10		300	
^ lead	µg/L	1	13	1	1	1.3		2.2	4.4	6.6	12	1		50	ANZECC almost met at end of pipe
lithium	µg/L	5	5	4	9	15									No relevant ANZECC guideline
manganese	µg/L	1	6	0	70	189						10		100	
^ mercury	µg/L	0.1	12	1	0.1	0.2		0.1	0.4	0.7	1.4	1		1	ANZECC almost met at end of pipe
molybdenum	µg/L	1	6	5	5	15									No relevant ANZECC guideline
nickel	µg/L	1	6	6	7	11		7	70	200	560	100		100	ANZECC almost met at end of pipe
^ selenium	µg/L	5	13	0	5	10								10	Observed maximum at, or below, ANZECC
silver	µg/L	0.1	6	1	0.1	0.3		0.8	1.4	1.8	2.6	3		50	Observed maximum at, or below, ANZECC
sodium	µg/L	50	4	4	169000	350000								300000	ANZECC almost met at end of pipe
strontium	µg/L	10	6	6	255	389									No relevant ANZECC guideline
tin	µg/L	2	4	0	2	2									Data at, or below, limit of reading (LOR)
titanium	µg/L	10	6	0	10	10									Data at, or below, limit of reading (LOR)
vanadium	µg/L	1	6	6	3	5		50	100	160	280	100			Observed maximum at, or below, ANZECC
^ zinc	µg/L	5	13	13	43	106		7	15	23	43	5	5	5000	
ammonia	mg/L	0.1	1	1	4.6	4.6	0.020	0.5	0.91	1.2	1.7			0.01	"Marine waters" value is for ammonium (NH_4^+) Insufficient data to generate reliable statistics
^ total nitrogen	mg/L	0.05	73	73	31.5	55.4	0.120								
^ total phosphorus	mg/L	0.01	73	73	3.4	10.9	0.025								
^ hydrogen sulphide (un-ionised)	mg/L	0.005	36	0	0.005	0.005						2			Data at, or below, limit of reading (LOR)
^ CBOD	mg/L	2	186	150	4	135									Single reading of 135. Second largest reading is 50 No relevant ANZECC guideline.
COD	mg/L	10	18	18	50	87									No relevant ANZECC guideline
^ total chlorine residual	mg/L	0.05	10	2	0.1	1.6									No relevant ANZECC guideline
conductivity	mS/cm	0.007	11	11	4.6	8.2									No relevant ANZECC guideline
^ total suspended solids	mg/L	2	257	59	2	34	3					10			
^ oil and grease	mg/L	5	81	0	5	5							15		Data at, or below, limit of reading (LOR), LOR<ANZECC
^ faecal coliforms	cfu/100mL	1	184	157	64	510000								150 / 600	50%ile <150 cfu/100mL, 80%ile <600 cfu/100mL

					Data 2007-2010			ANZECC (2000) water quality guidelines							
Substance	units	LOR					Marine	Species protection (marine)				aqua-	tainting	recreation	COMMENTS
			#	#>LOR*	Median	Max.	waters	99%	95%	90%	80%	culture			
enterococci	cfu/100mL	1	160	106	1	83								35, 60-100 40	50%ile <35 cfu/100mL, Maximum < 60-100 cfu/100mL 95%ile <40 cfu/100mL (NHMRC 2008 guideline)
2,4,5-T	µg/L	5	5	0	5	5								2	Data at, or below, limit of reading (LOR)
2,4-D	µg/L	5	6	0	5	5								100	Data at, or below, limit of reading (LOR), LOR<ANZECC
aldrin	µg/L	0.01	12	0	0.01	0.01								1	Data at, or below, limit of reading (LOR), LOR<ANZECC
amitrol	µg/L	0.5	7	0	0.5	0.5								1	Data at, or below, limit of reading (LOR), LOR<ANZECC
atrazine	µg/L	3	4	0	3	3									Data at, or below, limit of reading (LOR). No relevant ANZECC guideline
lindane	µg/L	0.01	12	0	0.01	0.01								10	Data at, or below, limit of reading (LOR), LOR<ANZECC
chlordane	µg/L	0.01	12	1	0.01	0.04						0.004		6	Single reading 0.04. Remaining data at, or below, limit of reading (LOR)
chlorpyrifos	µg/L	0.05	12	0	0.05	0.05		0.0005	0.009	0.4	0.3			2	Data at, or below, limit of reading (LOR)
DDE	µg/L	0.01	12	0	0.01	0.01									Data at, or below, limit of reading (LOR). No ANZECC guideline.
DDT	µg/L	0.01	12	0	0.01	0.01								3	Data at, or below, limit of reading (LOR)
demeton	µg/L	0.1	3	0	0.1	0.1								30	Data at, or below, limit of reading (LOR), LOR<ANZECC
^ diazinon	µg/L	0.1	36	0	0.1	0.1								10	Data at, or below, limit of reading (LOR), LOR<ANZECC
dicamba	µg/L	5	6	0	5	5								300	Data at, or below, limit of reading (LOR), LOR<ANZECC
dichlorbenil	µg/L	0.01	6	0	0.01	0.01								20	Data at, or below, limit of reading (LOR), LOR<ANZECC
dieldrin	µg/L	0.01	12	0	0.01	0.01								1	Data at, or below, limit of reading (LOR), LOR<ANZECC
diquat	µg/L	5	6	0	5	5								10	Data at, or below, limit of reading (LOR), LOR<ANZECC
diuron	µg/L	3	6	0	3	3								40	Data at, or below, limit of reading (LOR), LOR<ANZECC
endosulphan	µg/L	0.01	12	0	0.01	0.01		0.005	0.01	0.02	0.05	0.001		40	Data at, or below, limit of reading (LOR)
glyphosate	µg/L	10	6	0	10	10								200	Data at, or below, limit of reading (LOR), LOR<ANZECC
guthion	µg/L	0.1	3	0	0.1	0.1									Data at, or below, limit of reading (LOR). No ANZECC guideline.
heptachlor	µg/L	0.005	12	0	0.005	0.005								3	Data at, or below, limit of reading (LOR), LOR<ANZECC
hexazione	µg/L	2	6	0	2	2								600	Data at, or below, limit of reading (LOR), LOR<ANZECC
malathion	µg/L	0.05	12	0	0.05	0.05									Data at, or below, limit of reading (LOR). No ANZECC guideline.
molinate	µg/L	5	6	0	5	5								1	Data at, or below, limit of reading (LOR)
total organochlorine pesticides	µg/L	0.2	4	0	0.2	0.2									Data at, or below, limit of reading (LOR). No ANZECC guideline.
total organophosphate pesticides	µg/L	2.5	4	0	2.5	2.5									Data at, or below, limit of reading (LOR). No ANZECC guideline.
paraquat	µg/L	5	6	0	5	5						0.01		40	Data at, or below, limit of reading (LOR)
parathion	µg/L	0.1	12	0	0.1	0.1								30	Data at, or below, limit of reading (LOR), LOR<ANZECC
picloram	µg/L	5	5	0	5	5								30	Data at, or below, limit of reading (LOR), LOR<ANZECC
^ PCBs	µg/L	0.1	12	0	0.1	0.1						2			Data at, or below, limit of reading (LOR), LOR<ANZECC
trichloroacetic acid	µg/L	1	6	3	2	10									No relevant ANZECC guideline
triclorpyr	µg/L	5	5	0	5	5								20	Data at, or below, limit of reading (LOR), LOR<ANZECC
(m+p) xylene	µg/L	1	6	0	1	1									Data at, or below, limit of reading (LOR). No ANZECC guideline.
(o) xylene	µg/L	1	5	0	1	1									Data at, or below, limit of reading (LOR). No ANZECC guideline.

* LOR = Limit Of Reading # = number of samples

^ Contaminants are monitored as part of licence requirements. Unmarked contaminants were obtained for specific projects and do not form part of the licence requirements.

3.2 Shellharbour Outfall Model Results

As for the Wollongong outfall, results from the modelling of the Shellharbour outfall are presented as probability of exceedance curves. These exceedance curves apply at a distance of 1,000 m from the Shellharbour outfall. Figure 12, Figure 13 and Figure 14 plot exceedance probabilities for ammonia, total nitrogen and total phosphorus, respectively and include both the ANZECC (2000) default water quality guidelines and background data. Faecal coliform and enterococci plots (Figure 15 and Figure 16, respectively) compare with ANZECC (2000) and NHMRC (2008) guidelines only. Their background concentrations are assumed to be zero.

Monitoring for ammonia is required as part of the licence conditions for Shellharbour but is not required for monitoring at Wollongong. Therefore, there is a plot for ammonia at Shellharbour (Figure 12), but no equivalent plot for Wollongong.

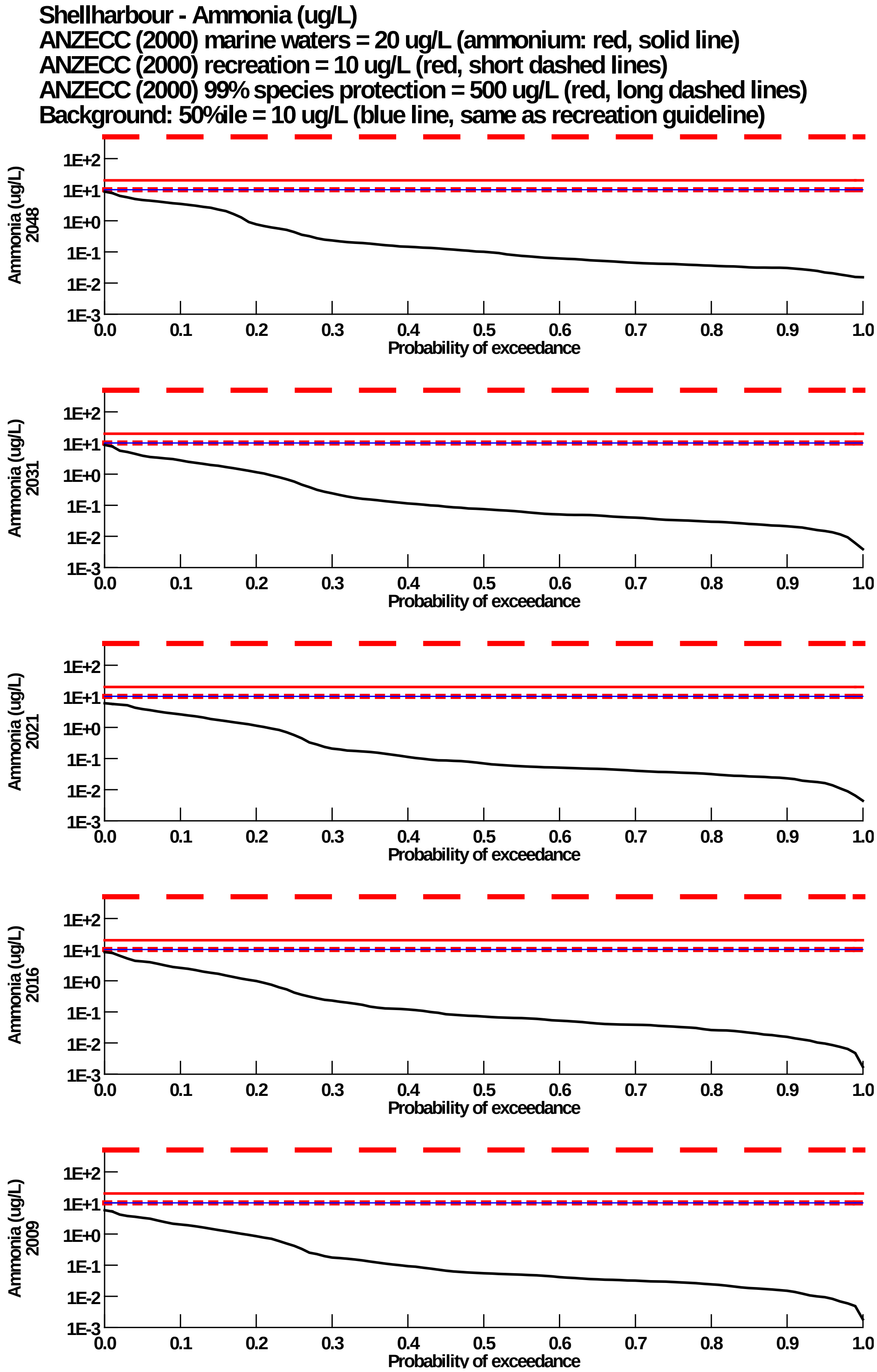

Figure 12. Probability of exceedance plots for Shellharbour ammonia at the edge of the initial mixing zone. The median background concentration is the same as the ANZECC (2000) recreation level (10 µg/L). (ug/L = micrograms per litre).

Concentrations of ammonia lie well below the ANZECC (2000) default trigger values for protection of 99% of species and below the guideline for recreational purposes (Figure 12) and the water quality guideline for ammonium. The median background concentrations for ammonia already lies at the recreational guideline.

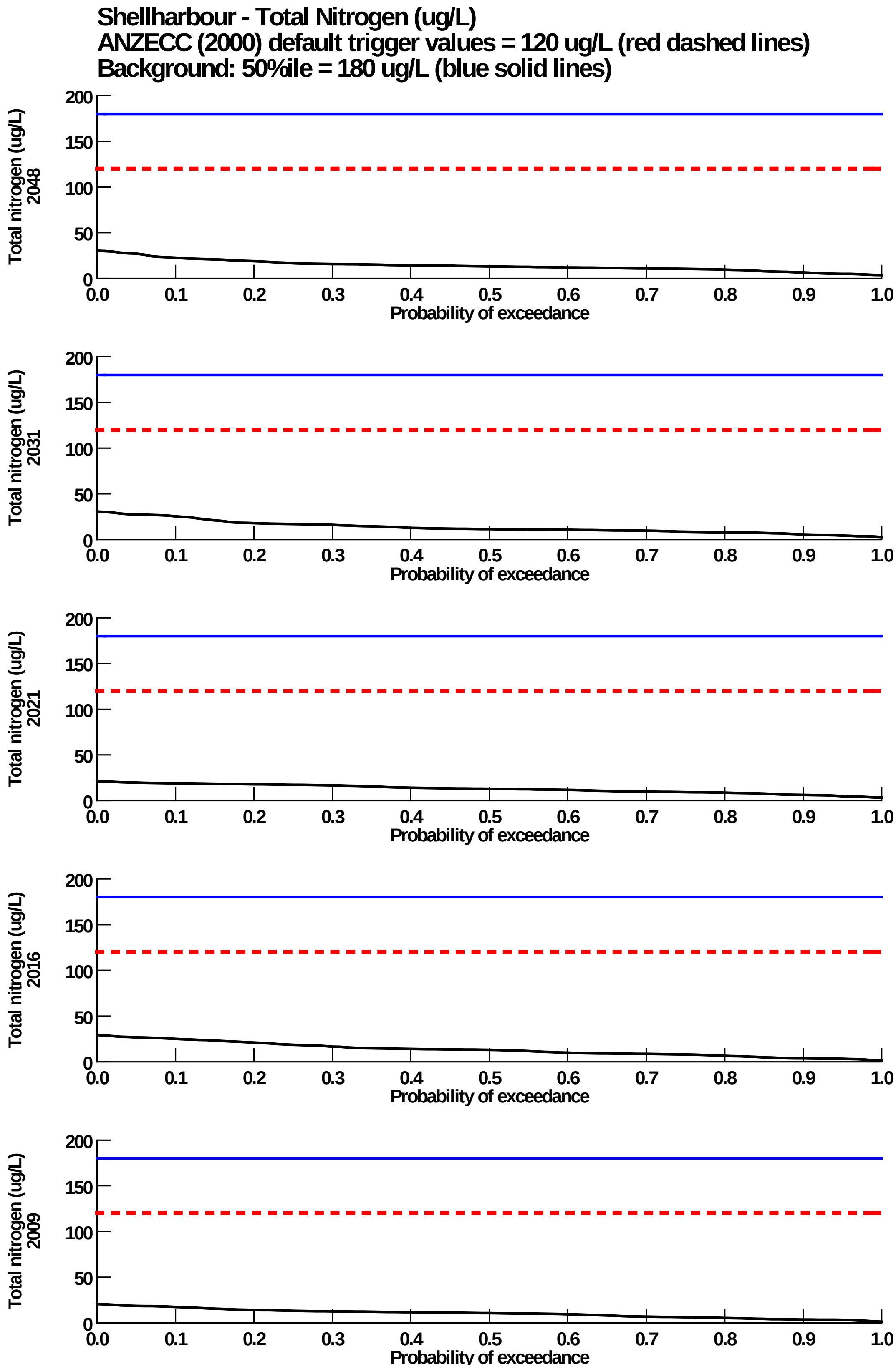

Figure 13. Probability of exceedance plots for Shellharbour total nitrogen at the edge of the initial mixing zone. (ug/L = micrograms per litre).

Concentrations of total nitrogen lie well below the ANZECC (2000) default trigger values for all scenarios examined (Figure 13). The median background concentration for total nitrogen lies well above the ANZECC (2000) default trigger value.

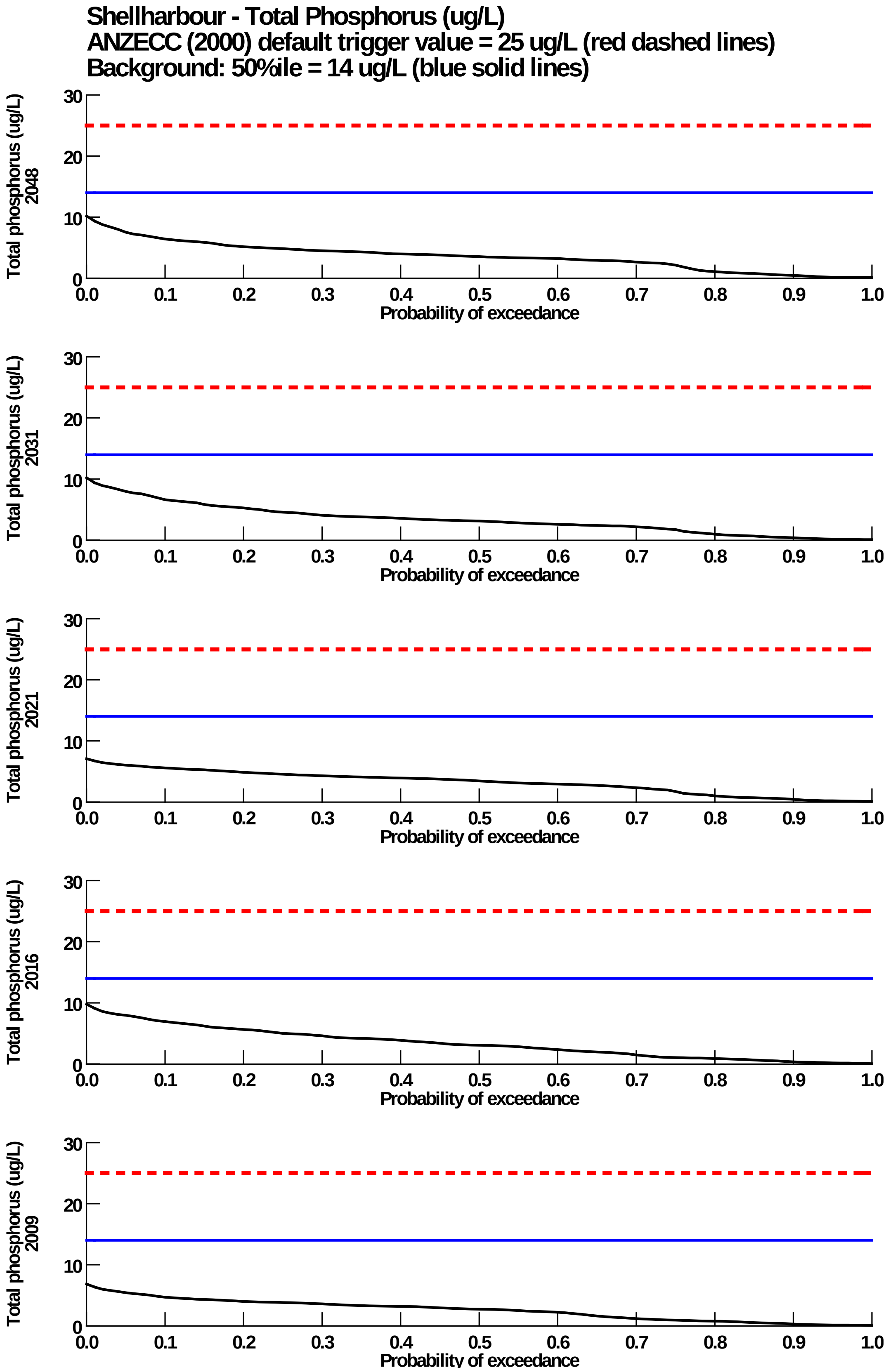

Figure 14. Probability of exceedance plots for Shellharbour total phosphorus at the edge of the initial mixing zone. (ug/L = micrograms per litre).

Concentrations of total phosphorus lie below the ANZECC (2000) default trigger values for all scenarios examined (Figure 14).

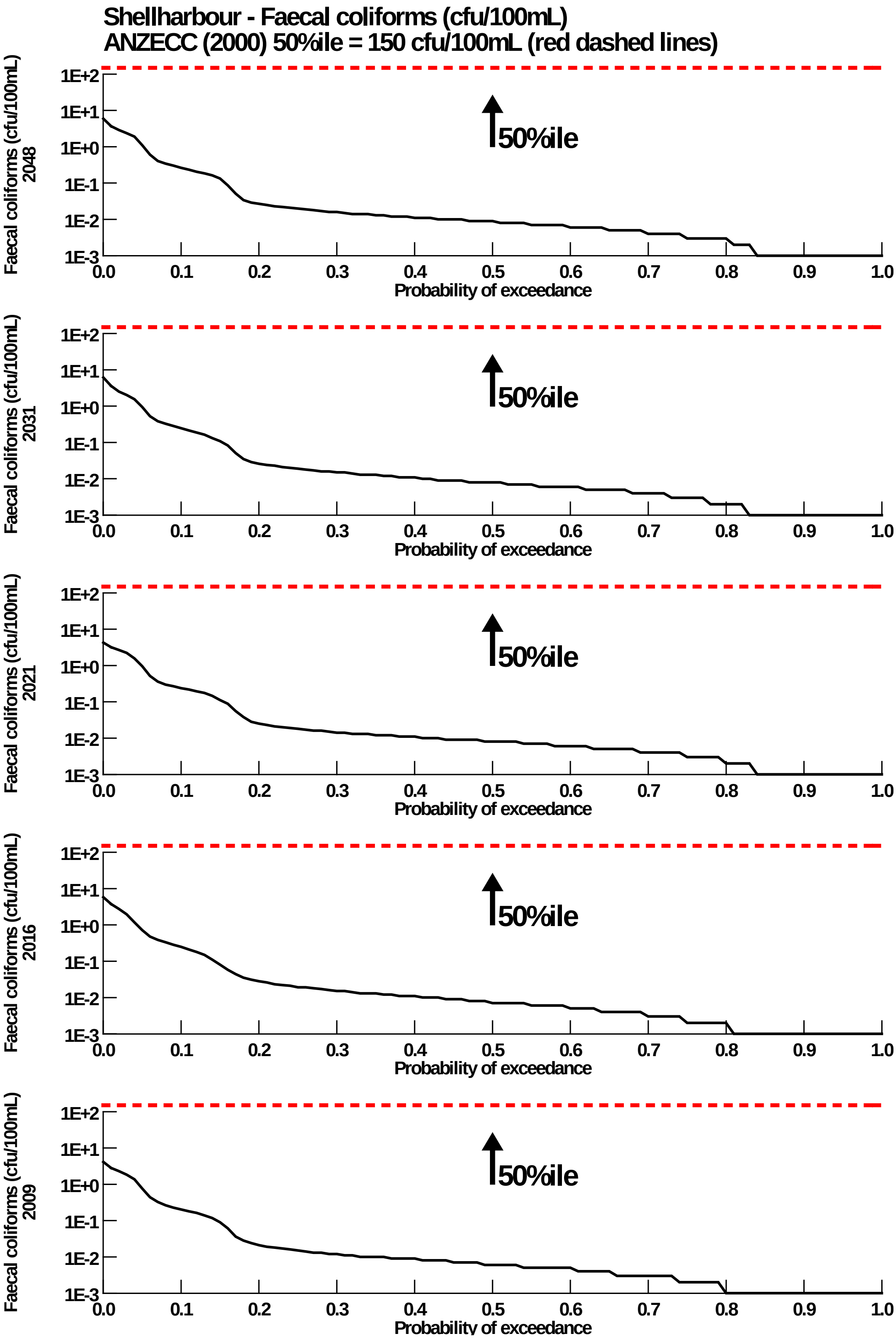

Figure 15. Probability of exceedance plots for Shellharbour faecal coliforms at the edge of the initial mixing zone. The arrows indicate where the guideline applies. (cfu/100ML = colony forming units per 100 millilitres).

Concentrations of faecal coliforms (Figure 15) and enterococci (Figure 16) lie well below the relevant guidelines for all scenarios examined.

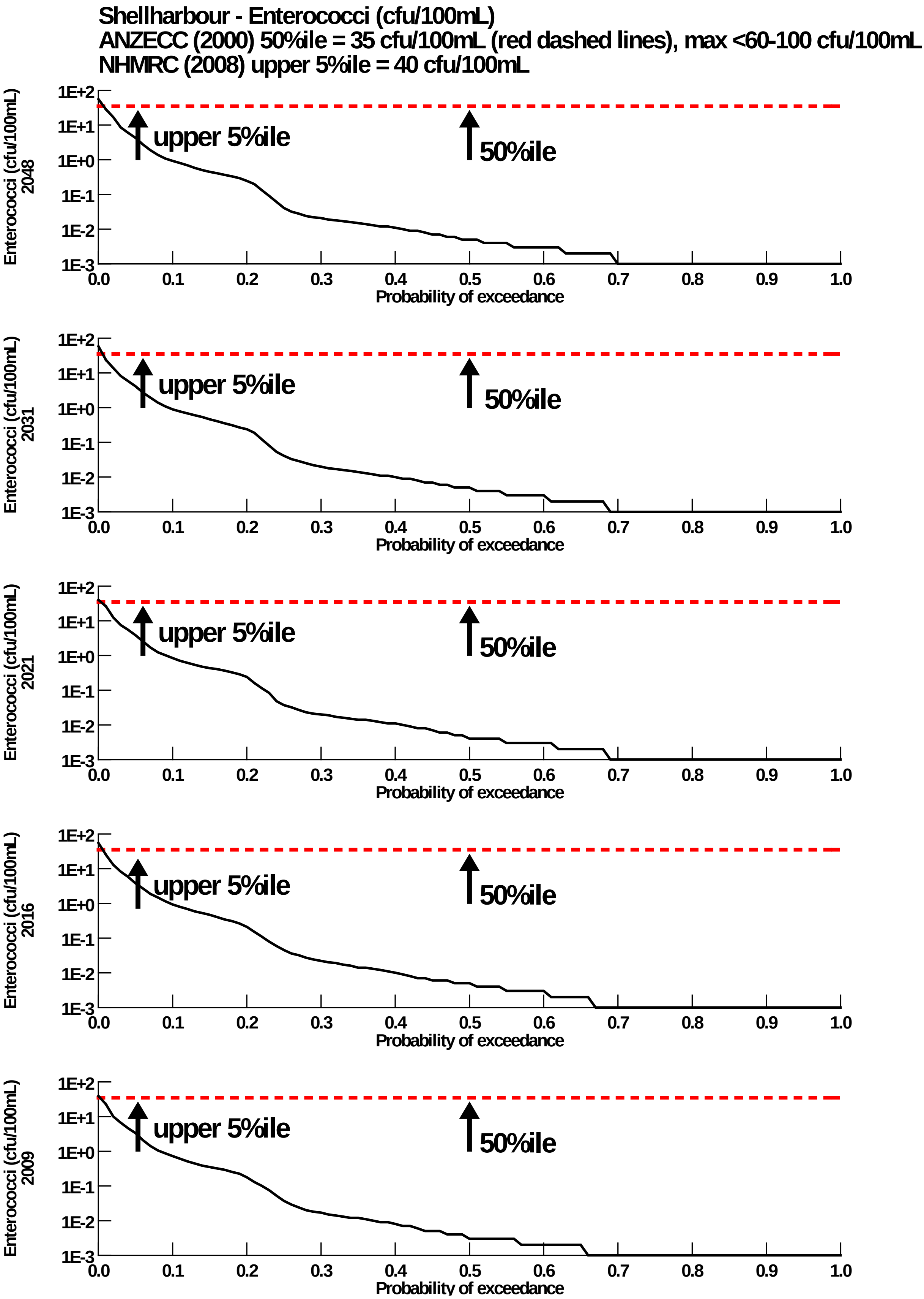

Figure 16. Probability of exceedance plots for Shellharbour enterococci at the edge of the initial mixing zone. The arrows indicate where the guidelines apply. (cfu/100ML = colony forming units per 100 millilitres).

Table 6. Concentrations of contaminants in the normally treated Shellharbour wastewater and corresponding ANZECC (2000) water quality guidelines.

			Data 2007-10				ANZECC (2000) water quality guidelines								
Substance	**units**	**LOR**					**Marine**	**Species protection (marine)**				**aqua-**	**tainting**	**recreation**	**COMMENTS**
			#	**#>LOR***	**Median**	**Max.**	**waters**	**99%**	**95%**	**90%**	**80%**	**culture**			
^ aluminium	µg/L	5	36	36	28	499						10		200	
^ copper	µg/L	1	36	36	5	15		0.3	1.3	3	8	5	1	1000	
^ ammonia	mg/L	0.01	34	31	0.1	6.5	0.020	0.50	0.91	1.20	1.70	0.1		0.010	"Marine waters" value is for ammonium (NH_4^+)
^ total nitrogen	mg/L		36	36	20.4	22.8	0.120								
^ total phosphorus	mg/L	0.01	36	36	6.75	9.80	0.025								
^ hydrogen sulphide (un-ionised)	mg/L	0.005	36	1	0.005	0.020						2			Observed maximum below ANZECC
^ CBOD	mg/L	2	190	155	3	37									No relevant ANZECC guideline
COD	mg/L	10	18	18	69	687									No relevant ANZECC guideline
chloride	µg/L	5	25	25	727	938								400000	Observed maximum below ANZECC
sulphate	µg/L	1	25	25	140	224								400000	Observed maximum below ANZECC
total chlorine residual	mg/L	0.05	10	3	0.05	1.60									No relevant ANZECC guideline
conductivity	mS/cm	0.007	28	28	3.0	3.8									No relevant ANZECC guideline
total dissolved solids	mg/L	10	24	24	1693	2221								1000000	Observed maximum below ANZECC
^ total suspended solids	mg/L	2	256	197	5	73	3					10			
^ oil and grease	mg/L	5	45	0	5	5							15		Data at, or below limit of reading (LOR), LOR<ANZECC
^ faecal coliforms	cfu/100mL	1	183	161	12	10000								150 / 600	50%ile <150 cfu/100mL, 80%ile <600 cfu/100mL
enterococci	cfu/100mL	1	162	99	1	97								35, 60-100 40	50%ile <35 cfu/100mL, Maximum < 60-100 cfu/100mL 95%ile <40 cfu/100mL (NHMRC 2008 guideline)
^ diazinon	µg/L	0.1	36	0	0.1	0.1								10	Data at, or below, limit of reading (LOR), LOR<ANZECC
^ nonylphenol ethoxylates	µg/L	5	36	1	5	7									Only one sample >LOR. No relevant ANZECC guideline

* LOR = Limit Of Reading

= number of samples

^ Contaminants are monitored as part of licence requirements. Unmarked contaminants were obtained for specific projects and do not form part of the licence requirements.

3.3 Metals and Other Substances

Additional substances are monitored in the Wollongong and Shellharbour wastewaters as part of their respective Environment Protection Licences (Table 7). The concentrations of these substances are low, in many cases much less than the ANZECC (2000) guidelines.

Comparison with the ANZECC (2000) guidelines is made using a maximum likelihood argument. The maximum concentration of each substance in the wastewater is divided by the minimum modelled dilution. This results in the maximum concentration of each substance at the edge of the initial mixing zone. If this maximum concentration is less than the relevant ANZECC (2000) guideline, then the modelled concentrations at the edge of the initial mixing zone will always lie below the ANZECC (2000) guideline.

From Table 7 it is observed that the maximum concentration of all substances at the edge of the respective initial mixing zones lie well below the relevant ANZECC (2000) guideline. Therefore, the concentrations of these substances will always meet the ANZECC (2000) guidelines at the edge of the initial mixing zones.

Table 7. Maximum modelled concentrations of substances at the edge of the initial mixing zones and comparison with ANZECC (2000) guidelines and Lake Illawarra Authority WQOs.

			ANZECC (2000) water quality guidelines								Lake Illawarra Authority WQO		Wollongong		Shellharbour	
Substance	**units**	**LOR***	**Marine waters**	**Species protection (marine)**				**Aqua-culture**	**Tainting of flesh**	**Recreation**	**Coastal waters**	**Aquatic foods**	**Observed maximum in wastewater**	**Modelled maximum concentration at edge of IMZ^**	**Observed maximum in wastewater**	**Modelled maximum concentration at edge of IMZ^**
				99%	**95%**	**90%**	**80%**									
Minimum modelled dilution at the edge of the initial mixing zone														420		747
Aluminium	µg/L	5						10		200			681	1.6	499	0.7
Cadmium	µg/L	0.1		0.7	5.5	14	36	0.5		5			0.1	0.0002	Not monitored	
Chromium	µg/L	1		7.7	27.4	48.6	90.6	20		50			3	0.007	Not monitored	
Cobalt	µg/L	0.1		0.005	1	14	150						1.6	0.004	Not monitored	
Copper	µg/L	1		0.3	1.3	3	8	5	1	1000	1.3	5	14	0.033	15	0.020
Lead	µg/L	1		2.2	4.4	6.6	12	1		50	4.4		1.3	0.003	Not monitored	
Manganese	µg/L	1						10		100			189	0.45	Not monitored	
Iron	µg/L	10						10		300			359	0.85	Not monitored	
Mercury	µg/L	0.1		0.1	0.4	0.7	1.4	1		1		1	0.2	0.0005	Not monitored	
Selenium	µg/L	5								10			10	0.024	Not monitored	
Zinc	µg/L	5		7	15	23	43	5	5	5000	15.0	5	106	0.25	Not monitored	
Hydrogen sulphide (un-ionised)	mg/L	0.005						2					0.005	0.00001	0.02	0.00003
Total suspended solids	mg/L	2	3 #					10				5	34	0.1	73	0.1
Oil and grease	mg/L	5							15				5	0.012	5	0.007
Diazinon	µg/L	0.1								10			0.1	0.00024	0.1	0.00014
PCBs	µg/L	0.1						2				2	0.1	0.00024	Not monitored	
chlordane	µg/L	0.01										0.004	0.04	0.0001	Not monitored	
chlorpyrifos	µg/L	0.05									0.009		0.05	0.0001	Not monitored	
Ammonia	µg/L	10	20	500	910	1200	1700	100		10			Not monitored		6,500	9
Total nitrogen	µg/L	50	120								300		55,400	132	22,800	31
Total phosphorus	µg/L	10	25								30		10,900	26	9,800	13
Faecal coliforms	cfu/100 mL	1	150								150		64 (median)	<1	12 (median)	<1
Enterococci	cfu/100 mL	1	35								35		21 (median)	<1	16 (median)	<1

* LOR = Limit Of Reading
^ IMZ = Initial Mixing Zone
# based on turbidity < 10 NTU (assumes 1 mg/L of suspended solids equals a turbidity of 3 NTU)

Exceedance plots of these substances are provided in Appendix 2 .

3.4 Wet Weather

Unlike average dry weather flow, average wet weather flow is not meaningful – wet weather flow varies in magnitude, duration and frequency. Therefore wet weather events need to be treated individually. Wet weather flows will be, generally, independent of time. The five scenarios used for modelling in the previous section, are replaced by individual wet weather events of specific volume and duration. Similarly, the presentation of results for wet weather events differs from those for dry weather events.

3.4.1 Shellharbour and Port Kembla Outfalls

The CORMIX model was run for several wet weather scenarios (Table 8). There is a limit to the amount of wastewater that can be transferred from Port Kembla to Wollongong (approximately 51 ML/day). Beyond this limit (and after the capacity of the storage at Port Kembla is reached) discharge of wastewater will occur through the Port Kembla outfall. Effectively, Port Kembla is the discharge location for Wollongong wet weather flows.

Wet weather flow data for Port Kembla and Shellharbour were obtained from 2009-10 wastewater flow data. Modelled wet weather flows through the outfalls corresponded to rainfall average recurrence intervals (ARI) of approximately one, three, six, 12, 24 and 48 months. (An ARI of 12 months is the rainfall that will occur, on average, once every year). A summary of the results is provided in Table 8.

Table 8. Wet weather flow scenarios and results using 2009-10 flow data and emission factors.

Rainfall ARI (months)	Shellharbour	Port Kembla
<1	Full treatment at Shellharbour	Full treatment at Wollongong WRP
1-3	Full treatment at Shellharbour	Approximately 12 events per year Average event duration: 14 hours, total volume discharged is 15 ML Faecal coliforms, enterococci, ammonia, total phosphorus, total nitrogen, total suspended solids, aluminium, cobalt, copper, iron, lead, manganese and zinc all exceed ANZECC (2000) guidelines.
6	Full treatment at Shellharbour	Average event duration: 21 hours, total volume discharged is 47 ML Substances above exceed ANZECC (2000)
12	Occurs when flows exceeds 5xADWF Average event duration: 4.2 days, total volume discharged is 346 ML Total phosphorus exceeds ANZECC (2000) in 2% of samples (i.e. once in 50 years)	Average event duration: 27 hours, total volume discharged is 85 ML Substances above exceed ANZECC (2000)
24	Occurs when flows exceeds 7xADWF Average event duration: 7.3 days, total volume discharged is 892 ML Total phosphorus exceeds ANZECC (2000) in 30% of samples	Average event duration: 28 hours, total volume discharged is 109 ML Substances above exceed ANZECC (2000)
48	Occurs when flows exceeds 8xADWF Average event duration: 8 days, total volume discharged is 1070 ML Total phosphorus exceeds ANZECC (2000) in 45% of samples	Average event duration: 53 hours, total volume discharged is 228 ML Substances above exceed ANZECC (2000)

Emission factors and the most restrictive ANZECC guidelines are presented in Table 9.

Concentrations of a number of contaminants exceed their relevant ANZECC (2000) guidelines. At Port Kembla, almost any discharge will results in a range of contaminants exceeding the ANZECC (2000) guidelines (Table 8). The reason for this is the relatively low level of wastewater treatment at Port Kembla and the low dilution (median value of 22:1) achieved by the outfall. At Shellharbour, only wastewater flows beyond five times ADWF result in total phosphorus concentrations exceeding the ANZECC (2000) guideline. However, as outlined in the following section, any impacts that may occur as a result of wet weather will be short-lived.

Table 9. Wet weather contaminants and their emission factors.

Contaminant (all units are in mg/L)	Emission factor	ANZECC (2000) guideline[6]
Aldrin	0.000005	0.001
Cadmium	0.00004	0.0005
Chlorpyrifos	0.000177	0.0000005
Chromium	0.00544	0.0077
Copper	0.04532	0.0003
DDT	0	0.003
Dieldrin	0.00006	0.001
Diazinon	0.000181	0.01
Endosulphan	0	0.000001
Heptachlor	0.000007	0.003
Mercury	0.00006	0.001
Oil and grease	18	15
Lead	0.01269	0.001
PCB	0	0.002
Parathion	0	0.03
Selenium	0.00205	0.01
Total suspended solids	80	3
Chlordane	0.000008	0.000004
Total nitrogen	13	0.120
Total phosphorus	1.9	0.025
Zinc	0.10629	0.005

3.4.2 Stormwater Drains

Three stormwater drains discharge wastewater in wet weather. One discharges to the waters near Port Kembla Beach, a second to a beach within Shell Harbour and the third to Shellharbour South Beach. Outlined in Table 10 is the average number of overflow events per year and the average volume of each of these overflow events. This information is provided for each of the three stormwater drains and for each of the five scenarios.

[6] The most restrictive ANZECC guideline is used. Generally, this guideline is the "protection of 99% of species".

Table 10. Number of stormwater events and their duration

Directed overflow point to stormwater drain	Year 2009	2016	2021	2031	2048
Port Kembla Beach (id AA1111)					
# overflows per year	4.6*	0.1	0.2	0.3	0.5
Volume per overflow (kL)	37.2	210	175	217	230
Shell Harbour Beach (id 4808651)					
# overflows per year	0.2	0.2	0.2	0.3	0.3
Volume per overflow (kL)	55	65	70	53	67
Shellharbour South Beach (id CM1101A)					
# overflows per year	0.2	0.2	0.2	0.3	0.3
Volume per overflow (kL)	1220	1425	1570	1243	1573

* Note: SewerFix work is presently underway and the number of overflow events per year will reduce markedly by 2016.

The stormwater drain at Port Kembla Beach discharges to ocean waters and the CORMIX model is appropriate for estimating dilutions. As identified in Table 10, the difference in the volume of wastewater discharged under the future scenarios is small compared with the 2009 scenario (usually less than 10%). Therefore, it is not surprising that the difference in dilutions resulting from each of the modelled scenarios is also small. Ten metres from the discharge outlet, dilutions lie between 3:1 and 8:1 with a median value of 5:1. Twenty metres from the discharge outlet, dilutions lie between 4:1 and 12:1 with a median value of 7:1. The lower dilutions are obtained from the more intense events.

These dilutions are comparable with the median wet weather dilution obtained for discharges through the Port Kembla outfall of 22:1. Assuming the same types and concentrations of contaminants in both the Port Kembla rising main and the stormwater discharges, similar environmental effects would be anticipated. That is; under wet weather conditions, contaminants that do not meet the ANZECC (2000) default trigger values in the wastewater will not meet these guidelines in the receiving waters. From Table 10 this is modelled to occur approximately once every two years for the 2048 scenario.

The two stormwater drains at Shellharbour discharge to the sand. Therefore, there will be no dilution of contaminants contained in these wastewaters. Concentrations of contaminants that do not meet the ANZECC (2000) default trigger values in the wastewater, will not meet these guidelines after discharge to the sand. Therefore, it is the duration for which wastewater pools in the sand near the stormwater outlet that is critical for assessing environmental and public health impacts.

Darcy's Law ($Q_{OUT} = A_z.K$) and a simple mass-balance ($[Q_{IN} - Q_{OUT}].t=V$, where t is the time and V is the volume of the pooled wastewater) are used to estimate the length of time wastewater remains pooled in the sand near the outlet. For the stormwater drain near the beach inside Shell Harbour this duration is up to 14 hours after the cessation of discharge. For the stormwater drain near Shellharbour South Beach, this duration is up to 28 hours after the cessation of the discharge. It is noted that these values are sensitive to the hydraulic conductivity, which, for sand, can vary by up to four orders of magnitude.

Discharges to the beach sand are modelled to occur approximately once every three years for the 2048 scenario.

During these periods the indicator bacteria (faecal coliforms and enterococci) may exceed the relevant ANZECC (2000) guidelines. Bathing in waters pooled at the end of the stormwater drain is not recommended. The ANZECC (2000) guideline for faecal coliforms requires samples to be collected over the bathing season. It is unlikely that a storm event will last for the bathing season (or longer), so this guideline is not strictly applicable to the wet weather discharges. However, it is recognised that concentrations of faecal coliforms exceeding 150 cfu/100mL will increase the risk of infection to the public.

3.5 Reversibility of Effects

The modelling results demonstrate that, outside the initial mixing zones, future discharges through the Wollongong and Shellharbour outfalls will meet the ANZECC (2000) and NHMRC (2008) guidelines. However, these guidelines may not always be met inside the initial mixing zones and the potential exists for impacts to occur inside these zones. Several recent, local studies have examined recovery of marine communities when the discharge of wastewater ceases. These are briefly outlined below.

Although the model results do not predict significant impacts as a result of the WDURA and AGA developments beyond the initial mixing zone, the initial mixing zone itself may contain contaminants in concentrations that exceed the relevant guidelines. When the outfalls cease to discharge so will the release of these contaminants. Within a relatively short period of time (circa months) the environment within the initial mixing zone will return to natural levels as defined by the nearby reference locations. This is evidenced using two local examples of recovery – from outfalls in the Illawarra and Sydney regions.

The Illawarra Waste Water Strategy (IWWS) included the decommissioning of the wastewater treatment plants at Bellambi and Port Kembla and the transfer of their wastewater to new facilities at Wollongong. Part of the marine monitoring program for the IWWS examined the recovery of the intertidal and subtidal communities as a result of the cessation of dry weather discharge through the respective outfalls. The program was also required to identify impacts associated with short-term discharge of wastewater through these old outfalls during large wet weather events. Below is a brief summary of the results of these studies.

3.5.1 Recovery at Bellambi and Port Kembla

The intertidal community is considered to be sensitive to wastewater discharges and was selected to monitor recovery at Bellambi and Port Kembla. Sampling was undertaken at three intertidal regions for each of the reference locations and at locations close to the wastewater discharge points. Sampling was undertaken prior to the decommissioning of the outfalls, then at periods of one week, one month, two months, four months, six months and one year after commissioning. Recovery was determined by similarity of the outfall locations with the reference locations.

Recovery was more noticeable at Port Kembla than at Bellambi. At the Port Kembla discharge location recovery was seen within two months of the decommissioning. After six months, the Port Kembla location could not be distinguished from the reference locations. The movement of sand, which covered some of the monitoring locations, hindered the identification of recovery at Bellambi. Despite this hindrance, it appeared that recovery near Bellambi took place within six months of the decommissioning of the Bellambi outfall.

Subtidal sessile communities were also examined at Port Kembla. However, safety prevented the collection of samples from within approximately 100 m of the Port Kembla outfall. At this distance from the outfall, no statistically significant differences were detected (compared with reference locations). It is not possible to categorically determine whether this was due to recovery as a result of the cessation of the discharge, or because the monitoring location lay outside the Port Kembla outfall initial mixing zone.

3.5.2 Recovery after Rainfall

Intertidal communities were used to assess short-term impacts at the old Bellambi and Port Kembla outfalls resulting from wet weather events. Sampling was undertaken at reference locations and at locations close to the wet weather outlets. Sampling was undertaken as soon as possible after a wet weather event, then repeated one month later.

Difficulties associated with sampling safely during and immediately after wet weather events and the difficulty in separating different sources (stormwater from wastewater sources) and physical processes (e.g. waves associated with large storm events) were evident. Despite these difficulties, the results indicate that rains affect intertidal communities but recovery is evident within one month of cessation of the wet weather event. It was also concluded (Harper, 2008) that discharges from stormwater drains contributed more to impacts on intertidal rocky foreshore communities than the bypasses from the Wollongong WRP and/or the Shellharbour WWTP.

3.5.3 Recovery at North Head

In addition to the recovery studies undertaken as part of the IWWS, a similar study had been undertaken investigating recovery of the cliff-face outfall at North Head. This study formed part of the environmental monitoring program for the Sydney deepwater ocean outfalls.

Underwood and Chapman (1996) described the results from a study examining the changes in subtidal habitats when the cliff-face outfall at North Head was turned off and the flows diverted to the deepwater ocean outfalls. Although they raised some issues in terms of whether the habitat was actually stressed by the old discharges or the impacts caused by physical processes, within four months of the cessation of the discharge, the putatively impacted location could not be distinguished from the reference locations. They concluded that "…… this study provides no indication of it (wastewater discharges) being a large ecological problem affecting the distributions and abundances of common sessile fauna and the composition of assemblages in immediately adjacent subtidal rocky habitats".

4 Overall Environmental Assessment

This section provides an overall assessment of the marine environmental impacts predicted as part of this study. Work carried out to quantify impacts on the marine environment (which formed the Marine Monitoring Program for the IWWS) is used to support the results from this study and is summarised below. This is a recent study following the commissioning of upgrades of the treatment processes and outfalls at both Wollongong and Shellharbour. Sections that address the specific requirements of the DGRs and comments from DECCW follow this summary.

4.1 The Illawarra Waste Water Strategy

The Illawarra Waste Water Strategy (IWWS) formed part of Sydney Water's long-term strategy for sustainable wastewater management in the Illawarra region. Part of this strategy includes works "to protect or enhance the ecosystem and health of the waterways and to protect public health across Sydney Water's area of operations". The IWWS is achieving this by "protecting aquatic ecosystems, ensuring safe water-based recreation, encouraging maximum reuse of treated waste water, operating all the sewerage systems effectively and efficiently and meeting the demands of urban growth while avoiding damage to waterways".

The objectives of the IWWS were identified in the Environmental Impact Statement for the IWWS (Sydney Water, 1999) and they are summarised below:

- to sufficiently improve water quality at beaches such that ANZECC and NHMRC guidelines for bathing waters are met
- to improve water quality at beaches to ensure the protection of aquatic ecosystems
- to reduce the impact of unsewered areas and wastewater overflows to Lake Illawarra, rivers, lagoons and streams in the region
- to facilitate effluent reuse where this is commercially viable
- to improve the performance of the existing systems and service growth and new development in the region.

The IWWS was planned in a number of stages, with the early stages focussing on

(a) the transfer of wastewater from Bellambi and Port Kembla to upgraded tertiary wastewater treatment facilities at Wollongong, reuse of a substantial proportion of the effluent and disposal of the waste through an extended ocean outfall

(b) the upgrade of existing wastewater treatment facilities at Shellharbour and disposal of the waste through an upgraded ocean outfall.

An inter-disciplinary marine monitoring program was designed and executed (between 2002 and 2008) with the aim of quantifying impacts on the marine environment resulting from these changes. The results from these studies may be used to infer potential changes as a result of the WDURA developments. Further, these studies provide a background against which future investigations can be compared.

The following paragraphs summarise the main results from that program, the details of which can be found in Harper (2008).

Toxicity results remained well within the 2% limit imposed by PRP 004 (Tate and Pera, 2008) and the threshold for Toxic Identification and Evaluation (TIE) together with improved results in the post-commissioning period. Also observed were significantly decreased loads of most contaminants in the wastewater indicating that effluent discharged from the upgraded wastewater systems pose a reduced risk to marine biota. The re-use program with Blue Scope Steel has resulted in a net reduction in dry weather wastewater flows from the Wollongong WRP to the ocean from approximately 50 ML/day of primary and secondary treated wastewater to near shore outfalls prior to commissioning to approximately 30 ML/day of tertiary treated wastewater. Wastewater quality and toxicity were variable throughout the post-commissioning monitoring period, particularly during the first twelve months of operation. However both were well within acceptable limits and had shown improvement compared with results from the pre-commissioning period.

There were significant reductions in the concentrations of bacterial indicators at beach bathing locations, reducing the human health risks associated with recreation at beaches near each outfall. One exception was Port Kembla Beach, which experienced episodic spikes in bacterial indicator concentrations to levels above those observed in the baseline period. An investigation indicated that wastewater discharges from wastewater infrastructure may have been occurring at the northern end of Port Kembla Beach. Remedial works effectively resolved this problem. All previously impacted beaches now have concentrations of bacterial indicators similar to those of reference sites under dry-weather conditions.

Results from the Beachwatch monitoring program indicated that beach bathing waters located near the Wollongong WRP and the Shellharbour WWTP complied with the median faecal coliform and enterococci and maximum faecal coliform primary contact recreational guidelines (ANZECC 2000) on 100 % of occasions since commencement of operations. The maximum enterococci guideline was exceeded on one sampling occasion, which occurred after several days of coastal rainfall in the Wollongong area.

Marine water quality improved markedly at all previously impacted locations. A slight deterioration (as expected) in water quality was measured at the new Wollongong outfall as a result of the new wastewater discharges. No statistically significant differences could be detected at the Bellambi and Port Kembla discharge locations – concentrations of a range of indicator bacteria and nutrients at these locations were consistent with levels observed at reference locations. Results from the Optimum Multi-Parameter analysis indicated that water quality inside Port Kembla Harbour was largely governed by discharges from Allans and Tom Thumb Creeks. The results gave no suggestion that discharges from the Wollongong extended ocean outfall were influencing water quality at the entrance to (or inside) Port Kembla Harbour.

Outfall dilution studies validated the numerical models with no statistically significant difference between the results of the numerical model and the outfall dilution studies. Numerical modelling scenarios found that predicted wastewater dilutions are higher than originally expected in the far field and that ANZECC (2000) guidelines are being met at the boundary of the initial mixing zone.

Intertidal studies demonstrated improved ecosystem health at Bellambi and Port Kembla in the first 12 months of operation with recovery evident at both locations. Wet-weather impacts on intertidal rocky foreshores were found to be largely due to urban run-off rather than wet-weather discharges from the new Bellambi and Port Kembla WWTPs (Harper, 2008). Recovery at all locations was evident within one month after each wet-weather event.

No significant impacts were detected at the subtidal rocky reef marine communities near both the new Wollongong outfall and the Shellharbour outfall with conditions at these locations remaining close to those observed at respective reference locations.

The soft substrate community composition at the new Wollongong outfall was found to be within the range of natural variability observed at reference locations indicating that no significant impact had occurred due to operation of the new outfall.

The initial video survey of the outfall pipeline following construction showed few fish adjacent to the concrete structures supporting the pipeline and that they were void of any marine growth. However, within 12 months, the pipeline had extensive growth of sponges, corals and other marine plant life with large numbers of fish in the immediate vicinity of the pipeline.

The orientation of the Wollongong outfall was changed to avoid habitats that are occupied by Weedy Seadragons. Habitats near to the outfall (and at reference locations) were surveyed using video footage. Weedy Seadragons were observed both before and after commissioning in highly variable numbers. Their presence after commissioning of the Wollongong outfall indicates no significant change in their distribution has occurred.

4.2 Deposition and Visual Amenity

The high level of treatment at both Wollongong and Shellharbour effectively eliminates the discharge of particulate matter and hence the discharge of contaminants that can settle or substances that can result in aesthetic impacts. Similarly, the modelling results indicate that the concentrations of nutrients are well below the ANZECC (2000) guidelines, hence the likelihood of excessive growth of nuisance species is small.

Common among most environmental guidelines is the assertion that aesthetics are subjective and difficult to quantify. Therefore many organisations do not present numeric guideline values for aesthetics. Odour issues can be assessed via complaints received, noting that the discharge location is remote from most users of the marine environment and any potentially objectionable odours may not be detected. Similarly, ocean colour is subjective and may differ at different times of the year, as a result of storm events or under cloud cover. Here, potential aesthetic and colour issues are addressed using turbidity and concentrations of suspended solids and results compared with available water quality guidelines. It is assumed that, if the water quality guidelines are met, there will be no colour or aesthetic issues.

Both the Wollongong WRP and the Shellharbour WWTP treat the wastewater to a very high level: tertiary plus disinfection and secondary plus disinfection, respectively. One result is the discharge of suspended solids at very low concentrations. On average, suspended solids concentrations (measured every four days between July 2007 and June 2010) have 50%ile values of 2 mg/L and 5 mg/L for Wollongong and Shellharbour, respectively. The corresponding 99%ile values are 17 mg/L and 25 mg/L. The ANZECC (2000) water quality guideline for suspended solids is 10 mg/L for aquaculture and 3 mg/L for marine waters (based on 3 mg/L of suspended solids is equivalent to a turbidity of approximately 1 NTU e.g. Packman et al, 1999[7]). At the edge of the initial mixing zones, both of these guidelines are met, even for the maximum observed concentrations in the wastewater.

Concentrations of oil and grease (collected at least monthly between July 2007 and June 2010) were less than 5 mg/L for both wastewater treatment plants. The limit of reading for oil and grease is also 5 mg/L. The only ANZECC (2000) guideline available for oil and grease is for tainting of fish flesh and is 15 mg/L, well above the observed data.

Excessive growth of nuisance species (e.g. algal blooms) is more likely to occur in the presence of high concentrations of nutrients, which stimulate primary production. Other factors also affect the likelihood of producing algal blooms and include water temperature and turbulence. Nutrients from depth may move into shallower layers where light is more readily available, stimulating photosynthesis and the potential for excessive growth of marine phytoplankton. This is a natural process known as oceanic upwelling. The modelling scenarios indicate that the concentrations of nutrients at the edge of the initial mixing zone will always be below relevant ANZECC (2000) default trigger values. It is assumed that, if these concentrations remain at the predicted levels, then the likelihood of algal blooms caused by discharges from the outfalls is much less than the likelihood of algal blooms from natural mechanisms.

4.3 Summary of Aquatic Environmental Values

The aquatic environmental values for the Illawarra can be summarised by the Marine Water Quality Objectives (WQOs) for the South Coast of New South Wales (DEC, 2005). These objectives are presented below with a demonstration of how the proposed development meets each WQO.

4.3.1 Aquatic ecosystem health

Objective: To maintain or improve the ecological condition of ocean waters.

[7] It is noted that this relationship is uncertain and appears site-specific. Various authors suggest 1 NTU lies in the range 0.5 to 3 mg/L of suspended solids. A conservative option is adopted here.

Guidelines:

Biological

- Frequency of algal blooms – no change from natural conditions.
- Bioaccumulation of contaminants – no change from natural conditions.

Algal blooms have occurred in the Illawarra region in the past and will occur again in the future. Dela-Cruz et al (2002) and Pritchard et al (2003) both concluded that major algal blooms between Port Stephens and Jervis Bay were more likely to result from natural processes such as oceanic upwelling than from point source discharges. As late as 26 October 2010, Shellharbour Beach was closed due to a “red slick” believed to be an algal bloom (Illawarra Mercury, 27 October 2010). While the cause of the slick has not been confirmed, a spokesperson for Shellharbour Council suggested this was the result of an oceanic upwelling event.

Contaminants measured in the wastewater are either below the limit of reading or below the relevant guideline at the edge of the initial mixing zone, hence the discharge of bioavailable substances and the opportunity for bioaccumulation is much reduced. Further, there are multiple potential sources of contaminants and it is difficult to accurately determine from where biota may accumulate any contaminants.

Physico-chemical

- Nutrients
  - total nitrogen < 120 µg/L
  - total phosphorus < 25 µg/L
- Turbidity 0.5-10 NTU

Concentrations of total nitrogen and total phosphorus at the edge of the initial mixing zones were shown to be well below the WQOs for all scenarios tested (Figure 8 and Figure 9 for total nitrogen and total phosphorus at Wollongong and Figure 13 and Figure 14 for total nitrogen and total phosphorus at Shellharbour). Turbidity is not measured in the wastewater (the ANZECC (2000) water guidelines state that “turbidity is not a very useful indicator in estuarine and marine waters”). However turbidity levels can be estimated using suspended solids – with turbidity (NTU) being approximately one-third of suspended solids (mg/L). The largest modelled concentration of suspended solids at the edge of the initial mixing zone was 0.1 mg/L, which translates to (approximately) 0.03 NTU, well below the WQO of 0.5-10 NTU.

Toxicants in coastal waters

- Metals
  - copper < 1.3 µg/L
  - lead < 4.4 µg/L
  - zinc < 15 µg/L
- Pesticides
  - chlorpyrifos < 0.009 µg/L

The modelled maximum concentrations of copper and zinc at the edge of the Wollongong initial mixing zone are both 0.2 µg/L, well below the respective WQOs. Data for lead and chlorpyrifos were below their limits of reading (10 and 0.05 µg/L, respectively). Applying the smallest (most conservative) observed dilution to these limits results in the concentrations of all of these toxicants being at least one order of magnitude below the guideline at the edge of the initial mixing zone.

At Shellharbour no monitoring is undertaken for lead, zinc and chlorpyrifos. Concentrations of copper at the edge of the initial mixing zone are at least two orders of magnitude less than the WQO for copper, above.

Toxicants in bottom sediments

- Metals
  - copper < 65 mg/kg dry weight
  - lead < 50 mg/kg dry weight
  - zinc < 200 mg/kg dry weight
  - mercury < 0.15 mg/kg dry weight
- Organochlorines
  - chlordanes < 0.5 µg/kg dry weight
  - total PCBs < 23 µg/kg dry weight

No assessment of toxicants in the bottom sediments has been made. However, the high level of treatment at the Wollongong WRP and the Shellharbour WWTP effectively prevents the discharge to the environment of particulate material that will settle in the marine sediments. Therefore, it is extremely unlikely that toxicants (attached to particulate matter) discharged as part of the WDURA and AGA development will finally end up in the sediments.

Whole-of-effluent toxicity testing will identify toxic responses of test organisms to toxicants in the wastewater. This includes toxicants for which no specific monitoring is undertaken.

4.3.2 Primary contact recreation

Objective: To maintain or improve ocean water quality so that it is suitable for activities such as swimming and other direct water contact sports.

Guidelines:

Biological

- Median over bathing season of less than 150 faecal coliforms / 100 mL, with 4 out of 5 samples < 600 /100mL (minimum of 5 samples taken at regular intervals not exceeding one month.
- Median over bathing season of less than 35 enterococci / 100 mL; (maximum number in any one sample: 100 organisms/100mL).

Model results presented in Figure 10 and Figure 11 (Wollongong) and Figure 15 and Figure 16 (Shellharbour) show that, even for the 2048 scenarios, the concentration of the indicator bacteria are well below the WQO guidelines at the edge of the initial mixing zones.

Physico-chemical

- Visual clarity. A 200 mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 m (approximately 6 NTU).

The worst-case suspended solids concentrations resulting from the modelling indicate a maximum concentration of 0.1 mg/L at the edge of the initial mixing zone. As a first approximation, turbidity (in NTU) is three times the suspended solids concentration (in mg/L). Therefore, the maximum turbidity resulting from the WDURA and AGA development at the edge of the initial mixing zone is approximately 0.3 NTU, an order of magnitude less than the WQO of (approximately) 6 NTU.

4.3.3 Secondary contact recreation

Objective: To maintain or improve ocean water quality so that it is suitable for activities such as boating and fishing where there is less bodily contact with the waters.

Guidelines:

Biological

- Median bacterial content in marine waters of < 1,000 faecal coliforms /100 mL, with 4 out of 5 samples < 4,000 /100mL (minimum of 5 samples taken at regular intervals not exceeding one month.
- Median bacterial content in marine waters of < 230 enterococci /100 mL (maximum number in any one sample: 450-700 organisms /100mL).

The modelling results demonstrated that the WQO for primary contact recreation will be met at the edge of the initial mixing zone for all scenarios tested. By definition, if the primary contact recreation guidelines are met, then so too will be the secondary contact recreation guidelines.

4.3.4 Visual amenity

Objective: To maintain or improve ocean water quality so that it looks clean and is free of surface films and debris.

Guidelines:

Surface films and debris

Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.

As noted in Section 4.2, aesthetics and visual amenity are subjective and difficult to quantify. Natural processes such as storm events will stir the bottom sediments reducing the water clarity. The high level of wastewater treatment will effectively eliminate the outfall as a source of floating debris and litter. Oil and grease levels in the wastewater measured between July 2007 and June 2010 were below the limit of reading, eliminating (or at least substantially reducing) their likelihood causing visual or odour issues.

Concentrations of suspended solids at both wastewater treatment plants are very low – resulting from the high level of treatment. At the edge of the initial mixing zones, the concentrations of suspended solids are much less than the guidelines. This suggests that the clarity of the water is high.

Nuisance organisms

Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae and wastewater fungus should not be present in unsightly amounts.

Concentrations of nutrients at the edge of the initial mixing zones are well below the respective guidelines reducing the potential for excessive growth of nuisance organisms.

4.3.5 Aquatic foods

Objective: To maintain or improve ocean water quality for the production of aquatic foods for human consumption (whether derived from aquaculture or recreational, commercial or indigenous fishing).

Guidelines:

Biological (as applied to the consumption of aquatic foods)

- The median faecal coliform concentration should not exceed 14 MPN / 100mL, with no more than 10% of the samples exceeding 43 MPN / 100mL.
- Fish destined for human consumption should not exceed a limit of 2.3 *E. coli* / g of flesh with a standard plate count of 100,000 organisms / g.

Median faecal coliform concentrations at the edge of the initial mixing zones were modelled to be less than unity, hence the most probable number (MPN) of these organisms will similarly be less than unity and hence meet this guideline.

Sydney Water does not undertake monitoring of *E. coli* in fish tissue. However, given the very low predicted concentrations of faecal coliforms in the receiving waters, it is very likely that this guideline will be met.

Toxicants (as applied to the consumption of aquatic foods)

- Metals
  - copper < 5 µg/L
  - zinc < 5 µg/L
  - mercury < 1 µg/L
- Organochlorines
  - chlordane < 0.004 µg/L
  - PCBs < 2 µg/L

The modelled maximum concentrations of copper and zinc at the edge of the Wollongong initial mixing zone are both 0.2 µg/L. Data for mercury, chlordane and PCBs were all below the limit of reading (0.1, 0.01 and 0.1 µg/L, respectively). Applying the smallest modelled dilution (420:1) to these limits results in the concentrations of all of these toxicants being at least two orders of magnitude below the guideline at the edge of the initial mixing zone.

At Shellharbour the minimum modelled dilution was 747:1. The maximum concentration of copper in the wastewater was 15 µg/L. Therefore the maximum, modelled concentration of copper at the edge of the initial mixing zone was 0.02 µg/L well below the guideline above.

Physico-chemical (as applied to the consumption of aquatic foods)

- Suspended solids: < 5 µg/L
- Temperature: < 2^{o}C change over one hour

The median, modelled concentration of suspended solids at the edge of the initial mixing zone was 3 µg/L for both Wollongong and Shellharbour. Both lie below the WQO for all scenarios.

Hourly (or less) temperature data from the Wollongong WRP and the Shellharbour WWTP are not available. However, an analysis indicates that, for the minimum observed dilution of 420:1 of all model scenarios, the temperature of the wastewater would need to be in excess of 1,000^{o}C to exceed this criterion at the edge of the initial mixing zone. Clearly, this temperature for wastewater is unrealistic.

4.4 Summary of Human Health Impacts

Below is a brief description of the bacterial field data collected since 2007, demonstrating compliance with the ANZECC (2000) and NHMRC (2008) guidelines. The information provided here should be read in conjunction with the modelling results for the indicator bacteria (Sections 3.1 and 3.2) and the aquatic environmental values (Sections 4.3.2, 4.3.3 and 4.3.5.

Beachwatch undertakes daily monitoring of the beaches in the Illawarra region. For each of the three years 2007-08, 2008-09 and 2009-10 the beaches on either side of the outfalls (Coniston and Fishermans Beaches for the Wollongong outfall and Warilla and Shellharbour Beaches for the Shellharbour outfall) all showed 100% compliance with the NHMRC (2008) water quality guidelines for enterococci.

The water quality component of the IWWS examined, in part, concentrations of indicator bacteria in the marine waters and beaches in the Illawarra region (Harper, 2008). At the site of the new Wollongong outfall (after its commissioning) the median concentration of both faecal coliforms and enterococci was <1 cfu/100mL. The 95%ile value for enterococci was 2 cfu/100mL, while the maximum observed concentration for enterococci was 11 cfu/100mL. These results were based on 56 readings collected over a 14-month period. Similarly, near the Shellharbour outfall, the median values concentration of both faecal coliforms and enterococci was <1 cfu/100mL, the 95%ile value and the maximum observed concentration were 2 and 14 cfu/100mL for both indicators. These values are well below the respective guidelines for primary contact recreation.

Likewise, the model results from this study indicate concentrations of both indicator bacteria lie well below the ANZECC (2000) and NHMRC (2008) guidelines at the edge of the respective initial mixing zones. As observed in the IWWS data, the model predicted median concentrations of faecal coliforms and enterococci both <1 cfu/100mL. The 95%ile and maximum predicted values for enterococci at the edge of the initial mixing zones for both outfalls are both <1 cfu/100mL. These results are consistent with the observations.

Therefore, even under the worst-case scenario (i.e. 2048), the indicator bacteria always lie well under their respective guidelines.

4.5 Toxicity Testing

Summarised in this section are the results of the toxicity testing programs undertaken at the Wollongong WRP and the Shellharbour WWTP using wastewater samples collected between July 2007 and June 2010. The modelling predicts dilutions at the edge of the initial mixing zone of at least 500:1 (equivalent to wastewater concentrations of 0.2%). Toxicity testing indicated a toxic response (EC50 value) only when wastewater concentrations exceed 1%. Therefore, a toxic response beyond the initial mixing zone is very unlikely to occur.

A suite of toxicity tests was performed with the Wollongong wastewater as part of the IWWS and included test organisms from the phyla: echinodermata, mollusca, arthropoda and bacillariophyta. Generally, this component of work required that the acute and chronic toxicities be calculated for all phyla to determine the potential impact of contaminants being discharged to the marine environment.

Toxicity results for the Wollongong wastewater were highly variable over time and among the different organisms tested. All samples showed toxicity at some concentration of wastewater. However, none of the bioassays conducted with the range of test organisms (on any sampling occasion) returned median effect (EC50) concentrations of <2% wastewater concentration – the critical level for the study. The minimum modelled dilution at the edge of the Wollongong initial mixing zone was 420:1, well in excess of the 50:1 dilution associated with 2% wastewater concentration. This minimum modelled dilution represents a 10-fold safety margin. A Toxicity Identification and Evaluation (TIE) procedure isolated ammonia as the likely substance that caused the observed toxicity.

Monthly toxicity testing is carried out in the Shellharbour wastewater only. The test used is the "1-hour sea urchin fertilisation test". Data between July 2007 and June 2010 indicated only one sample showed an EC50 value of <2%. This occurred on 8 September 2009 at 1% wastewater concentration. This is equivalent to a dilution of 100:1. The minimum dilution at the edge of the Shellharbour initial mixing zone resulting from the modelling exceeded 750:1 (for the 2048 scenario), well above the maximum dilution at which toxicity was observed.

Therefore, based on the toxicity results obtained thus far and the numerical modelling performed for this study, the wastewater concentrations at the edge of the respective initial mixing zones will be less than 0.2%. This value is at least one order of magnitude lower that the critical concentration (2%) for toxicity in the wastewater. This applies under the 2048 worst-case scenario.

Further, as described in Section 4.6, substances that may induce toxicity are either below the limit of reading or below the respective ANZECC (2000) water quality guideline for protection of 99% of marine species (the most restrictive ANZECC guideline). Again, this applies under the 2048 worst-case scenario.

There are no planned changes to the constituents in the wastewater and the existing toxicity testing program will be appropriate to future wastewaters.

4.6 Bioaccumulation

Substances that bioaccumulate are usually lipophilic (for organics) or attached to particulate matter (for metals). The high level of treatment at both the Wollongong WRP and at the Shellharbour WWTP effectively eliminates the discharge of particulate matter and hence the discharge of substances that can bioaccumulate.

It is generally accepted that contaminants are adsorbed onto the surface of particulate matter. Biota in the receiving waters feed on microorganisms that are attached to the particles. There is a potential for biota to also ingest contaminants that are attached to the particles and for accumulation of these contaminants to other levels within the food web.

As noted above, both the Wollongong WRP and the Shellharbour WWTP treat the wastewater to very high levels. This includes the removal of particulate matter from the wastewater. Between July 2007 and June 2010 the concentration of total suspended solids (measured on average, every 4 days) in the Wollongong and Shellharbour wastewaters were (50%ile values) 2 mg/L and 5 mg/L and (99%ile values) 17 mg/L and 25 mg/L, respectively. When dilutions at the edge of the initial mixing zones are applied these concentrations are much less than 1 mg/L, which, in turn, is much less than the most restrictive ANZECC (2000) guideline (<10 mg/L for the protection of aquaculture species). Further, the concentrations of many contaminants in the wastewater are below the limit of reading.

As also observed from Table 5 and Table 6 the concentrations of metals at the edge of the respective initial mixing zones were below the ANZECC (2000) water quality guideline for the protection of 99% of marine species. These metals are known to occur naturally in the marine environment and the accurate separation of contributions from the wastewater, other anthropogenic sources and natural sources is very difficult to achieve.

This high level of wastewater treatment and lack of detection of many substances in the wastewater effectively removes (or at least substantially reduces) the pathway for the entry to the marine environment of substances that can bioaccumulate. Therefore, at the present level of wastewater treatment, the potential for bioaccumulation of substances is very small.

4.7 Environmental Monitoring

The extensive field programs carried out as part of the IWWS indicate very little statistically significant change as a result of the upgrades to the Wollongong and Shellharbour wastewater systems. The numerical modelling carried out as part of this study indicates only small incremental changes in the water quality.

A field based monitoring program is not recommended because.

- such small changes will be difficult to quantify in field programs with, in many cases, the magnitude of the change lying within levels of natural variation
- one would question whether the sizes of such small changes are meaningful
- due to the high level of wastewater treatment, many substances (particularly those of a more harmful nature) have never been detected in the wastewater and hence, would not be detected in the field.

It is recommended that existing monitoring of contaminants in the wastewater be continued together with whole of wastewater toxicity testing.

5 Summary and Conclusions

Outlined in this report is an assessment of the potential impacts on the marine environment of discharges through the Wollongong and Shellharbour outfalls and some stormwater drains as a result of the proposed West Dapto Urban Release Area and Adjacent Growth Area development. The main objective of the work was to address the DGRs and assess the impacts of discharges to the marine environment. The focus lay on impacts to public health, water quality and marine aquatic ecology.

The assessment was undertaken using a combination of numerical modelling, analyses of the concentrations of contaminants in the existing wastewater and the results from recently conducted field surveys associated with the implementation of the Illawarra Waste Water Strategy. The commentary responds to the DGRs and associated comments by DECCW (now OEH).

The model was calibrated and successfully validated as part of the Illawarra Waste Water Strategy. Under normally operating, dry weather conditions numerical modelling predicts that the ANZECC (2000) default trigger values (for nutrients and indicator bacteria) and the NHMRC (2008) guidelines (for enterococci) will be met at the edge of the initial mixing zones. This applies to all scenarios examined.

When flow at Shellharbour exceeds 5xADWF, only partial treatment will be achieved. In such cases concentrations of total phosphorus may exceed the ANZECC (2000) guideline for, up to, a few days per year. For a one-in-one-year rainfall event, modelled total phosphorus concentrations exceeded the ANZECC (2000) by less than 20%. Wet weather discharge does not occur at Wollongong because the pump capacity limits the volume of flow that can be delivered to the WRP. Wet weather flow is discharged through the old Port Kembla outfall. On average, this for a total of 10 days per year. Little treatment occurs at Port Kembla, the outfall is inefficient and plume dilution is small. Therefore, a range of contaminants, including, indicator bacteria, nutrients, total suspended solids and a range of metals do not meet their relevant ANZECC (2000) guidelines. Similarly, discharges from stormwater drains into receiving waters or onto the sand will unlikely meet the ANZECC (2000) guidelines.

The surface area of initial mixing zones is the same at both outfalls, approximately 0.06 km^2, while the volume enclosed by the two initial mixing zones is in proportion to the volume of wastewater being discharged. However, the shape of the initial mixing zones differs at the two outfalls, in response to the different diffuser lengths and different water depths.

An analysis of background data indicates that, for a substantial proportion of the time, concentrations exceed the ANZECC (2000) default trigger values. The background data included surface nutrient data from the Port Hacking 50m reference station for the period 1960 to 2007 and local data obtained over two 12-month periods in 2003-04 and 2006-07. These two independent sets of background data show essentially the same features. Background concentrations of total nitrogen near both the Wollongong and Shellharbour outfalls lie well above the ANZECC (2000) default trigger level. This may suggest that ANZECC (2000) default trigger values for some guidelines are not appropriate to the Sydney and Wollongong regions.

Many contaminants that have been monitored in the wastewater always lay below the limit of reading. In many cases, the limit of reading was less than the ANZECC (2000) guideline. For the remaining cases, the concentration of contaminants at the edge of the initial mixing zone was substantially less than the respective guideline. Therefore, provided the present level of wastewater treatment is maintained, the potential for bioaccumulation is very small.

Toxicity testing of the wastewater resulted in only one EC50 value at an wastewater concentration of less than 2%. This occurred at Shellharbour at 1% wastewater concentration. This concentration corresponds to a dilution of 100:1. The minimum dilution at the edge of the Shellharbour initial mixing zone predicted by the models was approximately 750:1. Therefore, even the appearance of toxic effects at 1% wastewater concentration is unlikely to cause a toxic response outside the initial mixing zones.

The visual amenity is subjective and difficult to quantify. However, the high level of wastewater treatment results in the removal of most suspended solids and an wastewater that is clear in colour. Noting also that oil and grease concentrations in the wastewater were always below the limit of reading, the discharge is unlikely to cause visual or odour problems.

The concentrations of nutrients at the edge of the initial mixing zone lie well below the ANZECC (2000) default trigger values, hence the likelihood of excessive growth of nuisance organisms is small. Major algal blooms are more likely to occur as a result of oceanic upwelling.

The marine monitoring program for the Illawarra Waste Water Strategy could not quantify statistically significant changes to the marine communities (intertidal or subtidal) as a result of the commissioning of the new Wollongong outfall. This was a change from zero discharge to a discharge of 23 ML/day. Environmental effects resulting from the proposed incremental increase in flow of 19 ML/day (42 ML/day is predicted in 2048) is unlikely to be detected.

Results from the marine monitoring program for the Illawarra Waste Water Strategy failed to find any statistically significant marine ecological impacts resulting from discharges through the new Wollongong outfall or the upgraded Shellharbour outfall. The primary reason for this is the high level of wastewater treatment and efficient wastewater disposal methods in both systems. Therefore, a marine field-based environmental monitoring program is not recommended.

Recommended environmental monitoring includes continued monitoring of the wastewater and toxicity testing, as presently undertaken by EPLs 218 (for Wollongong) and 211 (for Shellharbour).

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Appendix 1 Glossary

Below are explanations of some of the technical terms used in this report.

ADWF	Acronym meaning Average Dry Weather Flow. The average flow of wastewater delivered to the WRP or WWTP in the absence of rainfall.
ARI	Average Recurrence Interval. The average time interval between events e.g. the average time between rainfall events that deliver at least 10 mm of rain within 24 hours.
Bootstrapping	A statistical technique that randomly selects values from a small sample to generate a large synthetic data set, which has similar statistical characteristics to that of the small sample.
Buoyant jet (also known as a forced plume)	Where the fluid being discharged has a different density to that of the receiving waters and the velocity of the fluid being discharged is greater than that of the receiving waters. In this study the discharged fluid is wastewater, which has a density close to that of fresh water and is approximately 2.5% less than that of the receiving waters.
CORJET	The near-field component of the CORMIX model.
CORMIX	A numerical model that estimates the trajectory and dilution of a buoyant jet in both the near-field and the far-field.
DECCW	NSW Government Department of Environment, Climate Change and Water. Formerly called the Environment Protection Authority (EPA), Department of Environment and Conservation (DEC) and, since March 2011, the Office of Environment and Heritage (OEH).
EC50	Organisms are exposed to increasing concentrations of (in this case) wastewater until there is no further response. This is the maximal effect. The EC50 is the point midway between the zero and maximal effects.
Emission factors	Emission factors are assumed concentrations of contaminants in wastewaters and are, generally, more conservative than observed data. In the absence of reliable data, emission factors may be used. Sydney Water has only limited data on the concentrations of contaminants in wet weather and hence uses the wet weather emission factors.
EP&A Act	Environmental Planning and Assessment Act. The main law regulating land use in NSW. Administered by the NSW Department of Planning. The Act provides for member of the public to participate in planning decisions that will shape their community's future.
Far-field zone	A zone, beyond the near-field, where the turbulence levels of the receiving waters govern the dispersion of the wastefield. For outfalls located in shallow waters (e.g. Shellharbour) a substantial amount of plume dilution occurs in the far-field zone.
FFLOCATR	The far-field component of the CORMIX model.

Initial dilution	The dilution of the wastewater plume as a result of turbulence generated (via the difference in energy, or buoyancy, between the plume and the receiving waters) by the relative movement of the wastewater plume through the receiving waters. The initial dilution zone is defined at the end of the near-field model.
IWWS	Acronym for Illawarra Waste Water Strategy. A strategy to improve the quality of receiving waters in the Illawarra region. A marine monitoring program was undertaken between 2003 and 2007 to quantify environmental change resulting from this strategy.
Lipophilic substances	Substances that are attracted to, combine with or dissolve in, fats or lipids. They do so more readily that they dissolve in water.
Mixing zone	The zone surrounding the outfall where the wastewater plume mixes with the receiving waters. The initial mixing zone may extend beyond the near-field model (initial dilution zone).
MPN	Acronym for Most Probable Number. Items such as food are heterogenous and it is not possible to determine a precise value for the concentration of microbial organisms. The technique involves liquefying a sample, dividing the sample and diluting each division. This process is replicated several times. The MPN is a function of the dilution and the number of positive results obtained.
Near-field mixing zone	A zone close to the outfall where strong initial mixing of the discharged fluid occurs as a result of the different densities and speeds between the discharged fluid and the receiving waters. For outfalls located in deeper waters (e.g. Wollongong) the majority of the plume dilution occurs in the near-field zone.
Receiving waters	The oceanic waters into which the wastewater is discharged.
Stratification (pycnocline)	Where there is a rapid change density difference between two layers of the receiving waters. In highly stratified waters the wastewater plume may remain submerged.
Wastefield	The wastewater plume after initial mixing processes have taken place.
WRP	Acronym for Water Recycling Plant, which applies to the facilities at Wollongong.
WWTP	Acronym for Waste Water Treatment Plant, which applies to the facilities at Shellharbour.
cfu/100mL	Colony forming units per 100 millilitres
mg/L	Milligrams per litre
ug/L or µg/L	Micrograms per litre

Appendix 2 Exceedance plots for the substances in Table 7

Below are exceedance plots for those substances that are detailed in Table 7. Only the modelled results for 2048 are provided. If conditions for 2048 meet the respective guidelines, then scenarios modelled for previous years (where wastewater flow and contaminant load will be lower) will also be met.

Some substances are not monitored at Shellharbour and are not presented here. Plots for chromium, oil and grease, diazinon and total PCBs are not shown. For these substances, all measured readings were below the limit of reading, which, in turn, was below the respective minimum (i.e. most restrictive) guideline. There are no ANZECC (2000) or Illawarra WQOs for nonphenol ethoxylates (monitored only at Shellharbour) hence these results are not plotted.

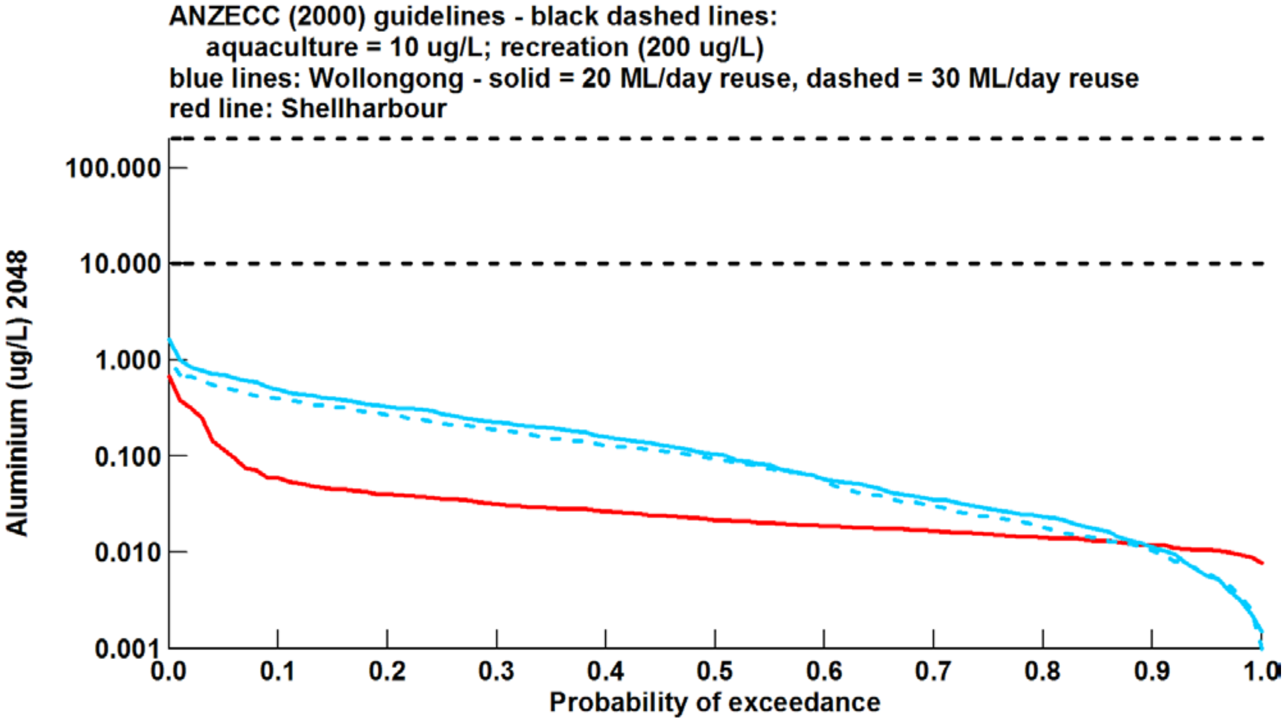

Figure 17. Modelled results for aluminium, 2048 scenario.

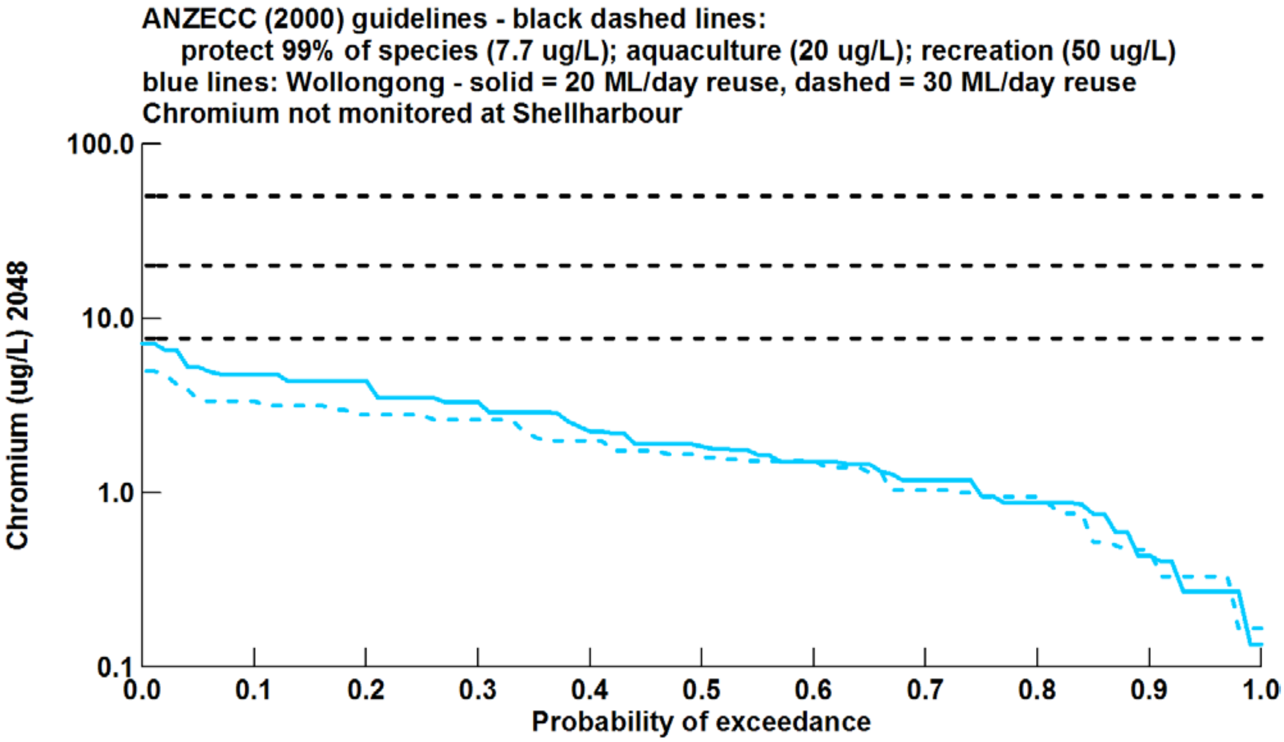

Figure 18. Modelled results for chromium, 2048 scenario.

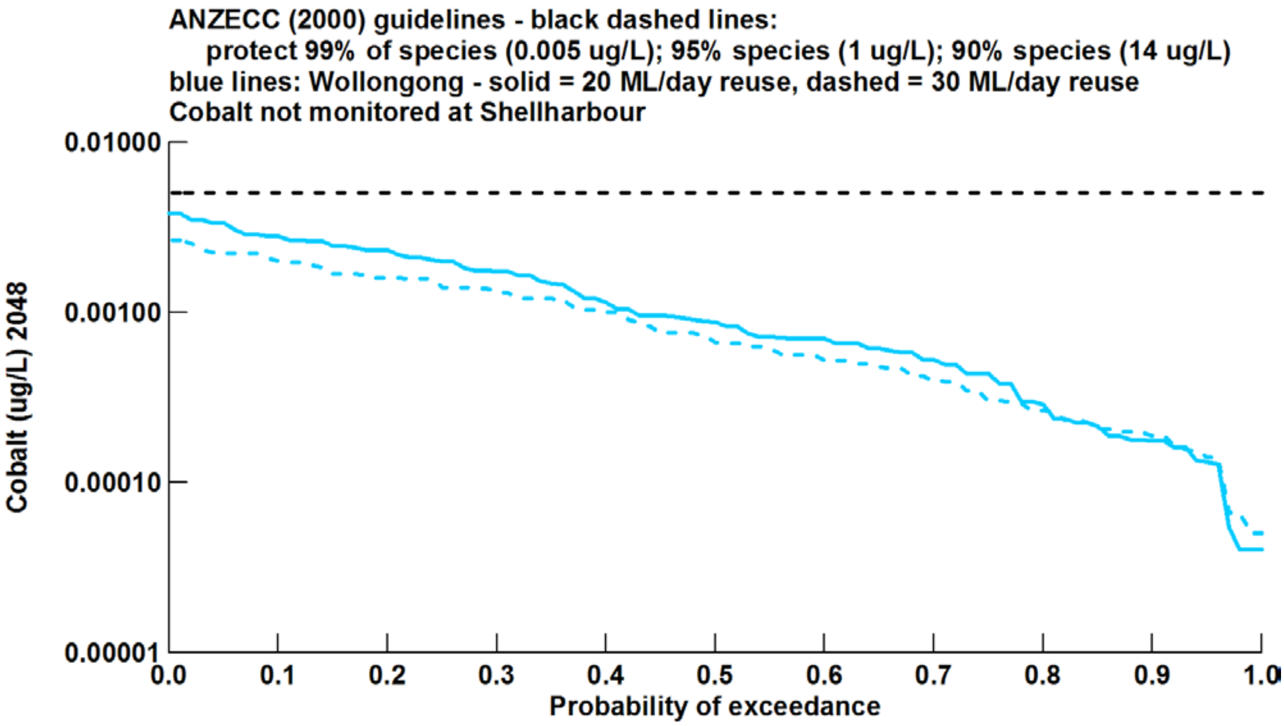

Figure 19. Modelled results for cobalt, 2048 scenario.

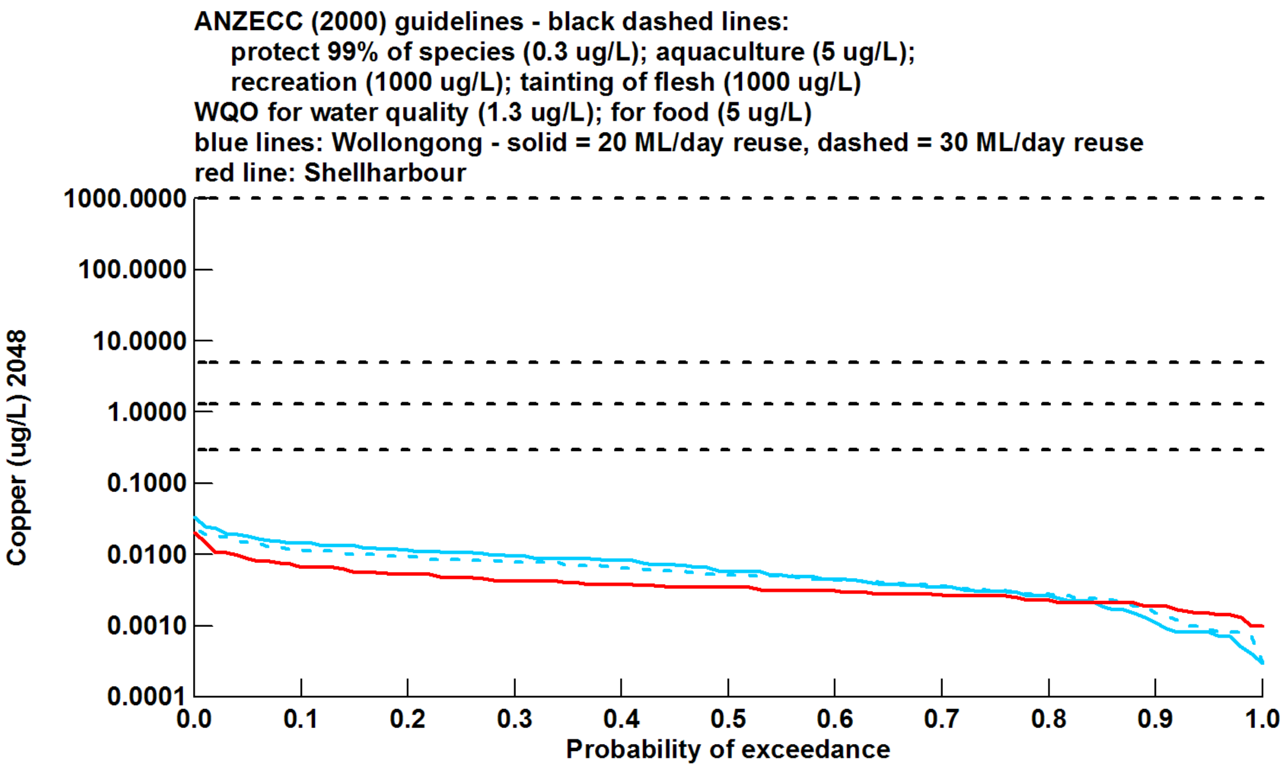

Figure 20. Modelled results for copper, 2048 scenario.

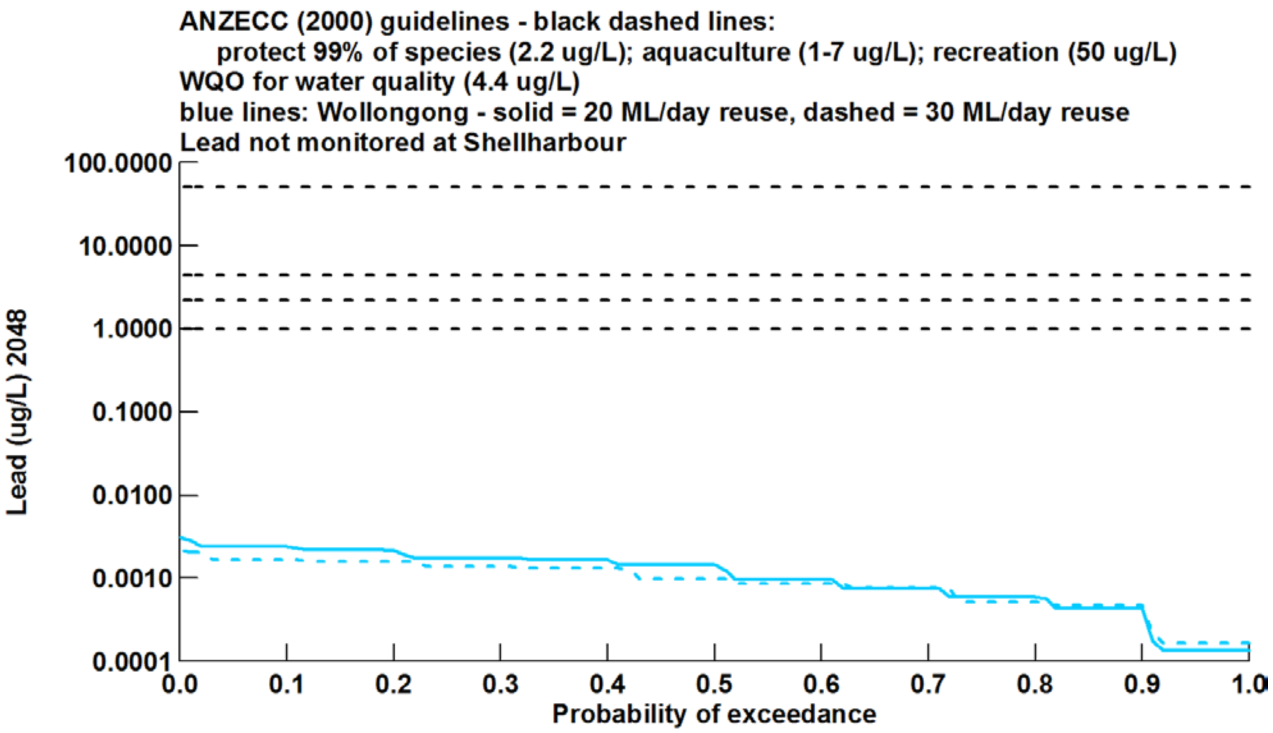

Figure 21. Modelled results for lead, 2048 scenario.

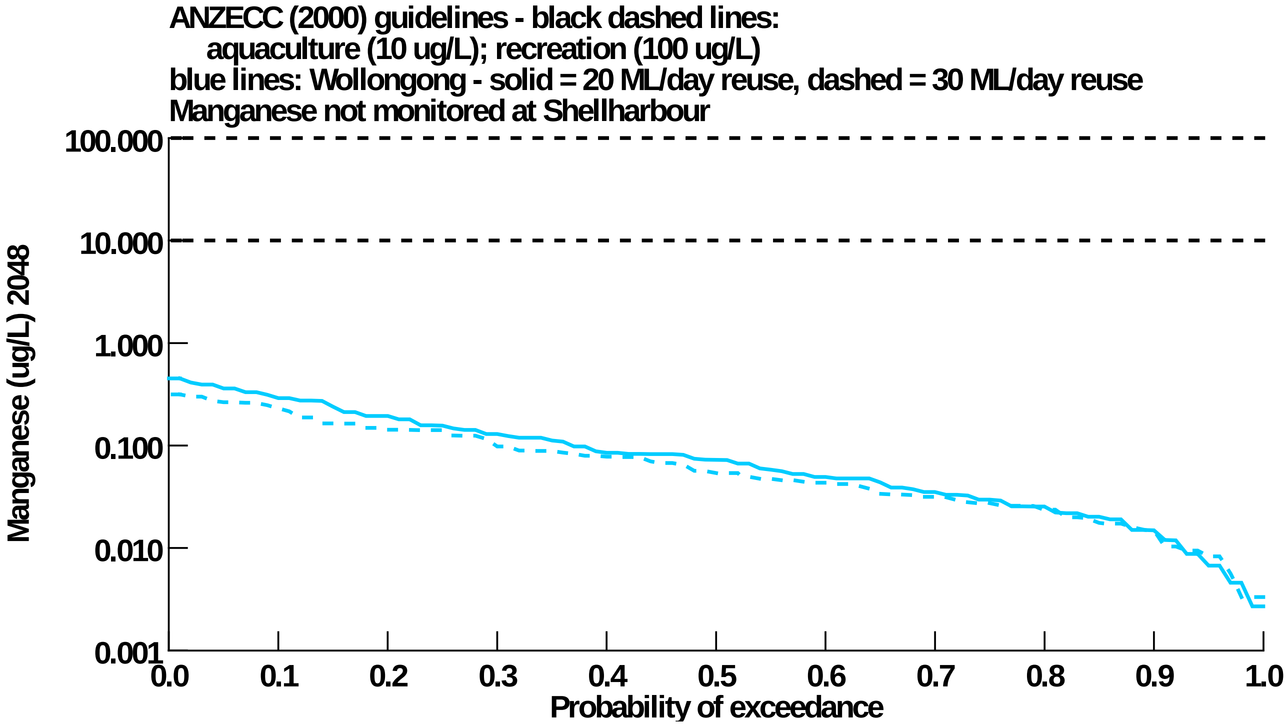

Figure 22. Modelled results for manganese, 2048 scenario.

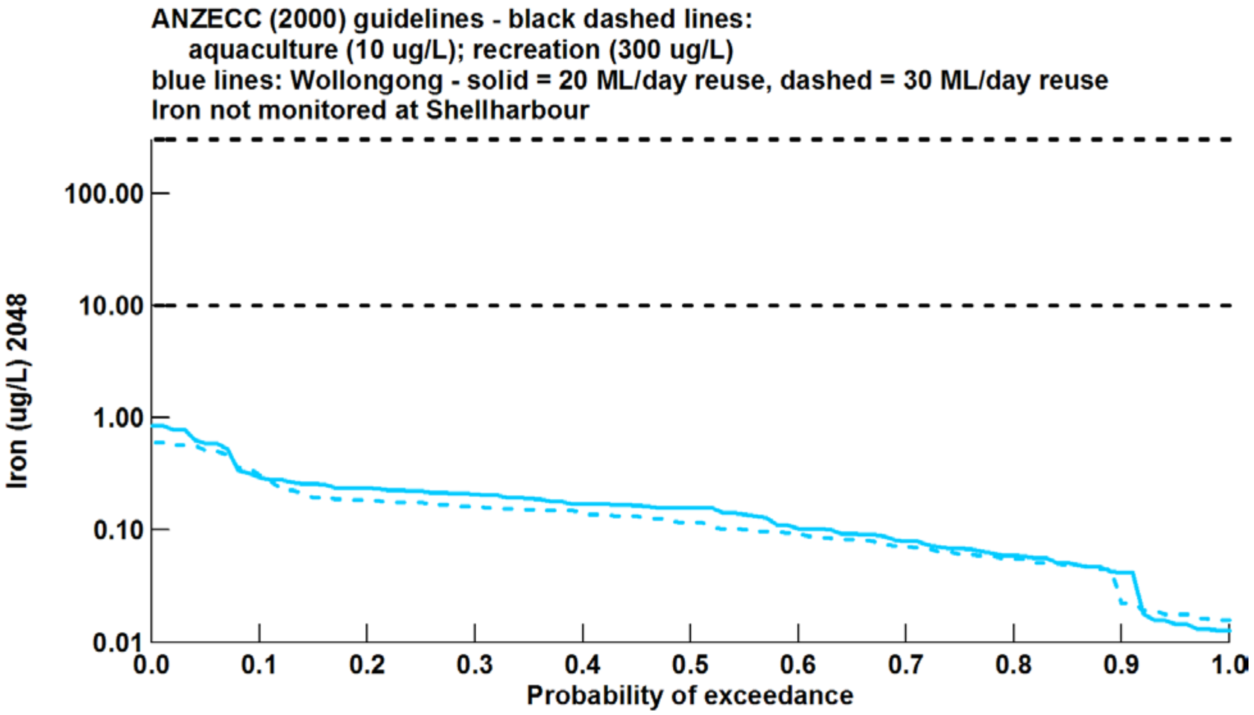

Figure 23. Modelled results for iron, 2048 scenario.

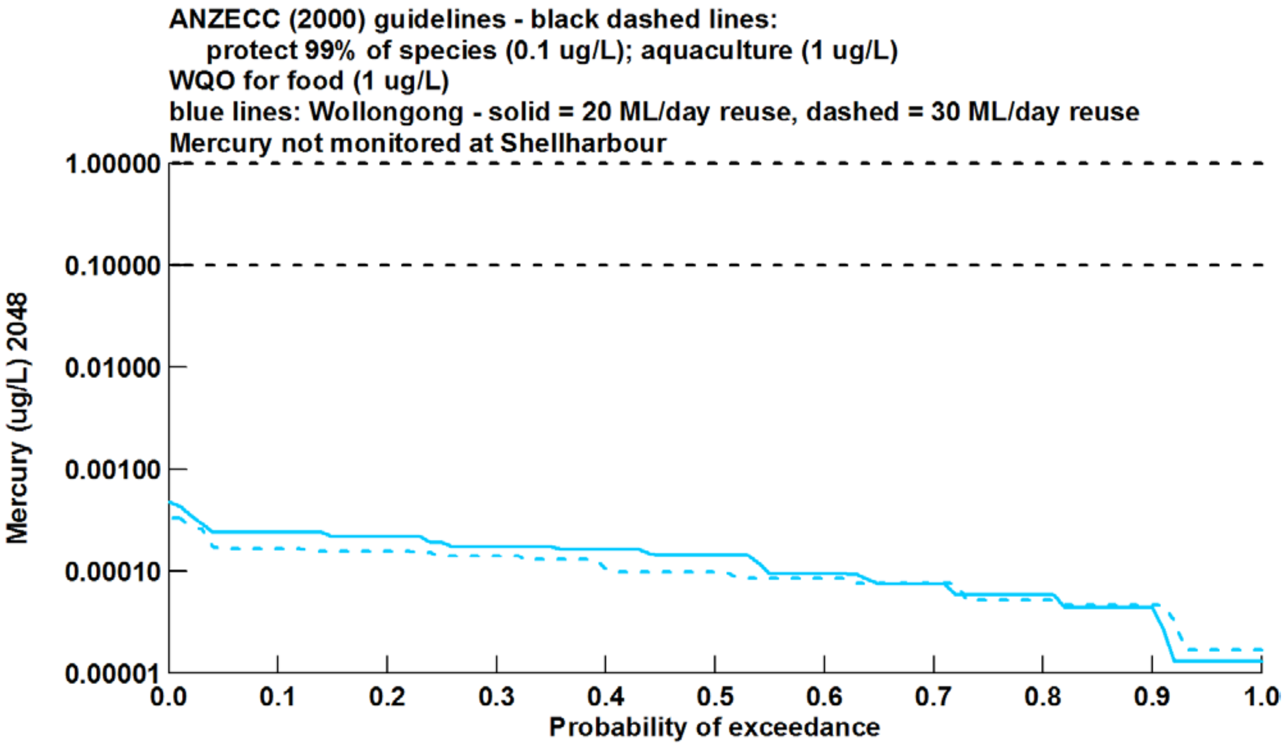

Figure 24. Modelled results for mercury, 2048 scenario.

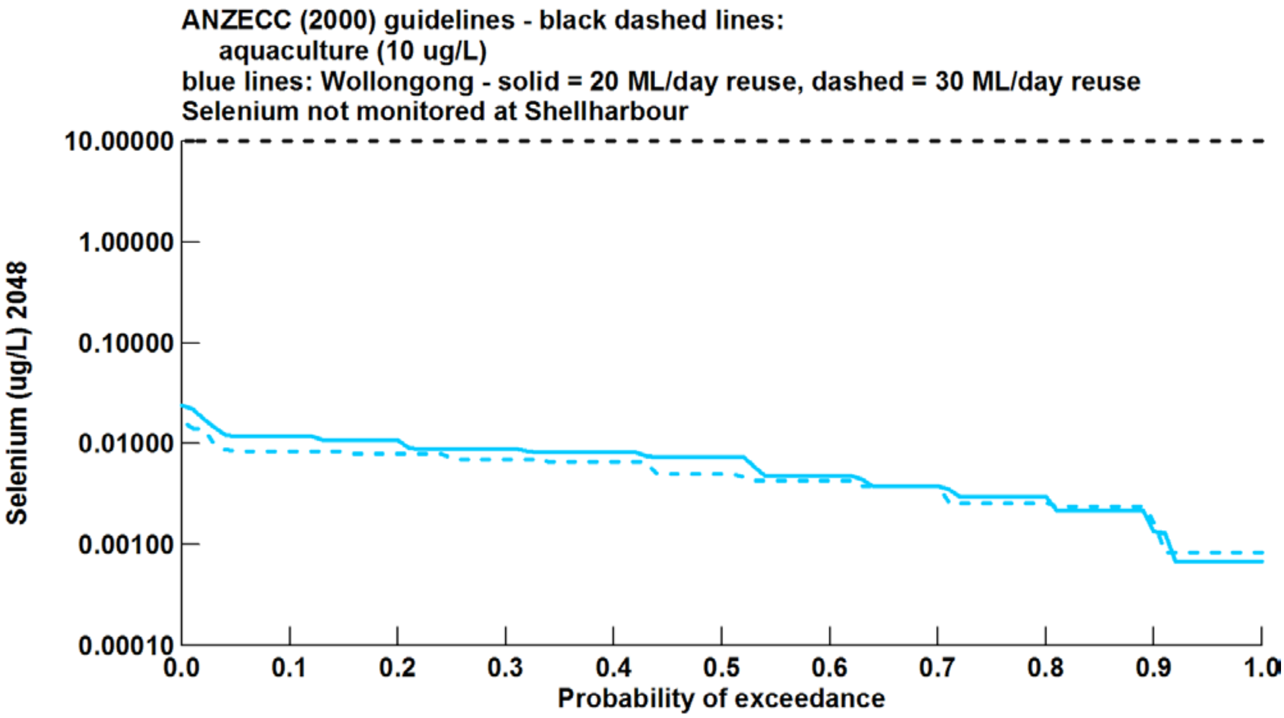

Figure 25. Modelled results for selenium, 2048 scenario.

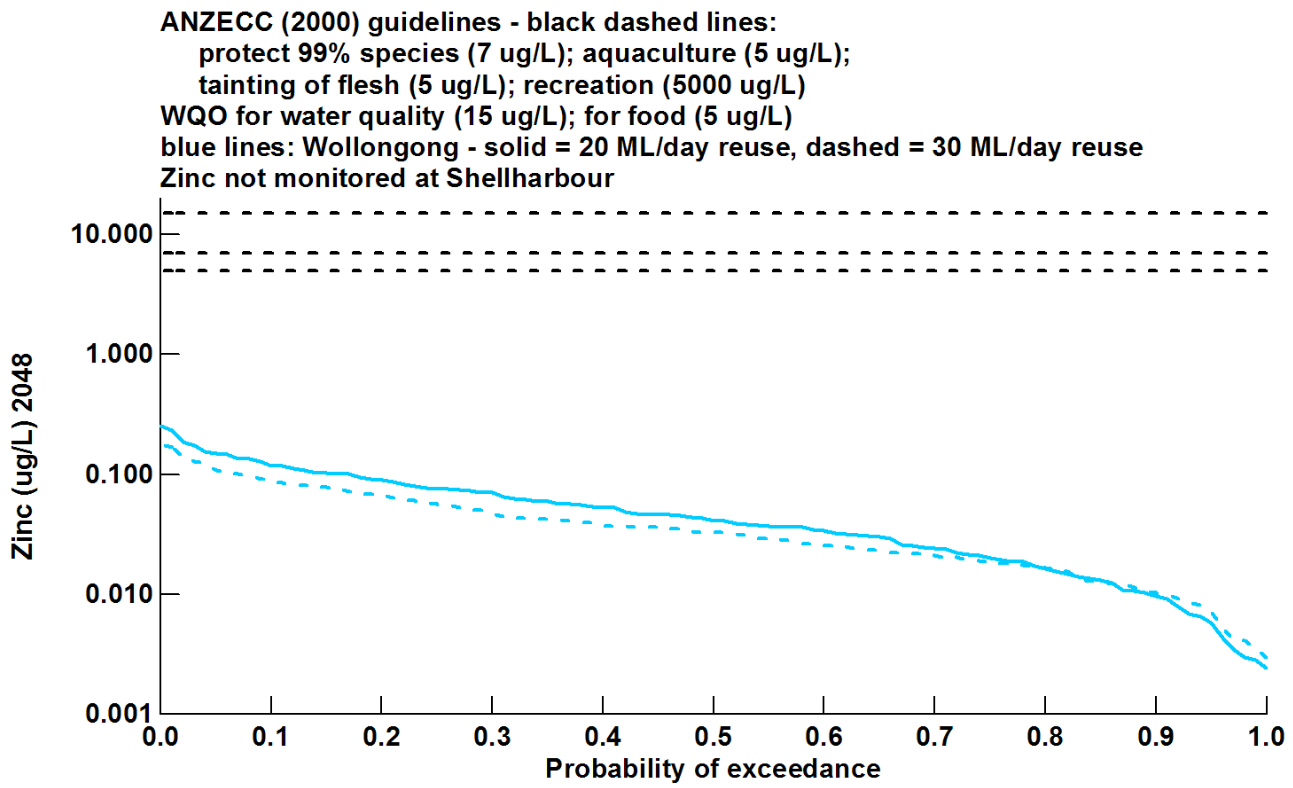

Figure 26. Modelled results for zinc, 2048 scenario.

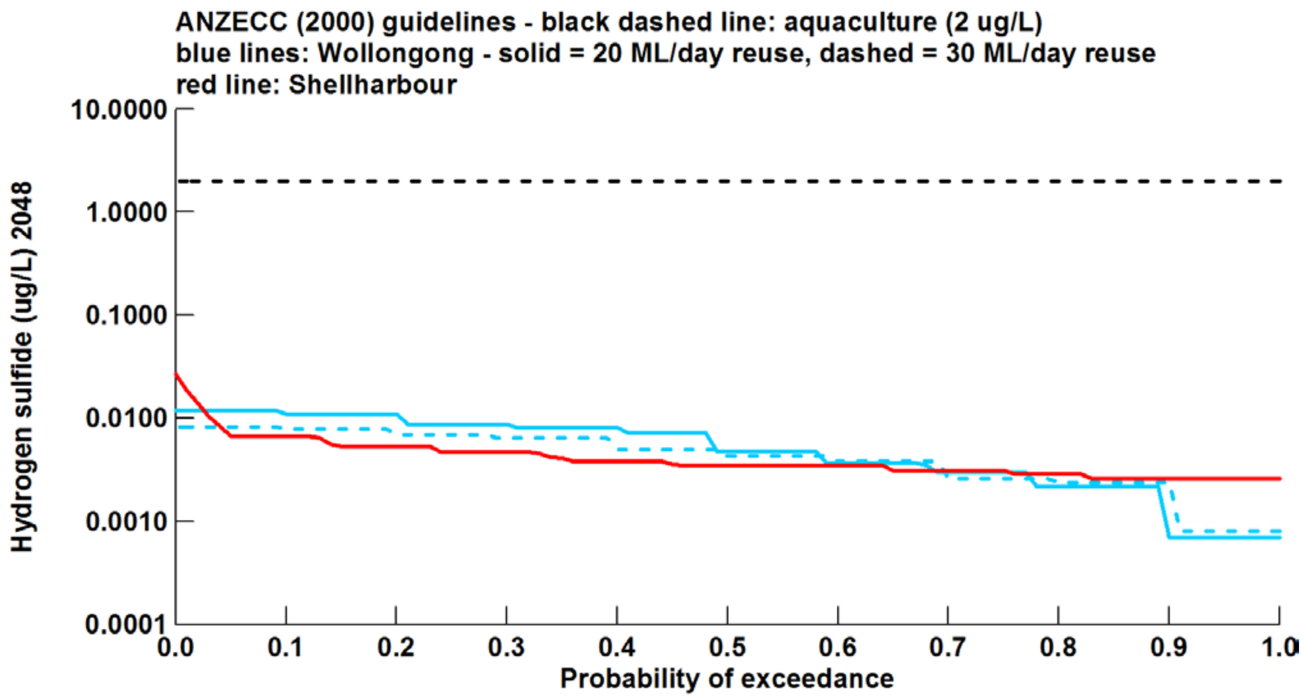

Figure 27. Modelled results for hydrogen sulphide, 2048 scenario.

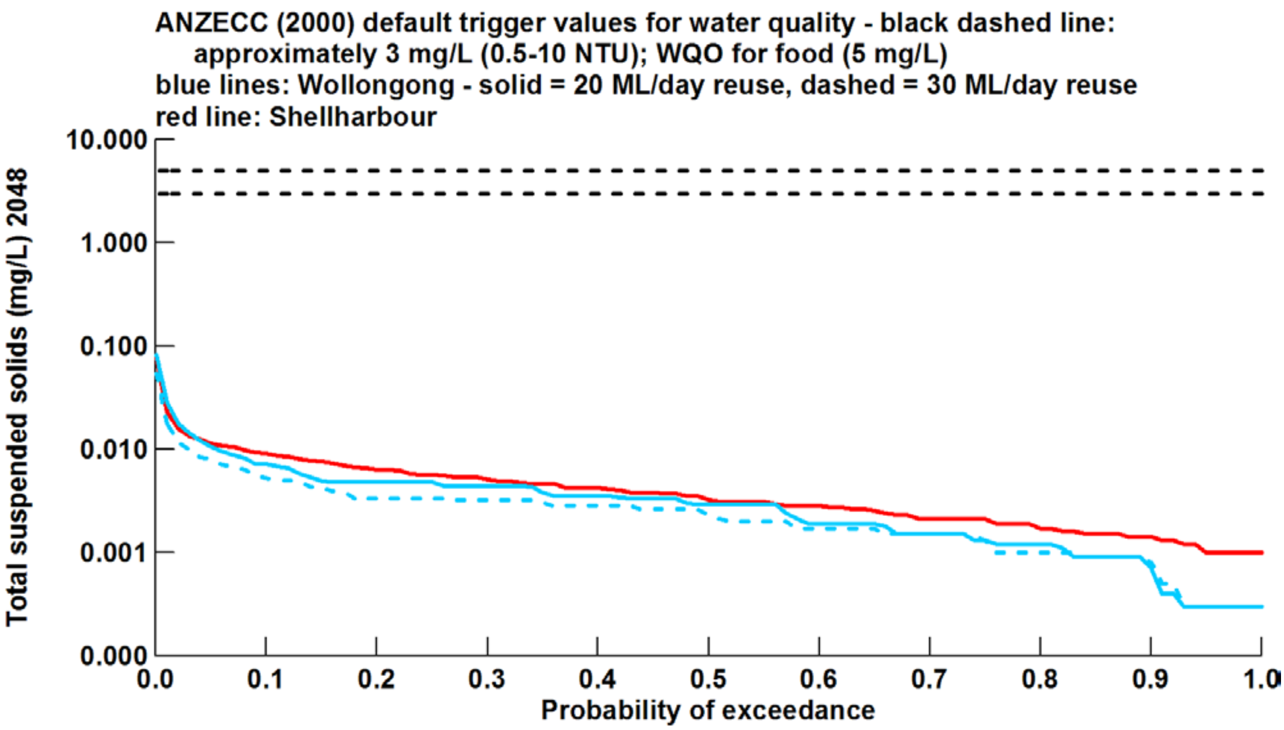

Figure 28. Modelled results for total suspended solids, 2048 scenario.

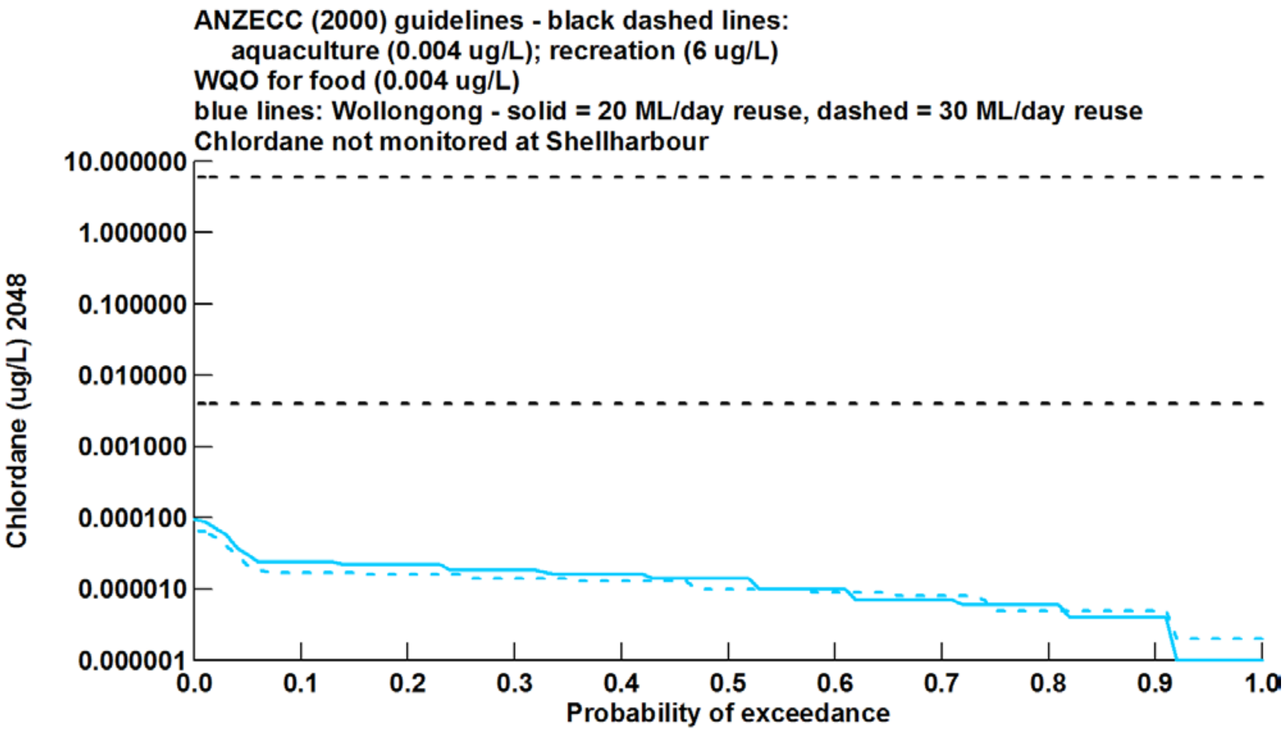

Figure 29. Modelled results for chlordane, 2048 scenario.

The “stepped” nature of this plot results from only one data point above the limit of reading.

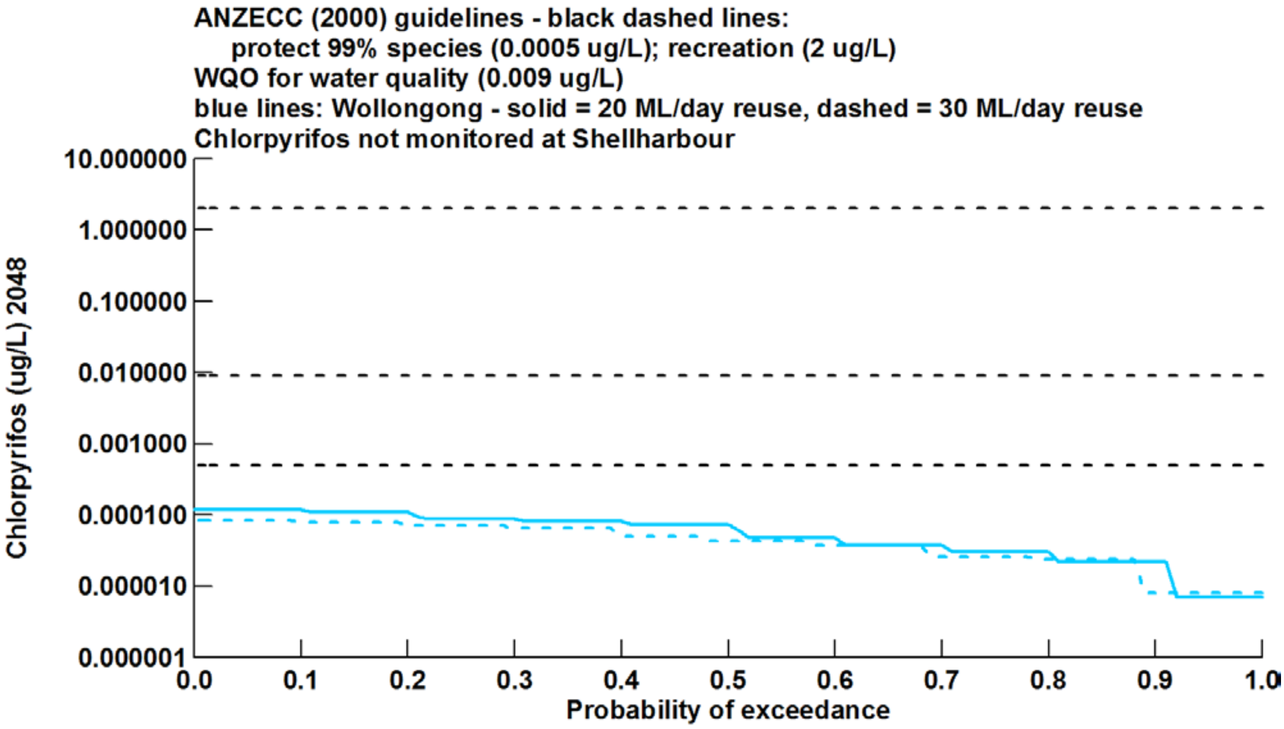

Figure 30. Modelled results for chlorpyrifos, 2048 scenario.