Perth Long Term Ocean Outlet Monitoring Program (PLOOM)

2014–2015 Annual Report: Ocean Reef

watercorporation.com.au

WATER CORPORATION

This report has been prepared for Water Corporation by BMT Oceanica Pty Ltd, June 2015, Report Number 1120_006/4_Rev0 .

Document history

Distribution

Revision	Author	Recipients	Organisation	No. copies & format	Date
A	C Hanson	G Shiell	BMT Oceanica	1 x .docm	10/06/2015
B	C Hanson	T Ridgway	BMT Oceanica	1 x .docm	11/06/2015
C	C Hanson	R Hillman M Nener	BMT Oceanica Water Corporation	1 x .docm	12/06/2015
0	C Hanson	M Nener	Water Corporation	1 x .pdf 2 x hardcopy	30/06/2015

Review

Revision	Reviewer	Intent	Date
A	G Shiell	Technical review	10/06/2015
B	T Ridgway	Editorial review	12/06/2015
C	R Hillman M Nener	Admin review Client review	12/06/2015 30/06/2015

Quality Assurance

BMT Oceanica Pty Ltd has prepared this report in accordance with our Health Safety Environment Quality Management System, certified to ISO 9001: 2008.

Status

This report is 'Draft' until approved for final release, as indicated below by inclusion of signatures from: (i) the author and (ii) a Director of BMT Oceanica Pty Ltd or their authorised delegate. A Draft report may be issued for review with intent to generate a 'Final' version, but must not be used for any other purpose.

Approved for final release:

Author
Date: 30/06/2015

Director (or delegate)
Date: 30/06/2015

Contents

List of Figures

List of Tables

List of Appendices

Acronyms

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASWQS	Annual Summer Water Quality Survey
CFU	Colony-forming unit
CTWWC	Comprehensive treated wastewater characterisation
DO	Dissolved oxygen
DoF	Western Australian Department of Fisheries
DoH	Western Australian Department of Health
EPA	Environmental Protection Authority
EQC	Environmental Quality Criteria
EQG	Environmental Quality Guideline
EQMF	Environmental Quality Management Framework
EQO	Environmental Quality Objective
EQS	Environmental Quality Standard
EV	Environmental Value
HEPA	High ecological protection area
LAC	Light attenuation coefficient
LEPA	Low ecological protection area
LOEC	Lowest observed effect concentration
MPN	Most probable number
NATA	National Association of Testing Authorities
NHMRC	National Health and Medical Research Council
NOEC	No observed effect concentration
NO_x	Nitrate+nitrite
OZI	Observed zone of influence
PLOOM	Perth Long Term Ocean Outlet Monitoring
TCM	Trial Compliance Monitoring
TTC	Thermotolerant coliforms
TTM	Total toxicity of the mixture
TWW	Treated wastewater
WASQAP	Western Australian Shellfish Quality Assurance Program
WET	Whole of effluent toxicity
WWTP	Wastewater treatment plant

Executive Summary

This report documents the findings of the 2014–2015 Ocean Reef ocean monitoring program undertaken between December 2014 and March 2015. The report outlines the findings of three environmental monitoring programs:

- summer Trial Compliance Monitoring (TCM)
- whole of effluent toxicity (WET) testing
- comprehensive treated wastewater characterisation (CTWWC).

Results presented here complement the findings of the in-line treated wastewater (TWW) monitoring required under Licence conditions (*Environmental Protection Act* 1986 – Licence Number L7882/1991/14), which are reported separately.

Results are reported in the context of the Environmental Quality Management Framework (EQMF) described in EPA (2015). Under the EQMF, Water Corporation is required annually to demonstrate achievement against Environmental Quality Objectives (EQOs):

- Maintenance of Ecosystem Integrity
- Maintenance of Seafood for Human Consumption
- Maintenance of Primary and Secondary Recreation.

The extent to which the EQOs were met was assessed against a suite of 'trial' Environmental Quality Criteria (EQC), each consisting of Environmental Quality Guidelines (EQGs) and Environmental Quality Standards (EQSs). The EQC have 'trial' status pending any formal criteria issued by the Environmental Protection Authority for the Ocean Reef ocean outlets.

The results are summarised in Report Card format (Table ES.1). The report cards for each EQO (Table ES.2–Table ES.4) contain colour-coded results, each representing the extent to which the EQC were met and, where necessary, the level of management required.

Table ES.1 Summary report card legend

Management response[1]	Colour
Monitor: EQG met (continue monitoring)	
Investigative: EQG not met (investigate against the EQS), EQS met (continue monitoring)	
Action: EQS not met (management response required)	

Note:
1. The required response following an exceedance of either the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS) is shown in parentheses.

EQO 'Maintenance of Ecosystem Integrity'

There are several EQC relevant to the 'EQO Maintenance of Ecosystem Integrity': the first are assessed based on in-line measurements of the constituents of the TWW stream and its potential toxicity, while the remainder are based on in-situ monitoring (water column nutrients, phytoplankton abundance and physical-chemical stressors) of the receiving environment.

Toxicants in treated wastewater: There are four EQGs relating to toxicants in the TWW, all of which are tested annually. EQG 1 and 2 relate to bioaccumulating and non-bioaccumulating toxicants, respectively. EQG 3 and 4 relate to the total toxicity of the mixture (TTM) and the results of WET testing, respectively.

To meet EQG 1, bioaccumulating toxicant (specifically, cadmium and mercury) concentrations must be below their respective 80% species protection guidelines prior to dilution with seawater. Concentrations of bioaccumulating toxicants were below the 80% species protection guidelines in all cases, thus meeting the EQG.

To meet EQG 2, non-bioaccumulating contaminants must not exceed the ANZECC/ARMCANZ (2000) guideline for 99% species protection at the LEPA boundary, located 100 m from the diffuser. Initial dilution modelling found that the Ocean Reef outlets were achieving worst-case average initial dilution of 1:81. This was sufficient to dilute contaminants to concentrations below the respective 99% species protection guidelines. EQG 2 for toxicants in TWW was therefore met (Table ES.2.

EQG 3 requires that the TTM for the additive effect of ammonia, copper and zinc in the diluted TWW plume is less than 1.0. The calculated TTM following initial dilution was 0.75, which is below the ANZECC/ARMCANZ (2000) guideline value and meets the EQG.

To meet EQG 4, the NOEC (highest concentration with no significant effect) derived from WET testing must be greater than 1.0% TWW concentration (i.e. less than a 100-fold dilution). The NOEC values for all sampling dates were 100% TWW concentration, thus meeting the EQG.

To assess EQG 4 for TWW toxicants, WET testing is used to measure effluent toxicity by exposing sea urchin gametes to different concentrations of TWW and then measuring fertilisation success. The highest concentration of TWW at which there is no statistically significant observed effect on gamete fertilisation (NOEC) is used to establish whether the EQG was met; for this, the NOEC must be greater than 1.0% TWW concentration (i.e. less than a 100-fold dilution). WET tests were undertaken in July 2014, October 2014, January 2015 and April 2015. The NOEC values for all sampling dates were 100% TWW, thus meeting EQG 4 (Table ES.2).

Water quality monitoring – receiving environment: Ocean water quality was assessed fortnightly over December 2014 to March 2015 as part of the TCM program. Samples were collected at fixed distance intervals down-current of the outlets. The TCM program includes analyses of nutrients (ammonium, nitrate+nitrite and orthophosphate), chlorophyll-a (a measure of phytoplankton biomass) and physical properties (water temperature, salinity, dissolved oxygen and light attenuation coefficient). Data collected over the 2014–2015 monitoring period indicated that all associated EQGs were met (Table ES.2).

Table ES.2 Summary report card for the Environmental Quality Objective 'Maintenance of Ecosystem Integrity'

Environmental quality indicator		Comments	Compliance
Toxicants in treated wastewater (TWW)	Bioaccumulating toxicants	Cadmium and mercury in the undiluted TWW stream were measured at concentrations well below the ANZECC/ARMCANZ (2000) values for 80% species protection	■
	Non-bioaccumulating toxicants and initial dilution	The rate of initial dilution achieved on 3 February 2015 (1:81) was sufficient to reduce contaminant concentrations to values lower than the ANZECC/ARMCANZ (2000) values for 99% species protection	■
	Total toxicity of the mixture (TTM)	The TTM for the additive effect of ammonia, copper and zinc after initial dilution (0.75) was lower than the ANZECC/ARMCANZ (2000) guideline value of 1.0	■
	Whole of effluent toxicity testing	No dilution of the TWW was required to meet the NOEC	■
Nutrient enrichment	Chlorophyll-a	The overall median chlorophyll-a concentration within the high ecological protection area (HEPA) was lower than the 80th percentile of historical reference site data	■
	Light attenuation coefficient (LAC)	The overall median LAC within the HEPA was lower than the 80th percentile of historical reference site data	■
Phytoplankton blooms	Phytoplankton biomass (measured as chlorophyll-a)	1. Median chlorophyll-a levels in the HEPA did not exceed 3-times median of reference sites	■
		2. Chlorophyll-a samples at any site (and at any time) exceeded 3-times reference levels on 3.1% of occasions	■
Physical-chemistry	Organic enrichment	Dissolved oxygen saturation remained above 90% concentration over the Trial Compliance Monitoring period	■
	Salinity	Within the HEPA, median salinity was within the 20th and 80th percentile of reference site data	■

Notes:

1. Green (■) symbols indicate the Environmental Quality Guidelines (EQGs) were met; amber (■) and red (■) symbols represent an exceedance of the EQG or Environmental Quality Standard (EQS), respectively.
2. NOEC = no observed effect concentration; the highest concentration of treated wastewater (TWW) at which there is no statistically significant observed effect on gamete fertilisation.

EQO 'Maintenance of Seafood for Human Consumption'

There are two trial EQC for the EQO 'Maintenance of the Seafood for Human Consumption': the first is based on in-water concentrations of thermotolerant coliforms (TTC), and the second is based on in-water concentrations of toxic phytoplankton species (to monitor for algal biotoxins).

TTC were sampled fortnightly at fixed sites over the December–March monitoring period. The ANZECC/ARMCANZ (2000) EQG for Maintenance of Seafood for Human Consumption states that median TTC for all data collected at the boundary of the observed zone of influence (OZI) must not exceed 14 CFU/100 mL with no more than 10% of samples exceeding 21 CFU/100 mL.

For the present reporting period, the EQC for microbiological contaminants (as TTC) were assessed based on pooled data from three sampling seasons (2012–2013, 2013–2014 and 2014–2015), with a sample size (n=120) that allowed for appropriate comparison with the EQC (EPA 2005a)[1]. The median value for TTC concentrations was at the limit of detection (<10 CFU/100 mL), and therefore below the 14 CFU/100mL trigger value. Over the three seasons, 12 of 120 samples exceeded 21 CFU/100 mL, thus equalling the second trigger that requires no more than 10% of the samples to exceed 21 CFU/100 mL. As the number of samples exceeding 21 CFU/100 mL was not greater than 10%, the EQG for microbiological contaminants (as TTC) was met (Table ES.3).

The EQC for algal biotoxins are based on the criteria listed in the Western Australian Shellfish Quality Assurance Program (WASQAP) for toxic phytoplankton species (DoF 2007). Phytoplankton samples were collected at approximately fortnightly intervals over the December–March non-river flow period. During the 2014–2015 sampling season, there were no instances where toxic phytoplankton species exceeded WASQAP guideline values, thus meeting the EQG (Table ES.3).

Table ES.3 Summary report card for the Environmental Quality Objective 'Maintenance of Seafood for Human Consumption'

Environmental quality indicator		Comments	Compliance
Microbiological contaminants	Thermotolerant coliforms (TTC)	The median value for TTC derived from 120 samples collected over the 2012–2013, 2013–2014 and 2014–2015 sampling seasons was at the limit of detection (<10 CFU/100 mL)	■
		There were 10.0% of TTC samples that exceeded 21 CFU/100 mL over the 3-season pooled dataset (n=120)	■
Algal biotoxins	Potentially toxic phytoplankton species	Results of the 2014–2015 monitoring program found no instances where toxic phytoplankton species were recorded in excess of WASQAP guideline values (DoF 2007)	■

Note:

1. Green (■) symbols indicate the Environmental Quality Guidelines (EQGs) were met; amber (■) and red (■) symbols represent an exceedance of the EQG or Environmental Quality Standard (EQS), respectively.

EQO 'Maintenance of Primary and Secondary Recreation'

There are two trial EQC for the EQO 'Maintenance of Primary and Secondary Recreation': the first is based on in-water concentrations of faecal coliforms (*Enterococci* spp.), and the second is based on in-water measures of total phytoplankton cell densities.

[1] *NHMRC (2008) guidelines and EPA (2005a) suggest that a minimum of 100 samples over the non-river flow period (pooled from multiple years if required) are needed for accurate assessment of microbial water quality EQC.*

The EQG for primary contact recreation requires that the 95th percentile value of faecal pathogens (*Enterococci* spp.) not exceed 200 MPN/100 mL outside the OZI boundary. To meet the EQG for secondary contact recreation, the 95th percentile is not to exceed 2000 MPN/100 mL. The EQG for microbiological contaminants was assessed based on pooled data (n=120) from three sampling seasons (2012–2013, 2013–2014 and 2014–2015). The 95th percentile of *Enterococci* spp. concentrations equalled 10 MPN/100 mL, and met the EQG for both primary and secondary contact recreation (Table ES.4).

To evaluate the trial EQC for phytoplankton cell concentrations, phytoplankton samples were collected at fixed monitoring sites along the boundary of the OZI at approximately fortnightly intervals over the December to March monitoring period.

The EQG for algal biotoxins states:

- the median total phytoplankton cell concentration for the area of concern is not to exceed 15 000 cells/mL or
- there are to be no reports of skin or eye irritation or potential algal poisoning in swimmers considered by a medical practitioner as potentially resulting from toxic algae when less than 15 000 cells/mL are present in the water column.

The median phytoplankton cell density at the contact recreation boundary was 25.2 cells/mL, thus meeting the EQG for this indicator (Table ES.4).

Table ES.4 Summary report card for the Environmental Quality Objective 'Maintenance of Primary and Secondary Contact Recreation'

Environmental quality indicator		Comments	EQC	Compliance
Faecal streptococci	*Enterococci* spp.	The 95th percentile of *Enterococci* spp. concentrations was 10 MPN/100 mL	EQG (primary contact)	■
			EQG (secondary contact)	■
Algal biotoxins	Phytoplankton (cell concentration)	The median total phytoplankton cell concentration was 25.2 cells/mL	EQG	■

Note:

1. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS), respectively.

1. Introduction

1.1 Document purpose

This annual report documents the findings of the 2014–2015 ocean monitoring around the Ocean Reef ocean outlets. The report outlines the findings of three environmental monitoring programs undertaken above and beyond the Licence condition (*Environmental Protection Act 1986* – Licence Number L7882/1991/14) to monitor contaminants within the treated wastewater (TWW) stream. The additional programs are:

- summer Trial Compliance Monitoring (TCM)
- whole of effluent toxicity (WET) testing
- comprehensive treated wastewater characterisation (CTWWC).

The Ocean Reef monitoring programs are underpinned by the Government of Western Australia's (Govt of WA 2003) Environmental Quality Management Framework (EQMF; EPA 2002), which requires Water Corporation to meet a number of Environmental Quality Objectives (EQOs). The results in this report are summarised and discussed in the context of meeting the EQOs (EPA 2015) for Ocean Reef, which encompass:

- Maintenance of Ecosystem Integrity (Section 2)
- Maintenance of Seafood for Human Consumption (Section 3)
- Maintenance of Primary and Secondary Contact Recreation Values (Section 4).

Results for each of the EQOs are described in standalone sections. Each section includes a description of the EQO, and details methods and the results of the monitoring programs, which are assessed in the context of 'trial' Environmental Quality Criteria (EQC). The EQC are trial pending the development of formal criteria for the Ocean Reef ocean outlets. Formal EQC are to be developed in the future as part of a Schedule to the Memorandum of Understanding (Anon 2003) between relevant Stakeholders.

1.2 Wastewater treatment plan infrastructure and discharge

Water Corporation operates four wastewater treatment plants (WWTPs) in metropolitan Perth: Beenyup, Subiaco, Woodman Point and Alkimos. Each plant produces advanced secondary TWW that is discharged to the sea through ocean outlets located at Ocean Reef, Swanbourne, Sepia Depression and Alkimos, respectively.

The Beenyup WWTP services Perth's northern suburbs, receiving predominantly domestic wastewater (from bathroom, toilet, kitchen and laundry greywater) and less than 2% light industrial wastewater. The plant produces secondary treated wastewater (TWW) using an activated sludge process with advanced nitrification and denitrification stages for nitrogen removal. The Beenyup WWTP (and the Ocean Reef ocean outlets) does not receive significant volumes of industrial wastewater; therefore the TWW is unlikely to contain significant volumes of contaminants introduced through industrial processes.

1.3 Ocean disposal of treated wastewater

1.3.1 History of ocean monitoring

Water Corporation has monitored the environmental effects of TWW discharge into Perth's coastal waters since the construction of the ocean outlets at Swanbourne in 1963, Sepia Depression in 1984, Ocean Reef in 1978 (Outlet A) and 1992 (Outlet B) and Alkimos in 2010. Over time, increasing awareness of the importance of environmental sustainability has led to the development of more rigorous ocean outlet monitoring programs. In 1992 the Perth Coastal Water Studies program was developed, which in turn led to the present-day Perth Long Term Ocean Outlet Monitoring (PLOOM) program that commenced formally in 1996.

In 2003 the PLOOM program was revised pending the development of a formal EQMF. In view of the pending regulatory developments, there was a shift in emphasis from investigative studies to a program of TCM. Results of the TCM program are reported in the PLOOM Annual Reports, which over the years have evolved to also include CTWWC and WET testing. The Ocean Reef component of the PLOOM program also includes an Annual Summer Water Quality Survey (ASWQS; reported separately in BMT Oceanica 2015).

1.3.2 Site of ocean disposal

The Beenyup WWTP discharges ~116 ML/day of secondary TWW to the sea through the two outlets at Ocean Reef. The outlets are 1.65 km (Outlet A) and 1.85 km (Outlet B) in length and located in ~10 m of water (Figure 1.1). The majority of TWW is discharged via Outlet B with only minimal flow through Outlet A. Discharge commenced from Outlet A in 1978 and Outlet B in 1992.

The discharge of TWW to the marine environment is characterised by a number of physical and chemical processes. The TWW is primarily fresh with a lower density than seawater. As a result, the TWW plume is buoyant – rising through the water column and mixing as it ascends. The effects of the TWW plume are therefore observed primarily at the surface of the water column in the immediate vicinity of the ocean outlets (see, for example, Oceanica 2011a, 2012).

Over time, the TWW outlets have become encrusted with an array of marine life, including ascidians, sponges and complex macroalgal communities. In turn, these communities attract and support a variety of marine life comprising demersal fin-fish, molluscs, crustaceans and echinoderms (BMT Oceanica, unpublished historical data).

The benthic (or seafloor) habitat around the outlets is predominantly sand, with areas of seagrass and low relief limestone reef. Surveys undertaken in February 2002 classified three types of seagrass habitat: dense seagrass cover (>70%), medium seagrass cover (30–70%) and sparse seagrass cover (<30%; DALSE 2003). Sandy habitats located close to the outlets contained sparse communities of the seagrass *Posidonia coriacea* (DALSE 2003). Dense seagrass (>70%) cover was restricted to the inshore regions of Whitfords Lagoon, south of the outlets. The Whitfords Lagoon habitats were dominated by *Posidonia sinuosa* and *Amphibolis griffithii* (DALSE 2003).

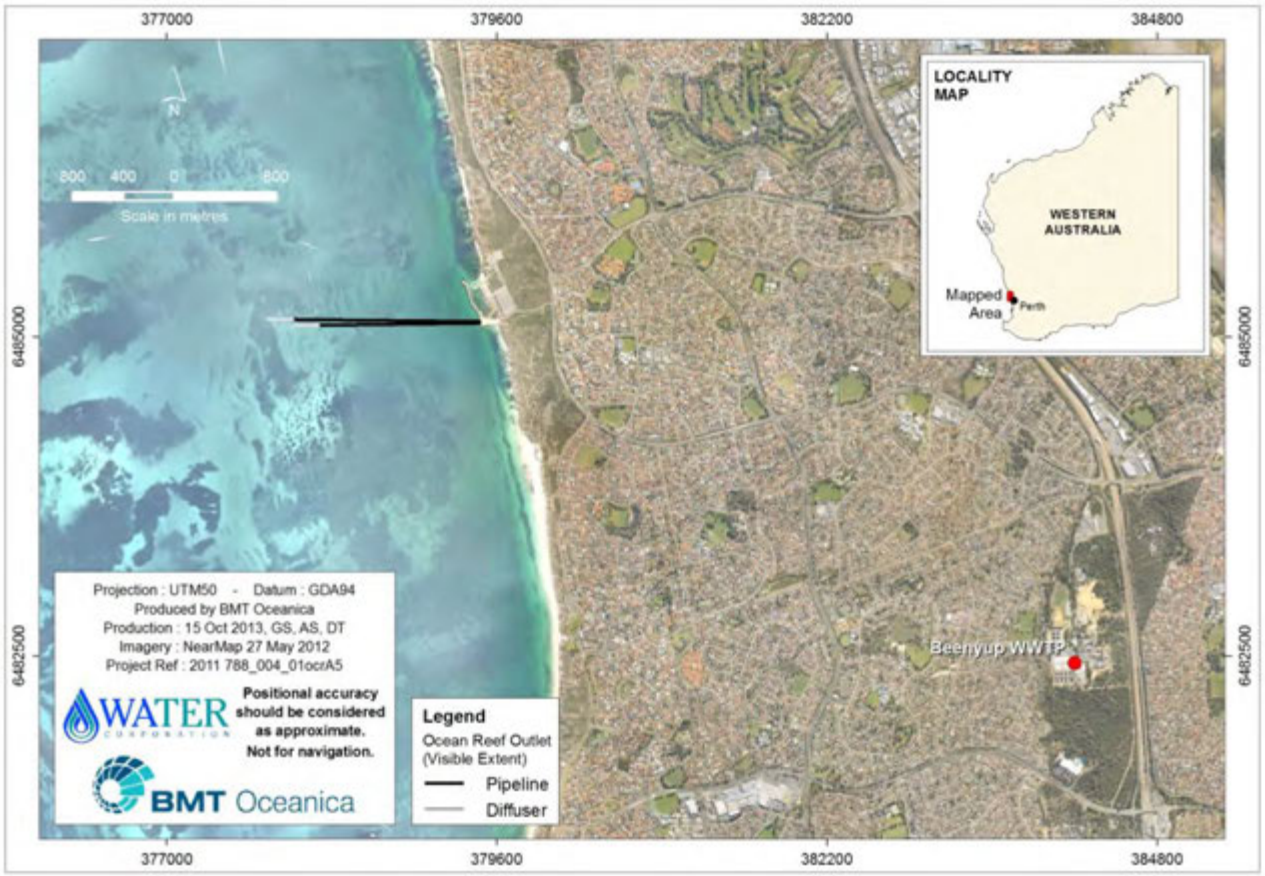


Figure 1.1 Location of the Beenyup WWTP and the Ocean Reef ocean outlets

1.3.3 Conditions of operation

Operation of the Beenyup WWTP and the ocean disposal of TWW are in accordance with Licence and Ministerial Conditions (Appendix A). These include the requirement to undertake:

- measurement of TWW flows and associated contaminant loads to ensure maximum nutrient loads are not exceeded
- a 3-yearly survey of metals and pesticides in marine biota.

The Condition to undertake in-line TWW flow and contaminant monitoring is fulfilled via submission of internal Performance and Compliance Reports. The Condition to undertake a 3-yearly metals and pesticides survey is fulfilled via the PLOOM Metals and Pesticides Survey (BMT Oceanica 2013). All other components of the PLOOM program at Ocean Reef (i.e. TCM, WET Testing, CTWWC and the ASWQS) are undertaken over and above regulatory conditions.

1.4 Environmental management

1.4.1 Environmental Quality Management Framework (EQMF)

In the absence of regulatory conditions to develop an ocean outlet monitoring and management plan, the potential effects of TWW disposal at Ocean Reef are monitored and managed under the PLOOM program. The Ocean Reef monitoring program is underpinned by the National Water Quality Management Strategy—the EQMF (EPA 2002). The State Government has endorsed the progressive implementation of the EQMF for all of the State's marine waters on a priority basis (Govt of WA 2003). This EQMF is based on:

- identifying **Environmental Values** (EVs)
- establishing and spatially defining **Environmental Quality Objectives** (EQOs) that need to be maintained to ensure the associated EVs are protected
- monitoring and managing to ensure the EQOs are achieved and/or maintained in the long-term in the areas they have been designated
- establishing **Environmental Quality Criteria** (EQC), which are quantitative benchmarks or 'trigger values' against which monitoring results can be compared.

The EVs and EQOs (Table 1.1) for use in Perth's coastal waters between Dawesville and Yanchep are outlined in EPA (2015).

Table 1.1 EVs and EQOs applied in Perth's coastal waters

Environmental Value (EV)	Environmental Quality Objective (EQO)
Ecosystem Health	EQO1 Maintenance of ecosystem integrity
Fishing and Aquaculture	EQO2 (i) Maintenance of seafood for human consumption
	EQO2 (ii) Maintenance of aquaculture
Recreation and Aesthetics	EQO3 Maintenance of primary contact recreation values
	EQO4 Maintenance of secondary contact and recreation
	EQO5 Maintenance of aesthetic values

Source: EPA (2015)

1.4.2 Environmental Quality Criteria

The extent to which the EVs and EQOs have been met is assessed against a suite of trial EQC. The EQC provide the quantitative benchmarks for measuring success in achieving the EQOs. For each of the EQOs, a set of trial EQC have been established to provide the benchmark against which environmental quality and the performance of environmental management can be measured. Two main types of EQC have been developed to remain consistent with ANZECC/ARMCANZ (2000), comprising EQGs and EQSs:

Environmental Quality Guidelines (EQGs): are quantitative, investigative triggers which, if met, indicate there is a high degree of certainty that the associated EQO has been achieved. If the guideline is not met, there is uncertainty as to whether the associated EQO has been achieved and a more detailed assessment against the EQS is triggered.

Environmental Quality Standards (EQSs): are management triggers based on multiple lines of evidence, which if exceeded signifies that the EQO is not being met and that a management response is required. EQSs are generally equivalent to the water quality objectives described in ANZECC/ARMCANZ (2000).

For the Ocean Reef monitoring program, EQGs have been developed according to the approach defined in EPA (2005b), such that exceedance of an EQG is a 'trigger' for further investigation against the corresponding EQS. EQSs have been developed according to the risk-based approach. If an EQS is exceeded, it is considered that there is a significant risk that the associated EQO has not been achieved, investigation of the cause is needed and an adaptive management response is triggered if the exceedance continues.

The EQGs and EQSs are provided in Table 1.2 to Table 1.4. These criteria and their framework for application have been used as the basis for assessing whether the EQOs have been met.

Table 1.2 Trial Environmental Quality Criteria for the EQO of Maintenance of Ecosystem Integrity

Environmental quality indicator	Environmental Quality Criteria (EQC)[1]	
	Environmental Quality Guideline	**Environmental Quality Standard**
Toxicants in treated wastewater • ammonia • metals • pesticides • herbicides • other chemicals	**Treated wastewater characterisation – bioaccumulating toxicants** Concentrations of contaminants will not exceed the ANZECC/ARMCANZ (2000) 80% species protection guideline trigger levels for bioaccumulating toxicants at the diffuser.	**Sentinel mussel monitoring** The median concentrations of metals that may bioaccumulate (cadmium and mercury) within mussel tissue from sites at the boundary of the low/high ecological protection areas will be compared to 80th percentile of values from reference sites.
	Treated wastewater characterisation – non-bioaccumulating toxicants The information on wastewater quality, in conjunction with the results from the initial dilution modelling, will be evaluated to determine whether: 1. The ANZECC/ARMCANZ (2000) 99% species protection guideline trigger levels for toxicants (with the exception of cobalt, where the 95% guideline trigger level will apply), are being achieved at the boundary of the low ecological protection area (LEPA) (i.e. a high level of protection is met beyond a 100 m radius of the diffuser). 2. The total toxicity of the mixture (TTM) for the additive effect of ammonia, copper and zinc (as per ANZECC/ARMCANZ (2000) guidelines) is less than 1.0 (refer to Section 2.2.1). Note that for metals, the assessment is to be based on bioavailable concentrations of metals in the wastewater (i.e. concentrations after filtering through a 0.45 µm filter). If any EQGs are exceeded, assessment against the EQS will commence.	**Whole of effluent toxicity (WET) testing** Undertake the full suite of WET testing of the waste stream in accordance with ANZECC/ARMCANZ (2000) guidelines. The EQS will be exceeded where: $\frac{DALEPA}{DR99\%BurrliOZ} \leq 1$ where *DALEPA* = dilutions achieved at the boundary of the LEPA; *DR99%BurrliOZ* = number of dilutions required to achieve the 99% species protection guideline specific to treated wastewater that is calculated with BurrliOZ software using the results of the full suite of WET tests, as per ANZECC/ARMCANZ (2000).
	Whole of effluent toxicity (WET) testing The EQG will be exceeded if following the 1-hour sea urchin test: $\frac{TDA}{DRNOEC} \leq 1.0$ where TDA = Typical Dilutions Achieved (constant based on 100-fold dilution) DRNOEC = Number of dilutions required to achieve the no observed effects concentration (NOEC). Breaching the above triggers investigations against the EQS, which would comprise the full suite of WET tests (minimum of five species from four trophic groups).	**Whole of effluent toxicity (WET) testing** As per EQS above.
Receiving water physical-chemical measures • nutrient enrichment • organic enrichment • salinity	**Nutrient enrichment** 1. Ambient value[2] of defined area[3] during non-river flow period[4] not to exceed chlorophyll-a: 80th percentile of reference sites data. 2. Ambient value[2] of defined area[3] during non-river flow period[4] not to exceed light attenuation: 80th percentile of reference sites data.	Not applicable. No suitable EQS available.
	Organic enrichment Ambient value[2] for dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) greater than 90% saturation at any site for a defined period of not more than 6 weeks.	**Organic enrichment** Ambient value[2] for dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) greater than 60% saturation at any site for a defined period of not more than 6 weeks. No deaths of marine organisms resulting from de-oxygenation.
	Salinity Median salinity (0.5 m below the water surface) at an individual site over any period not to deviate beyond the 20th and 80th percentile of natural salinity range over the same period.	**Salinity** No deaths of marine organisms resulting from anthropogenically-sourced salinity stress.
Receiving water direct biological measures (algal growth potential) • phytoplankton biomass (chlorophyll-a)	**Phytoplankton blooms** 1. Ambient value[2] for phytoplankton biomass measured as chlorophyll-a not to exceed 3-times median chlorophyll-a concentration of reference sites, on any occasion during non-river flow period[4]. 2. Phytoplankton biomass measured as chlorophyll-a at any site does not exceed 3-times median chlorophyll-a concentration of reference sites, on 25% or more occasions during the non-river flow period[4]. If either of these EQGs are exceeded, assessment will proceed against the EQS.	**Phytoplankton blooms** 1. Ambient value[2] for phytoplankton biomass measured as chlorophyll-a not to exceed 3-times median chlorophyll-a concentration of reference sites, on more than one occasion during non-river flow period[4] and in two consecutive years. 2. Phytoplankton biomass measured as chlorophyll-a at any site does not exceed 3-times median chlorophyll-a concentration of reference sites, on 25% or more occasions during the non-river flow period[4] and in two consecutive years.

Notes:
1. Based on the EQC Reference Document for Cockburn Sound (2003–2004) (EPA 2005b). Where there is more than one EQC for an indicator, each one is to be considered individually. If any one of these is exceeded then the guideline or standard for that indicator has not been met.
2. Ambient value = median value of individual sample data for a defined area.
3. Defined area = area to be characterised for environmental quality against pre-determined Environmental Quality Objectives and levels of ecological protection.
4. Non-river flow period = period December–March inclusive, when river flows are weak.

Table 1.3 Trial Environmental Quality Criteria for the EQO of Maintenance of Seafood for Human Consumption

Environmental quality indicator	Environmental Quality Criteria	
	Environmental Quality Guideline	**Environmental Quality Standard**
Thermotolerant coliforms (TTC)	Median TTC concentrations at sites at the boundary of the observed zone of influence (OZI) are not to exceed 14 CFU/100 mL, with no more than 10% of the samples exceeding 21 CFU/100 mL as measured using the membrane filtration method.	Median TTC concentrations at sites at the boundary of the OZI not to exceed 70 CFU/100 mL, with no more than 10% of the samples exceeding 85 CFU/100 mL as measured using the membrane filtration method.
Algal biotoxins	Concentrations of potentially toxic algae at sites at the boundary of the OZI not to exceed the WASQAP[1] trigger concentrations for any of the following: • *Alexandrium* spp. (100 cells/L) • *Gymnodinium* spp. (1000 cells/L) • *Karenia* spp. (1000 cells/L) • *Dinophysis* spp. (500 cells/L) • *Dinophysis acuminta* (3000 cells/L) • *Prorocentrum lima* (500 cells/L) • *Psuedo-nitzschia* spp. (250 000 cells/L) • *Gonyaulax* cf. *spinifera* (100 cells/L) • *Protoceratium reticulatum* (*Gonyaulax grindleyi*) (500 cells/L). If this EQG is exceeded, assessment will proceed against the EQS for sentinel mussel tissues.	Toxin concentrations in seafood[1] not to exceed EQS in any sample at the boundary of the OZI: • paralytic shellfish poison (0.8 mg Saxitoxin eq./kg) • diarrhoetic shellfish poison (0.2 mg/kg) • neurotoxic shellfish poison (200 mouse units/kg) • amnesic shellfish poison (domoic acid; 20 mg/kg).

Note:
1. Western Australian Shellfish Quality Assurance Program (WASQAP) Operations Manual (DoF 2007).

Table 1.4 Trial Environmental Quality Criteria for the EQOs of Maintenance of Primary and Secondary Contact Recreation

Environmental quality indicators	Environmental Quality Criteria	
	Environmental Quality Guideline	**Environmental Quality Standard**
Faecal pathogens	Primary contact: The 95th percentile value of *Enterococci* concentrations taken over the bathing season not to exceed 200 MPN/100 mL, outside the observed zone of influence (OZI) boundary. Secondary contact: The 95th percentile value of *Enterococci* concentrations taken over the bathing season not to exceed 2000 MPN/100 mL, outside the OZI boundary.	Primary contact: The 95th percentile value of *Enterococci* concentrations taken over the bathing season not to exceed 500 MPN/100 mL, outside the OZI boundary. Secondary contact: The 95th percentile value of *Enterococci* concentrations taken over the bathing season not to exceed 5000 MPN/100 mL, outside the OZI boundary.
Algal biotoxins	Median total phytoplankton cell concentration for the area of concern (either from one sampling run or from a single site over agreed period of time) should not exceed 15 000 cells/mL. or There should be no reports of skin or eye irritation or potential algal poisoning in swimmers considered by a medical practitioner as potentially resulting from toxic algae when less than 15 000 cells/mL is present in the water column.	There should be no confirmed incidences (by the Dept of Health) of skin or eye irritation caused by toxic algae, or of algal poisoning in recreational users.

2. Maintenance of Ecosystem Integrity

2.1 Environmental Quality Objective

The EQO for the EV 'Ecosystem Health' is aimed at maintaining ecosystem integrity and biodiversity, thereby ensuring the continued health and productivity of Perth's coastal waters (EPA 2015). There are two areas of ecological protection surrounding the Ocean Reef ocean outlets; a high ecological protection area (HEPA) and a notional low ecological protection area (LEPA). The notional LEPA includes waters within a 100 m radius around the diffuser; waters outside this zone are managed as a HEPA (Figure 2.1).

A comprehensive suite of contaminants are monitored in the TWW prior to discharge (i.e. in the undiluted TWW stream), as well as a subset of contaminants within the receiving environment (i.e. in the diluted TWW plume). Monitoring against trial EQC involves:

- toxicants in TWW
- metals and pesticides in marine biota
- receiving water physical-chemical measures
- receiving water direct biological measures.

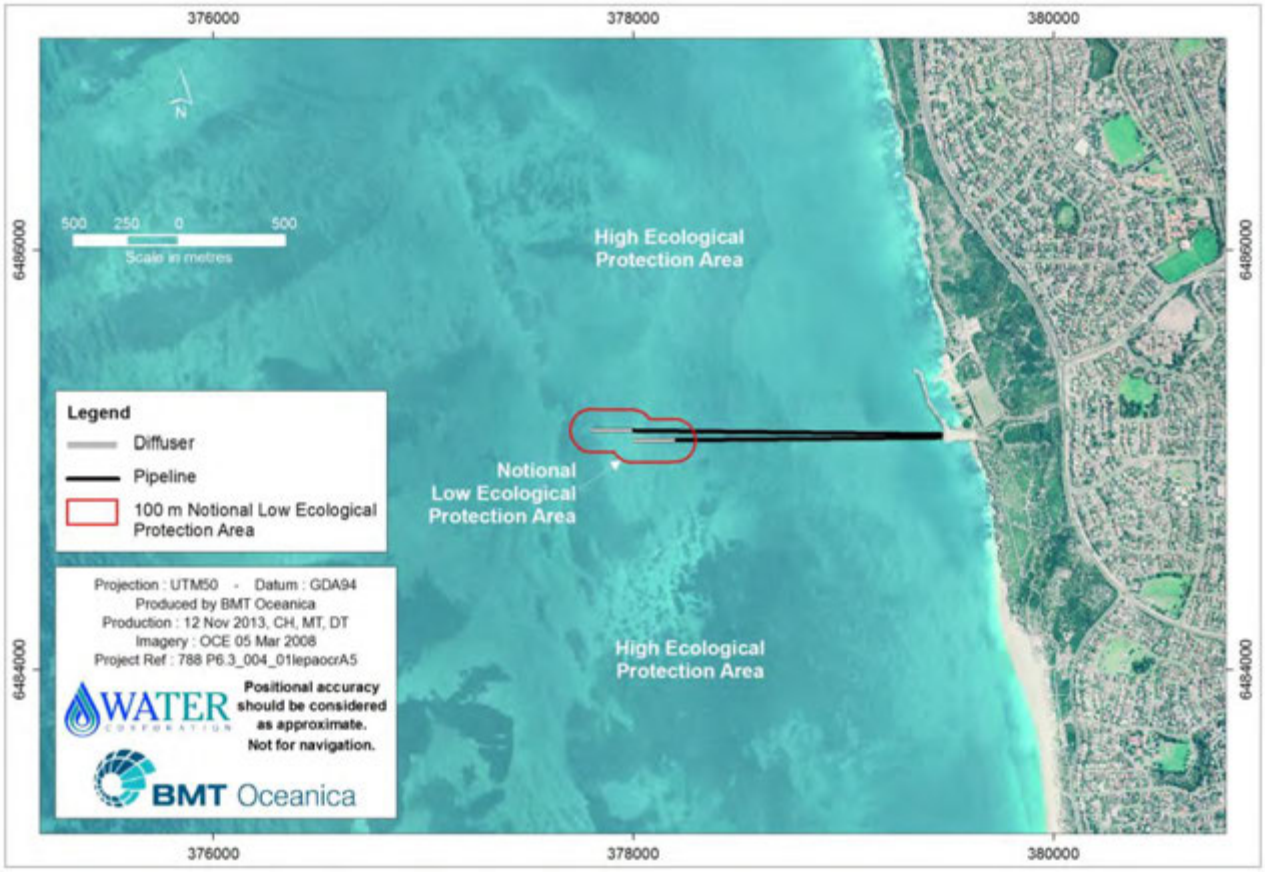


Figure 2.1 Ocean Reef ocean outlets notional ecological protection boundaries

2.2 Toxicants in treated wastewater

Toxicants in TWW are assessed using four trial EQG triggers (Table 1.2) that are evaluated annually for:

- bioaccumulating toxicants in the undiluted TWW stream (EQG 1)
- non-bioaccumulating toxicants at the notional LEPA boundary (EQG 2)
- total toxicity of the mixture (TTM) for key contaminants (ammonia, copper and zinc) at the notional LEPA boundary (EQG 3)
- WET testing using various dilution levels of the TWW stream (EQG 4).

Every three years, the EQS for bioaccumulating toxicants is also tested via sentinel mussel monitoring, irrespective of whether the EQG has been exceeded.

2.2.1 Comprehensive treated wastewater characterisation

TWW (final effluent) from the Beenyup WWTP is analysed for a suite of parameters comprising the major contaminants of concern for the Ocean Reef ocean outlets:

- nutrients (total nitrogen, ammonia, nitrate+nitrite, total phosphorus, orthophosphate)
- microbiological contaminants
- bioavailable metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc)
- pesticides and herbicides (organophosphate pesticides, organochlorine pesticides, triazine herbicides)
- polyaromatic hydrocarbons
- phthalates
- polychlorinated biphenyls
- benzene, toluene, ethylbenzene, and xylenes
- petroleum hydrocarbons
- surfactants
- dissolved organic carbon.

A 24-hour flow-weighted composite sample is obtained from the Beenyup WWTP on the same date as the ASWQS (refer BMT Oceanica 2015). This sample represents an average of the final treated effluent discharged from the Beenyup WWTP for the 24 hours prior to and during the sample collection.

The bulk sample is homogenised (agitated), split into separate sample containers for the various analyte groups and handled according to the National Association of Testing Authorities (NATA)-accredited laboratory requirements for those analytes. Samples for bioavailable metals are passed through a 0.45 µm filter prior to analysis, in accordance with Environmental Protection Authority (EPA) prescribed methods (EPA 2005a). Analyses are completed by laboratories with NATA-accredited methods (Appendix B), and the results are compared against ANZECC/ARMCANZ (2000) species protection guideline levels.

Bioaccumulating toxicants

For EQG 1, levels of bioaccumulating toxicants (specifically, cadmium and mercury) must meet the ANZECC/ARMCANZ (2000) 80% species protection guideline in the TWW stream prior to dilution. In the TWW sample obtained on 3 February 2015, both cadmium and mercury levels were below the analytical limit of reporting (<0.1 µg/L) and consequently well below their respective 80% species protection guidelines (ANZECC/ARMCANZ 2000; Appendix C), thus meeting the EQG.

Initial dilution modelling and non-bioaccumulating toxicants

Initial dilution modelling for the ambient conditions and TWW flows at the time of TCM was done using the VPLUMES initial dilution model (refer to BMT Oceanica (2015) for details). The VPLUMES model is accepted for use by the United States Environmental Protection Agency (http://www.epa.gov) and captures simple features concerning the surrounding environment such as depth at point of discharge, net current and wind speed. VPLUMES is designed to predict the near-field behaviour of wastewater effluent plumes in the region where the plume first jets into the surrounding waters and then, in the case of positively buoyant plumes, rises and mixes with the surrounding waters (generally <10 m from the diffusers). Additional dilution is expected between the point that the plume reaches the surface and the notional LEPA boundary. Although initial dilution therefore underestimates the dilution at the notional LEPA boundary, it is favoured as it represents a highly conservative approach.

For the ambient conditions on 3 February 2015, the modelling predicted average initial dilutions of 1:99 for Outlet A and 1:81 for Outlet B, and centreline dilutions of 1:49 for Outlet A and 1:40 for Outlet B (Figure 2.2). The plume was predicted to first reach the surface within ~5–7 m (horizontal distance) from the discharge point (see the ambient boundary[2] of the plume in Figure 2.2; the full model output is included in Appendix E).

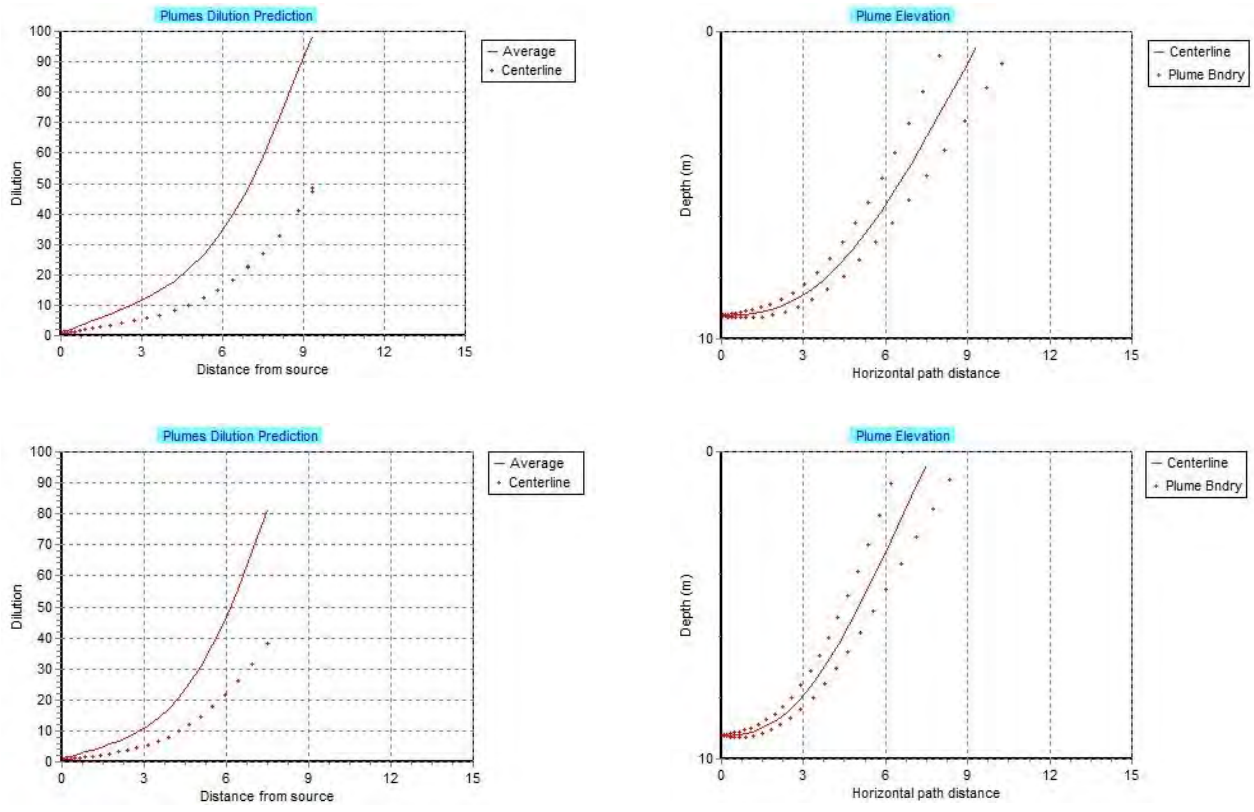


Figure 2.2 Initial dilution modelling output showing (left) predicted average and centreline dilution and (right) predicted centreline dilution and plume elevation trajectory at Ocean Reef Outlet A (top) and Outlet B (bottom) on 3 February 2015

[2] *The ambient boundary corresponds to the plume boundary at which concentrations are estimated to be equal to ambient conditions.*

To meet EQG 2, contaminant concentrations must not exceed the ANZECC/ARMCANZ (2000) guidelines for 99% species protection at the LEPA boundary. The initial dilution phase typically concludes within 10 m of the diffuser, and is thus a conservative estimate of dilution, with much higher rates of dilution expected at the LEPA (located 100 m from the diffuser). Contaminant concentrations after the initial dilution phase were calculated based on the worst-case initial dilution from Outlet B of 1:81. Comparison with trigger values was undertaken only for contaminants with available ANZECC/ARMCANZ (2000) 99% species protection guidelines. Results for analytes without triggers are provided for contextual purposes only in Appendix C and Appendix D.

Contaminants measured in the Ocean Reef TWW on 3 February 2015 were below the ANZECC/ARMCANZ (2000) 99% species protection guideline trigger values following initial dilution (Table 2.1), thus meeting EQG 2.

Table 2.1 Toxicants in the Ocean Reef TWW stream compared with relevant guideline trigger levels after initial dilution

Toxicant[1]	Ocean Reef TWW[2]	TWW value after initial dilution[3]	Trigger[4]
Nutrients (µg/L)			
Ammonia-N	2400	31	500
Dissolved metals (0.45 µm filtered) (µg/L)			
Chromium[5]	1	0.01	0.14 (Cr VI)
Copper	7	0.17	0.3
Lead	<1	–	2.2
Nickel	2	0.03	7
Silver	<0.8	–	0.8
Zinc	62	0.92	7
Organophosphate pesticides (µg/L)			
Chlorpyrifos[6]	<0.1	–	0.0005
Organochlorine pesticides (µg/L)			
Endrin	<0.001	–	0.004
Endosulfan sulfate[7]	<0.001	–	0.005
BTEX (µg/L)			
Benzene	<1.0	–	500
Poly aromatic hydrocarbons (µg/L)			
Naphthalene	<0.01	–	50
Benzo(g,h,i)perylene	<0.01	–	50

Notes:
1. Assessment against ANZECC/ARMCANZ (2000) 99% species protection guideline values was undertaken only for those toxicants where relevant trigger levels were available.
2. TWW = treated wastewater.
3. Initial dilution = 1:81 (worst case scenario for Ocean Reef; Outlet B). Contaminant dilution calculations were not performed (–) on any toxicants where concentrations were below the analytical limit of reporting.
4. The trigger values for marine waters are from Table 3.4.1 in ANZECC/ARMCANZ (2000). The EPA has provided advice that in WA waters where a high level of protection applies, the 99% species protection levels should be used.
5. Measured values are total chromium – while dissolved chromium in TWW is predominantly Cr III, a conservative approach was taken and assessment is against the Cr VI trigger.
6. Analytical limits for Chlorpyrifos were not low enough to confirm exceedance of, or compliance with, the ANZECC/ARMCANZ (2000) guidelines. Until detection limits required for direct comparison can be attained by commercial laboratories, WET testing will provide a test of the toxicity of the wastewater stream (see Section 2.2.2).
7. Trigger values are for Endosulphan, not Endosulphan sulfate (Table 3.4.1; ANZECC/ARMCANZ 2000).

Total toxicity of the mixture

The total toxicity of the mixture (TTM) calculation is an additional interpretative tool used for estimating the potential toxicity of TWW, and is used to evaluate EQG 3 for toxicants in TWW. The potential for cumulative toxic effects on marine organisms is assessed as per the ANZECC/ARMCANZ (2000) guidelines based on the effects of ammonia, copper and zinc (after initial dilution of the TWW with seawater), the three contaminants of concern most likely to exceed their respective guidelines.

$$\text{Total Toxicity of Mixture} = \frac{[\text{ammonia}]}{[\text{Trigger Value}]} + \frac{[\text{copper}]}{[\text{Trigger Value}]} + \frac{[\text{zinc}]}{[\text{Trigger Value}]}$$

The TTM must be <1 to meet the total toxicity criteria, in accordance with ANZECC/ARMCANZ (2000) guidelines. The initial mixing zone dilution calculated in the ASWQS (see above) is applied.

The calculated TTM following initial dilution was 0.75 (Table 2.2), which is below the ANZECC/ARMCANZ (2000) guideline value of 1.0 and meets the EQG. As a result, the combined additive effects of these contaminants are not likely to cause adverse effects on marine flora and fauna in the area surrounding the Ocean Reef outlets.

Table 2.2 Total toxicity of treated wastewater (TWW) at the edge of the initial mixing zone associated with the Ocean Reef ocean outlets

Natural concentrations in Perth's coastal waters (µg/L)			Initial dilution of TWW with seawater[2]	Total toxicity of the mixture (TTM) [3]
Ammonia[1]	Copper[1]	Zinc[1]		
1.5	0.08	0.15	1:81	0.75

Notes:
1. Background concentrations for copper and zinc from McAlpine et al. (2005); Perth marine waters (pp. 19; Table 12). Surface background concentration for ammonia calculated as median of reference site data from 2003–2015 (BMT Oceanica, unpublished data).
2. Calculated from data obtained at Outlet B, representing the 'worst-case' dilution.
3. TTM = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline.

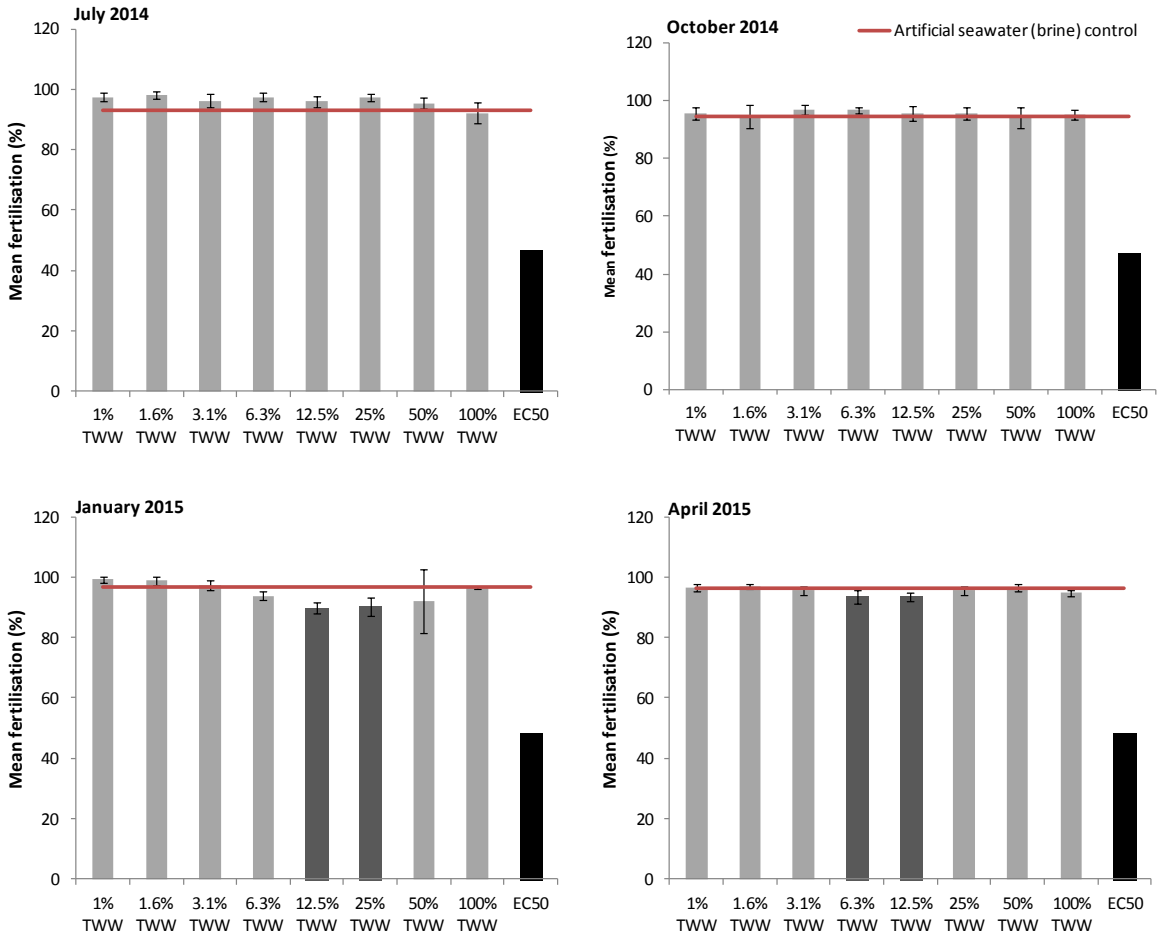
2.2.2 Whole of effluent toxicity (WET) testing

To meet the fourth EQG for TWW toxicants, quarterly WET testing is used to establish whether the TWW stream is toxic to marine biota. WET testing is particularly useful in the absence of reliable guidelines for toxicants that occur in low concentrations, or where the toxicity effects of contaminants are poorly understood. For example, the detection limits for pesticide analysis presently attainable by commercial laboratories in Australia are sometimes higher than the ANZECC/ARMCANZ (2000) guidelines.

WET testing involves exposing sea urchins (*Heliocidaris tuberculata*) to different concentrations of TWW effluent for ~1 hour and then measuring fertilisation success. This test has been chosen for its fast analytical turn-around time and the sea urchins' sensitivity to contaminants in TWW. The test results are used to calculate the NOEC (highest concentration where no significant effect is observed), LOEC (lowest concentration where a significant effect is observed) and the EC50 (the concentration of TWW causing 50% inhibition fertilisation rate). In some circumstances, sea urchin WET test results may act as a 'trigger' for a full suite of WET testing. This is an additional series of WET tests incorporating a suite of marine organisms from a variety of trophic levels. To trigger the full suite of WET tests, the NOEC must be ≤1.0% (equivalent to more than a 100-fold dilution; Table 1.2).

All WET tests were carried out by NATA-accredited Ecotox Services Australasia Pty Ltd (Ecotox), Sydney, New South Wales. Twenty-four hour flow-weighted composite samples were collected quarterly (July 2014, October 2014, January 2015, April 2015) from the Beenyup WWTP, using containers supplied by Ecotox. The test dilutions of TWW used were 1.0, 1.6, 3.1, 6.3, 12.5, 25, 50 and 100%. All TWW dilutions were salt-adjusted (using artificial sea salts) to achieve marine salinities, so that only the toxicity due to the presence of contaminants was examined, not the toxic effect of freshwater on the marine organism. Testing was also undertaken on a seawater control, and an artificial sea salt (brine) control.

There were no significant differences in fertilisation success between control and TWW solutions in July and October 2014 (Figure 2.3). Significantly lower fertilisation was reported for the 12.5% and 25% TWW concentrations in January 2015, and the 6.3% and 12.5% TWW concentrations in April 2015 (with all other concentrations not different to the control; Figure 2.3). All NOEC values were 100% TWW (Table 2.3). To meet the EQG for WET testing the NOEC must be greater than 1% TWW (i.e. ≤100−fold dilution). The trial EQG for WET testing was therefore met.



Notes:
1. Error bars are ± standard deviation.
2. TWW = treated wastewater.
3. Light grey bars represent concentrations of treated wastewater at which there is no observed significant effect on fertilisation. Dark grey bars represent concentrations of TWW that acted to significantly reduce the success of sea urchin fertilisation.
4. Percent fertilisation value for EC50 (black bars) was estimated by halving the number of gametes fertilised in the control sample; i.e. the artificial seawater control.

Figure 2.3 Results of 1-hour sea urchin fertilisation tests

Table 2.3 Calculated parameters from whole of effluent toxicity tests

Indicator	July 2014	October 2014	January 2015	April 2015
EC10	>100%	>100%	>100%	>100%
EC50	>100%	>100%	>100%	>100%
NOEC	100%	100%	100%	100%
LOEC	>100%	>100%	>100%	>100%

Notes:
1. EC10 = effective concentration of treated wastewater (TWW) causing 10% inhibition of fertilisation rate.
2. EC50 = effective concentration of TWW causing 50% inhibition of fertilisation rate.
3. NOEC = no observed effect concentration.
4. LOEC = lowest observed effect concentration.

2.3 Water quality monitoring – receiving environment

Water quality was monitored approximately fortnightly from the beginning of December 2014 to the end of March 2015 (Table 2.4), coinciding with the non-river flow period. The TCM program collects data for comparison with the trial EQC for nutrients, phytoplankton biomass and physical and chemical stressors (Table 1.2).

Table 2.4 Timing of water quality monitoring near the Ocean Reef ocean outlets between December 2014 and March 2015

Sample day	Date
1	03/12/2014
2	17/12/2014
3	08/01/2015
4	22/01/2015
5	13/02/2015
6	27/02/2015
7	11/03/2015
8	25/03/2015

On each sampling occasion, a surface drogue was deployed over the centre of the ocean outlet diffuser and retrieved ~30 min later. The drift direction of the drogue was used to provide a directional vector and samples were collected at five compliance sites located at intervals of 0, 100, 350, 1000, and 1500 m along that vector down-current of the outlets (Figure 2.4). Samples were also collected at four reference sites.

A composite sample representative of the top half of the water column, was collected from each site for analysis of chlorophyll-a and nutrients. Chlorophyll-a was measured using material retained on GF/C filters through which 1–5 L of water was passed. Water samples for inorganic nutrient analysis were passed through a 0.45 µm GF/C filter. All samples were immediately placed on ice before being transported to the laboratory for analysis. Samples were analysed at Murdoch University's Marine and Freshwater Laboratory using standard laboratory analytical procedures undertaken according to NATA-accredited methods (refer Appendix B).

At each of the sites the following physio-chemical parameters were measured in situ using a YSI 6600/YSI 600XL water quality sensor or LiCor Model LI–1000 light meter:

- dissolved oxygen (DO) depth profile
- salinity depth profile
- irradiance
- temperature depth profile (for contextual purposes).

Irradiance measurements are obtained with one sensor positioned 1 m below the surface and a second sensor 7 m below the surface and the light attenuation coefficient (LAC) calculated as follows:

LAC = [$\log_{10}$ (irradiance at depth) − $\log_{10}$ (irradiance at surface)/depth interval (in metres)][3]

The extent to which the EQG were met was assessed using data collected at distances ≥100 m from the ocean outlets. Sites positioned at distances >100 m from the diffuser are considered to lie within the HEPA. Any data collected inside the 100 m radius (notional LEPA) are presented for contextual purposes only.

[3] *Base 10 logs have been specified as they are generally the basis for environmental quality criteria favoured by the Office of the EPA.*

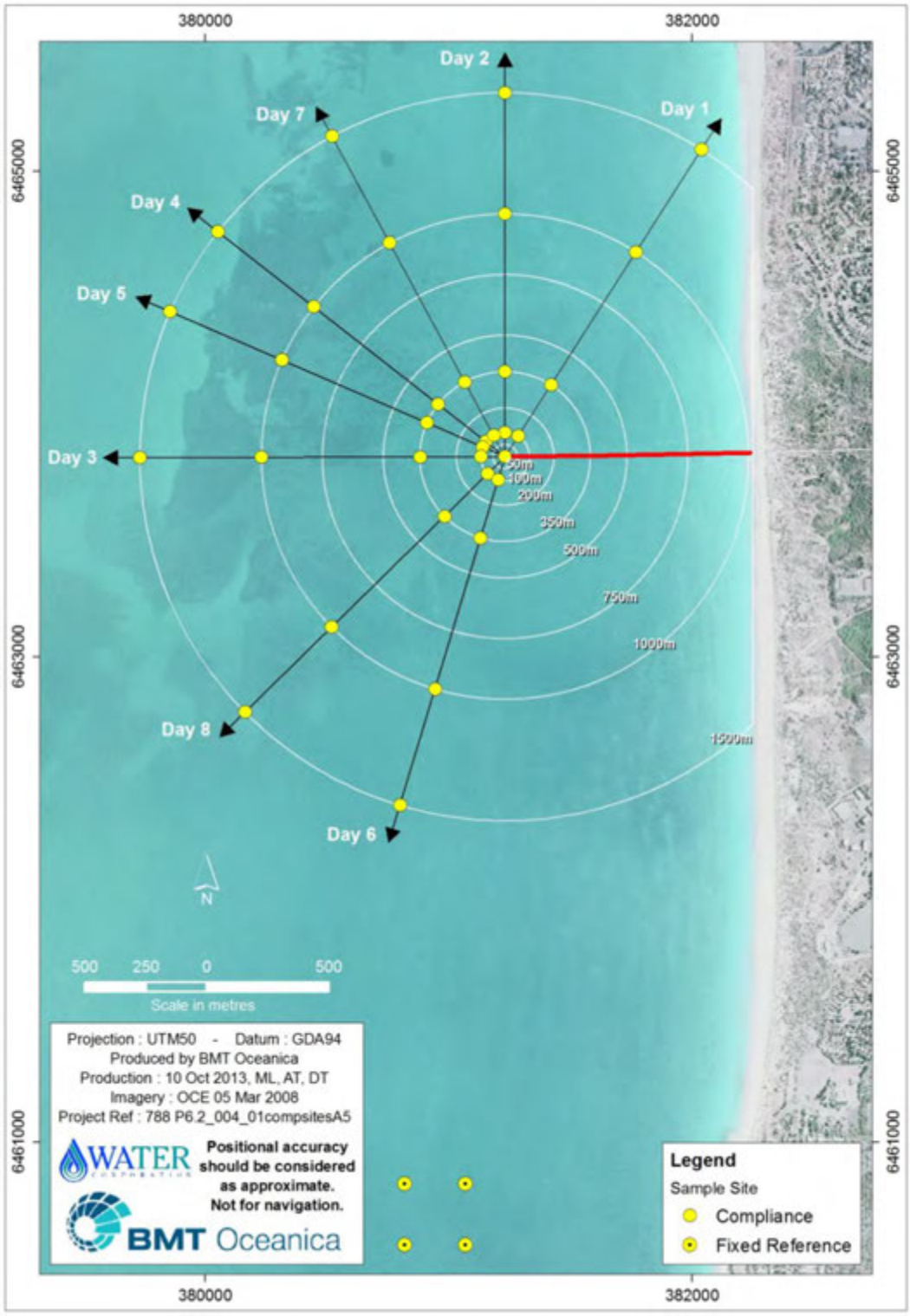


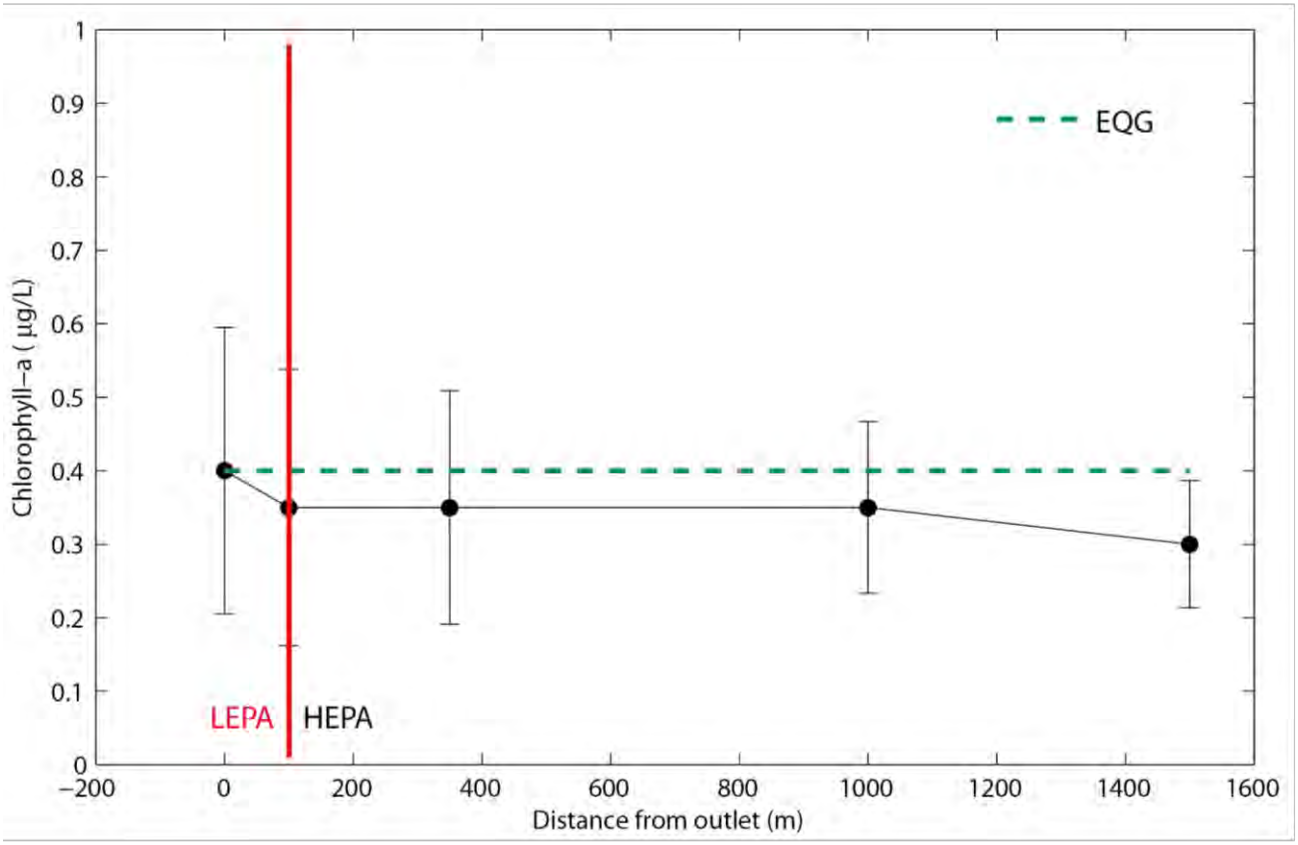
Figure 2.4 Conceptual diagram of the Trial Compliance Monitoring program showing hypothetical compliance sites and their relative distances from the outlet diffusers

2.3.1 Nutrient enrichment

TWW contains elevated concentrations of biologically available nutrients, including ammonia, nitrite, nitrate and orthophosphate. The addition of nutrients may act to stimulate phytoplankton growth beyond natural levels, which under some circumstances may lead to shading of benthic primary producing assemblages such as seagrasses and/or macroalgae. To monitor the potential adverse effects of these inputs, EQGs have been developed for in-water measures of chlorophyll-a (a measure of phytoplankton biomass) and light attenuation (a measure of water clarity).

The EQG for nutrient enrichment (chlorophyll-a) requires that the median chlorophyll-a concentration in the HEPA during non-river flow periods not exceed the 80th percentile of historical reference data.

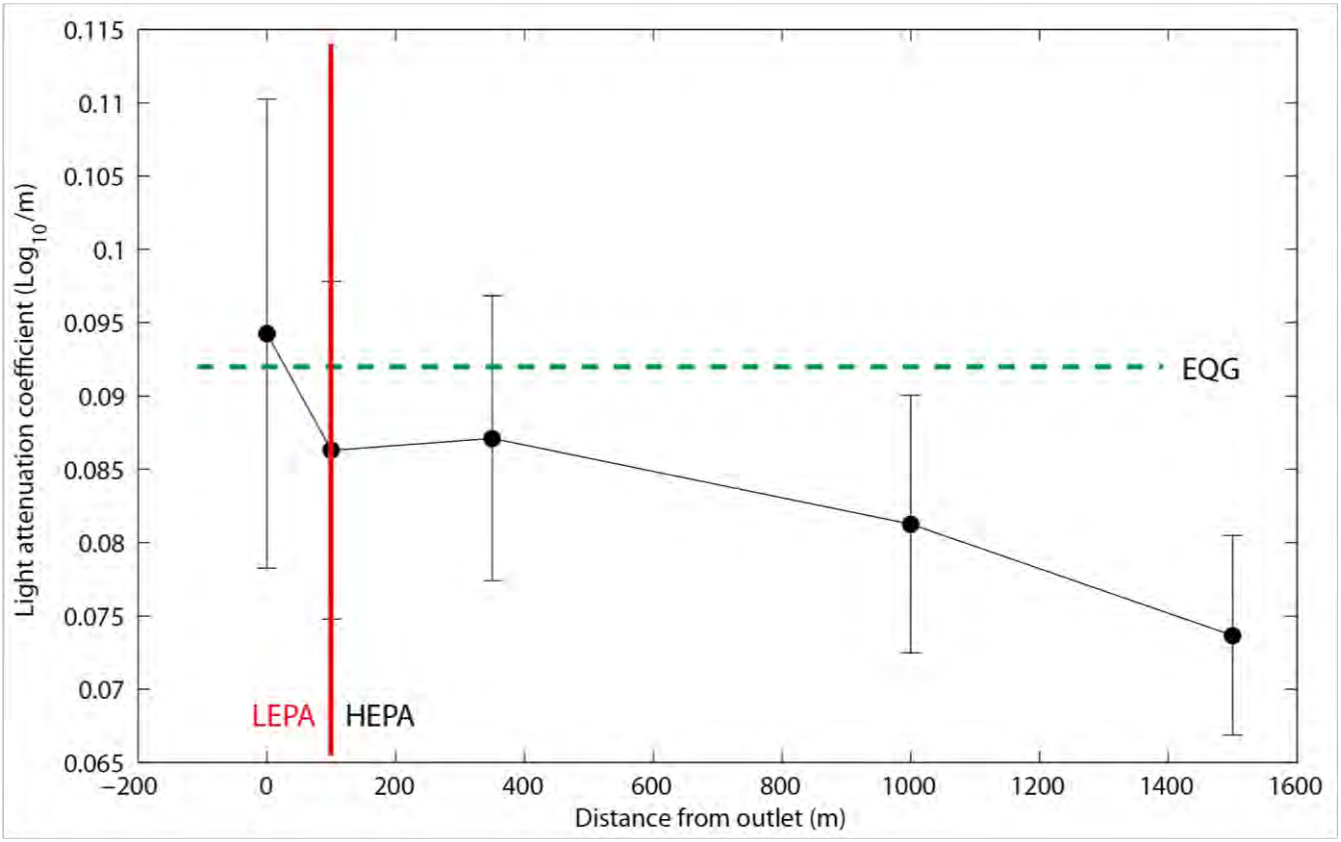
Median chlorophyll-a concentrations ranged from a high of 0.40 µg/L directly above the outlet to a low of 0.30 µg/L at 1500 m down-current (Figure 2.5). The overall median chlorophyll-a concentration in the Ocean Reef HEPA was 0.35 µg/L. This is below the 80th percentile of historical reference site data (0.40 µg/L; Figure 2.5), thus meeting the EQG.



Notes:
1. Error bars represent ±95% confidence intervals.
2. EQG is the 80th percentile of historical reference site data (0.4 µg/L chlorophyll-a).
3. Data were pooled across eight sampling days (n=8) over December 2014 to March 2015.
4. LEPA = notional low ecological protection area; HEPA = high ecological protection area.

Figure 2.5 Median chlorophyll-a concentrations obtained at fixed monitoring sites above and down-current of the Ocean Reef outlets during Trial Compliance Monitoring

The EQG for nutrient enrichment (light attenuation) in the receiving waters of the Ocean Reef outlets requires that the median LAC measured at sites ≥100 m from the outlets during the non-river flow period must not exceed the 80th percentile of historical reference site data (0.092 Log_{10}/m). During the 2014–2015 monitoring period, median LAC values ≥100 m from the outlet ranged between 0.074 and 0.087 Log_{10}/m, with elevated light attenuation directly above the outlet (0.095 Log_{10}/m; Figure 2.6). The overall median light attenuation within the HEPA (0.080 Log_{10}/m) was lower than the 80th percentile of historical reference data (0.092 Log_{10}/m; Figure 2.6), thus meeting the EQG.



Note:
1. Error bars represent ±95% confidence intervals.
2. EQG is the 80th percentile of historical reference site data (0.092 Log_{10}/m).
3. Data were pooled across eight sampling days (n=8) over December 2014 to March 2015.
4. LEPA = notional low ecological protection area; HEPA = high ecological protection area.

Figure 2.6 Median light attenuation coefficients obtained at fixed distances down-current of the Ocean Reef outlets during Trial Compliance Monitoring

2.3.2 Phytoplankton blooms

The EQG for phytoplankton blooms (measured as chlorophyll-a concentration) in the HEPA surrounding the Ocean Reef outlets are required to meet the following criteria:

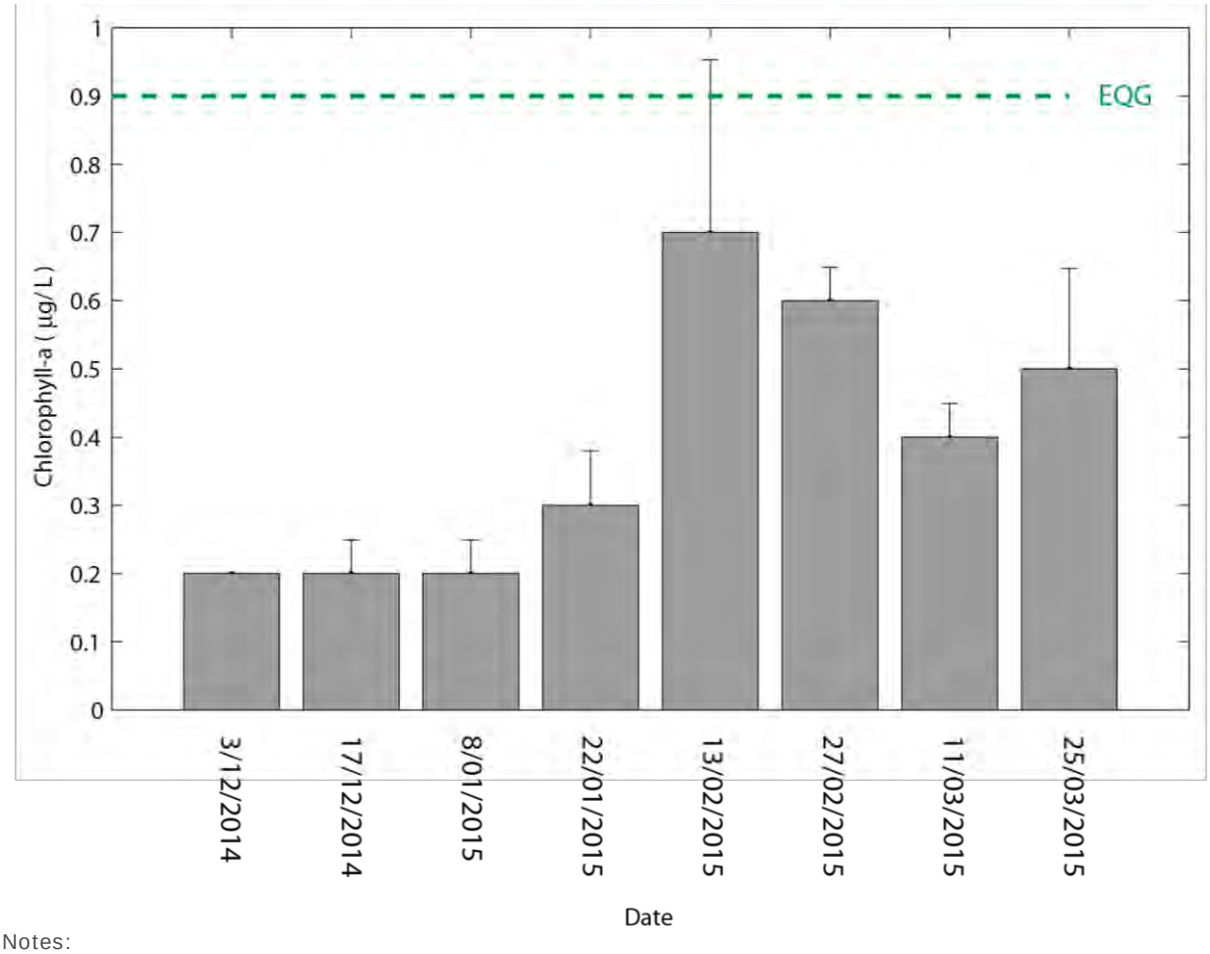
1. Ambient value[4] for phytoplankton biomass measured as chlorophyll-a not to exceed three times median chlorophyll-a concentration of reference sites, on any occasion during non-river flow period[5].
2. Phytoplankton biomass measured as chlorophyll-a at any site not to exceed three times median chlorophyll-a concentration of reference sites, on 25% or more occasions during the non-river flow period.

Ambient values are calculated on each sampling occasion using pooled data from sites located ≥100 m from the outlets (i.e. 100, 350, 1000 and 1500 m). Three times the median is calculated from historical reference site data collected between 2003 and 2015.

During the 2014–2015 non-river flow period, ambient chlorophyll-a concentrations in the HEPA ranged from 0.2 to 0.7 µg/L (Figure 2.7). On no occasion did the median chlorophyll-a value exceed three times the median of the reference sites (0.9 µg/L; Figure 2.7), so the requirements of EQG 1 were met.

Chlorophyll samples at any site (and at any time) exceeded three times the median of reference sites on 3.1% of occasions (Appendix G), thus meeting the requirements of EQG 2 (<25% of occasions).

[4] *Ambient value = median value of individual sample data for a defined area.*
[5] *Non-river flow period = December–March inclusive, when river flows are weak.*



Notes:
1. Error bars represent ±95% confidence intervals.
2. EQG is 3-times the median chlorophyll-a concentration of reference site data.
3. Values measured at 0 m are not included in the figure or EQG assessment, as the 0 m site is situated directly above the outlet within the notional LEPA.
4. Data were pooled across four sites within the HEPA (n=4).

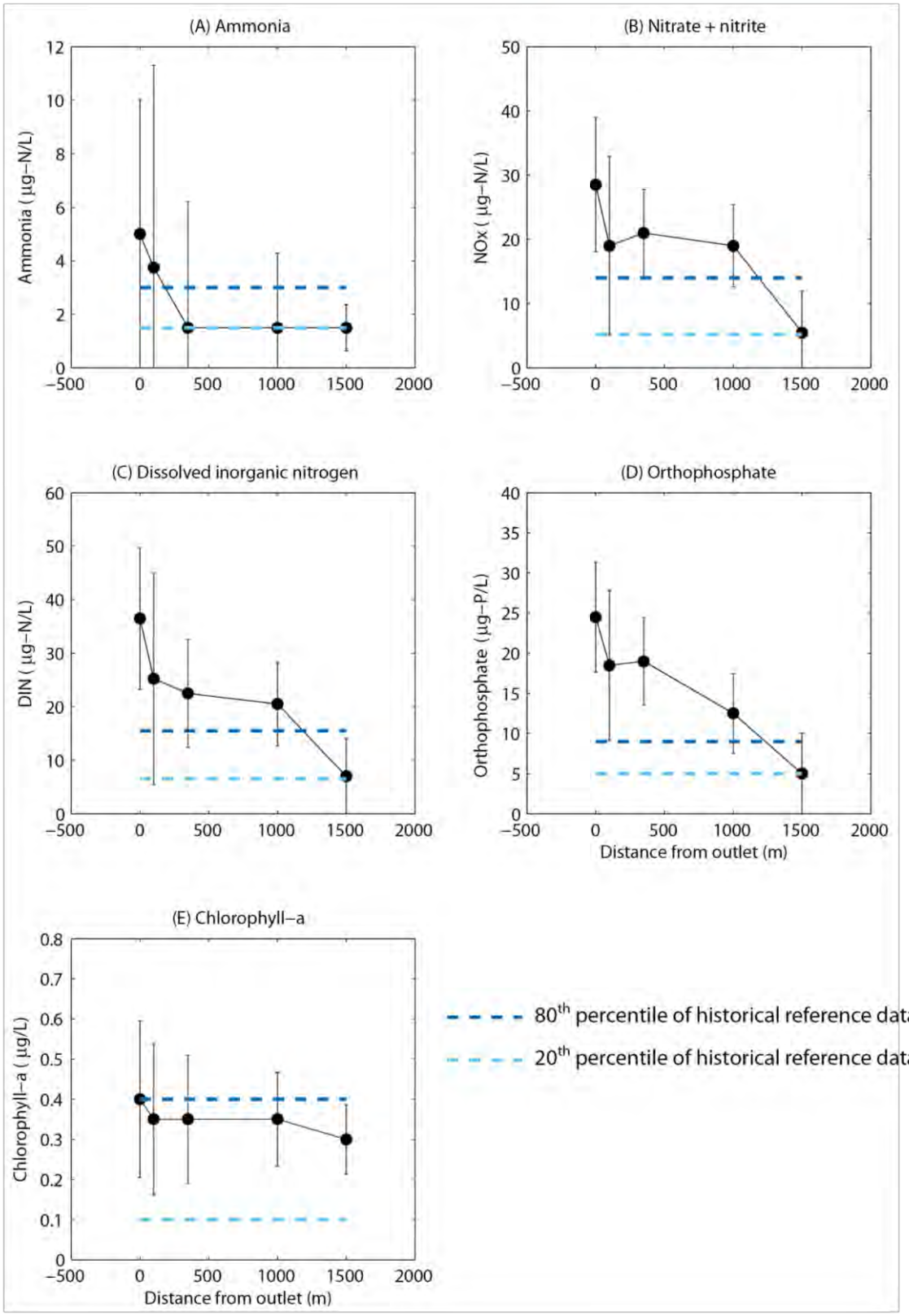
Figure 2.7 Median phytoplankton biomass on fortnightly sampling occasions, pooling data from fixed sites ≥100 m down-current of the Ocean Reef ocean outlets

Additional data – nutrient gradients

The characterisation of nutrient gradients in the area surrounding Perth's ocean outlets is a useful management tool and enables managers to detect the sphere of influence of the plume, including the distance down-current of the outlets where nutrient concentrations reach background levels. Background levels in this case are considered to be in the range between the 80th and 20th percentiles of all historical reference site data collected between 2003 and 2015 (dark blue and light blue broken lines, respectively, in Figure 2.8).

Median concentrations of nitrate+nitrite (NO_x) and orthophosphate were elevated above background concentrations at the outlets and remained higher than background until ~1200 m down-current (Figure 2.8B,D). Dissolved inorganic nitrogen was also elevated over the same region (Figure 2.8C) – this was predominantly due to the contribution of NO_x to the overall dissolved nitrogen load, although ammonia also made a contribution within the first ~200 m down-current (Figure 2.8A). NO_x comprises the majority of the dissolved inorganic nitrogen because the advanced nitrification processes employed at the Beenyup WWTP convert ammonia to nitrite and then nitrate.

These data, which were collected on eight occasions over a 16-week period, give a good indication of the rapid dilution down-current of the outlets (e.g. ~40% reduction in dissolved inorganic nitrogen in the first 350 m down-current of the outlets; Figure 2.8). However, nutrient concentrations varied considerably between sites and between sampling occasions due to variations in discharge, oceanographic conditions (mixing) on the day of sampling, and rates of biological uptake. Variation at each of the sites is indicated by the length of the 95% confidence interval bars, with the initial high variability of the TWW plume clearly evident closest to the outlets (i.e. 0–100 m; Figure 2.8).



Notes:
1. Error bars represent ±95% confidence intervals.
2. Data were pooled across eight sampling days (n=8).

Figure 2.8 Median nutrient and chlorophyll-a concentrations obtained at fixed monitoring sites above and down-current of the Ocean Reef ocean outlets during Trial Compliance Monitoring

2.3.3 Physical-chemical stressors

Two sets of EQC relevant to physical-chemical stressors are measured as part of the TCM program: dissolved oxygen (DO) and salinity.

TWW may contain organic matter that is decomposed by microorganisms, which use oxygen in the process. If more DO is consumed than is produced, DO levels decline. However, DO levels fluctuate naturally; therefore, the EQC compare DO saturation surrounding the outlets to the natural variation in the region (i.e. reference site data at the time of sampling). Should DO deviate beyond that expected naturally for a period of 6 weeks or longer, then there is considered to be a significant risk that the EQO may have been compromised.

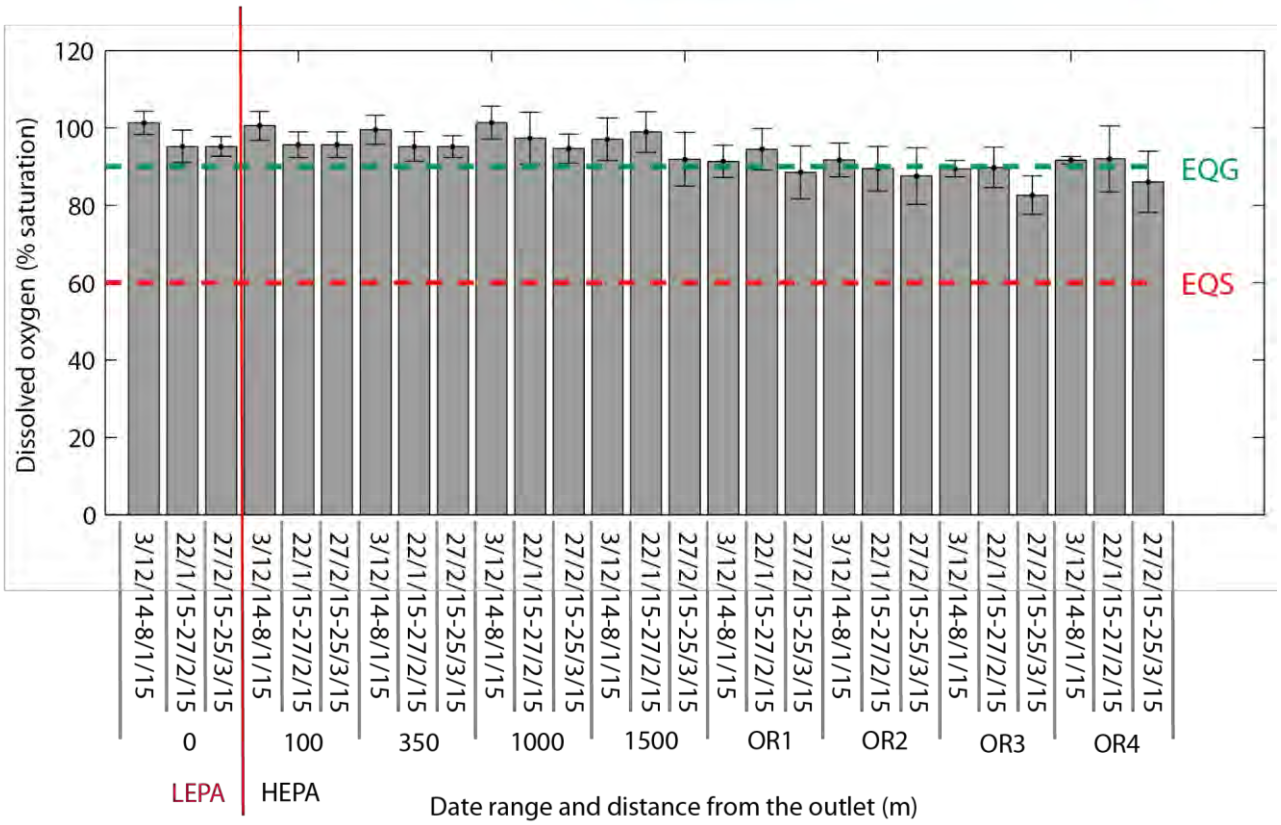
Salinity, which may have a direct effect on marine biota, can decrease as a result of the freshwater TWW plume. Similar to DO, salinity is naturally variable and the EQC is compared to the natural variation expected in the region at the time of sampling (i.e. reference site data).

Dissolved oxygen (DO)

The trial EQG for organic enrichment in the receiving waters of the Ocean Reef ocean outlets requires that the ambient value for DO in bottom waters (0−0.5 m above the sediment surface) must be >90% saturation at any site for a defined period of ≤6 weeks. The trial EQS requires that: (i) the ambient value for DO in bottom waters (measured 0−0.5 m above the seabed) is >60% saturation at any site for a defined period of ≤6 weeks, and (ii) that no deaths of marine organisms resulting from deoxygenation occur[6].

The near-bottom (0−0.5 m) DO measured at the Ocean Reef TCM sites on eight occasions between December 2014 and March 2015 remained >90% saturation at all times (Figure 2.9). Near-bottom DO saturation at the four Ocean Reef reference sites (OR1−OR4) was <90% saturation on a number of sampling occasions, and typically less saturated than in waters potentially exposed to the TWW plume (Figure 2.9). As the ambient value for DO in bottom waters at the TCM sites was >90% saturation over defined periods of ≤6 weeks during the 2014−2015 monitoring period, with no reported deaths of marine organisms as a result of deoxygenation, both the EQG and EQS for organic enrichment were met.

[6] *Note that where there is more than one EQC for an indicator designated by (i) or (ii), each one is to be considered individually. If any criteria are exceeded then the guideline or standard for that indicator has not been met.*



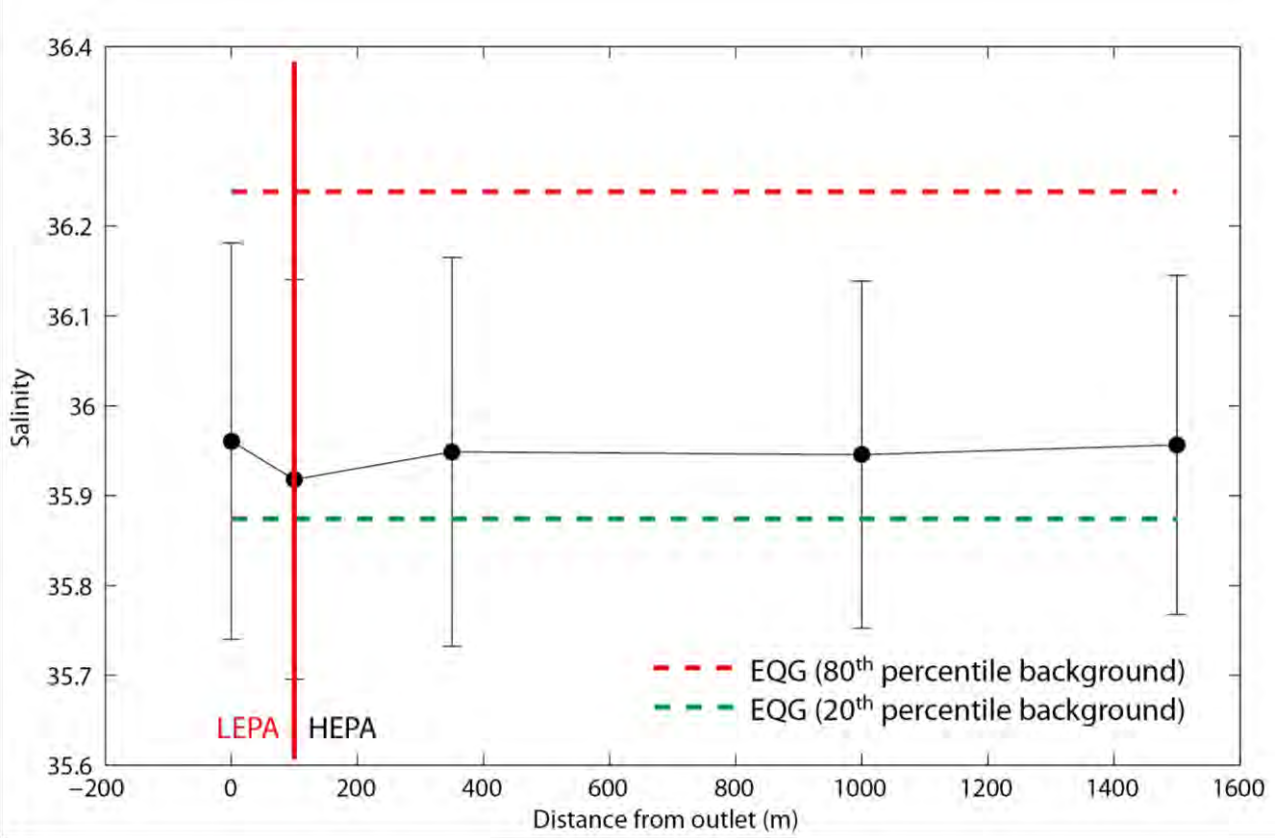
Notes:
1. Error bars represent ±95% confidence intervals.
2. DO measured 0–0.5 m above the seabed.
3. EQG is 90% DO saturation; EQS is 60% DO saturation.
4. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
5. Reference site data (OR1–OR4) are compared against EQG and EQG for contextual purposes only.

Figure 2.9 Median dissolved oxygen (DO) for defined periods of ≤6 weeks during Trial Compliance Monitoring

Salinity

The EQG for salinity in the receiving waters of the Ocean Reef outlets requires that median salinity (measured as parts per thousand, 0.5 m below the water surface) at any individual site over any period is not to deviate beyond the 20th and 80th percentile of the natural salinity range over the same period (i.e. reference site data). The EQS requires that no deaths of marine organisms resulting from anthropogenically sourced salinity stress are to occur.

Within the HEPA, median salinity ranged from 35.92 (at 100 m down-current) to 35.96 (at 1500 m down-current) and was well within the 20th and 80th percentile of reference data (Figure 2.10), thus meeting the EQG. The EQS for salinity requires that there are no deaths of marine organisms resulting from anthropogenically sourced salinity stress. As the EQG was met, and there were no observed (or reported) deaths of marine organisms over the reporting period, the EQS was also met.



Notes:
1. Error bars represent ±95% confidence intervals.
2. Salinity measured 0–0.5 m below the sea surface.
3. Data for each distance were pooled across eight sampling occasions (n=8) over December 2014 to March 2015.
4. LEPA = notional low ecological protection area; HEPA = high ecological protection area.

Figure 2.10 Median salinity compared to the 20th and 80th percentile of reference site data (EQG) over the same period

2.4 Compliance summary

Results of the 2014–2015 monitoring program found no exceedances of the EQC for the EQO Maintenance of Ecosystem Integrity (Table 2.5). Therefore, there is a high degree of certainty that the EQO has been met for the 2014–2015 reporting period. A compliance summary for each of the key indicators is provided below and summarised in Table 2.5.

Toxicants in treated wastewater:
There are four EQGs relating to toxicants in the TWW, all of which are tested annually.

To meet EQG 1, bioaccumulating toxicant (specifically, cadmium and mercury) concentrations must be below their respective 80% species protection guidelines prior to undergoing initial dilution with seawater. Concentrations of bioaccumulating toxicants were below the 80% species protection guidelines in all cases, thus meeting the EQG.

To meet EQG 2, non-bioaccumulating contaminants must not exceed the ANZECC/ARMCANZ (2000) guideline for 99% species protection at the LEPA boundary. Initial dilution modelling found that the Ocean Reef outlets were achieving worst-case average initial dilution of 1:81. Following initial dilution, contaminants measured in the Ocean Reef TWW on 3 February 2015 were below all available 99% species protection guidelines, thus meeting the EQG.

EQG 3 requires that the TTM for the additive effect of ammonia, copper and zinc in the diluted TWW plume is <1.0. The calculated TTM following initial dilution was 0.75, which is below the ANZECC/ARMCANZ (2000) guideline value and meets the EQG.

To meet EQG 4, the NOEC (highest concentration with no significant effect) derived from WET testing must be >1.0% TWW concentration (i.e. <100-fold dilution). The NOEC values for all sampling dates were 100% TWW concentration, thus meeting the EQG.

Water quality monitoring – receiving environment:
The EQG for nutrient enrichment (chlorophyll-a) requires that the median chlorophyll-a concentration in the HEPA during non-river flow periods not exceed the 80th percentile of historical reference site data. The overall median chlorophyll-a concentration within the Ocean Reef HEPA was 0.35 µg/L. This is below to the 80th percentile of historical reference site data (0.40 µg/L), thus meeting the EQG.

The EQG for nutrient enrichment also requires that the median LAC of a defined area during the non-river flow period does not exceed the 80th percentile of historical reference site data. Median LAC within the HEPA (0.080 Log_{10}/m) was lower than the 80th percentile of historical reference site data (0.092 Log_{10}/m). The EQG was therefore met.

The EQG for phytoplankton blooms (measured as chlorophyll-a concentration) requires that during the non-river flow period, median chlorophyll-a in the HEPA not exceed three times the median chlorophyll-a concentration of reference sites on any occasion (EQG 1), and that chlorophyll-a at any site does not exceed three times reference site levels on 25% or more occasions (EQG 2). During 2014–2015 monitoring, on no occasion did the median chlorophyll-a value exceed three times the median of the reference sites, and there were only 3.1% of individual chlorophyll-a samples at any site (or at any time) that exceeded three times reference site levels. The EQG were therefore met.

The EQG for organic enrichment requires that the median value for DO in bottom waters (0–0.5 m above the sediment surface) must be >90% saturation at any site for a defined period of ≤6 weeks. The near-bottom (0–0.5 m) DO remained >90% saturation at all times, thus meeting the EQG.

The EQG for salinity requires that median salinity (0–0.5 m below the water surface) at any individual site over any period is not to deviate beyond the 20th or 80th percentile of the natural salinity range over the same period (i.e. reference site data). Within the HEPA, salinity ranged from 35.92 to 35.96 and was well within the 20th and 80th percentiles of reference data, thus meeting the EQG.

Table 2.5 Compliance against EQC relevant to the EQO 'Maintenance of Ecosystem Integrity'

Environmental quality indicator		Comments	Compliance
Toxicants in treated wastewater (TWW)	Bioaccumulating toxicants	Cadmium and mercury in the undiluted TWW stream were measured at concentrations well below the ANZECC/ARMCANZ (2000) values for 80% species protection	■
	Non-bioaccumulating toxicants and initial dilution	The rate of initial dilution achieved on 3 February 2015 (1:81) was sufficient to reduce contaminant concentrations to values lower than the ANZECC/ARMCANZ (2000) values for 99% species protection	■
	Total toxicity of the mixture (TTM)	The TTM for the additive effect of ammonia, copper and zinc after initial dilution (0.75) was lower than the ANZECC/ARMCANZ (2000) guideline value of 1.0	■
	Whole of effluent toxicity testing	No dilution of the TWW was required to meet the NOEC	■
Nutrient enrichment	Chlorophyll-a	The overall median chlorophyll-a concentration within the high ecological protection area (HEPA) was lower than the 80th percentile of historical reference site data	■
	Light attenuation coefficient (LAC)	The overall median LAC within the HEPA was lower than the 80th percentile of historical reference site data	■
Phytoplankton blooms	Phytoplankton biomass (measured as chlorophyll-a)	1. Median chlorophyll-a levels in the HEPA did not exceed 3-times median of reference sites	■
		2. Chlorophyll-a samples at any site (and at any time) exceeded 3-times reference levels on 3.1% of occasions	■
Physical-chemistry	Organic enrichment	Dissolved oxygen saturation remained above 90% concentration over the Trial Compliance Monitoring period	■
	Salinity	Within the HEPA, median salinity was within the 20th and 80th percentile of reference site data	■

Notes:

1. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS), respectively.
2. NOEC = no observed effect concentration; the highest concentration of TWW at which there is no statistically significant observed effect on gamete fertilisation.
3. EQO = Environmental Quality Objective.

3. Maintenance of Seafood for Human Consumption

3.1 Environmental Quality Objective

The EQO for the EV 'Fishing and Aquaculture' is aimed at ensuring seafood is safe for human consumption. To ensure the EQO is being met, microbiological contaminants and algal (phytoplankton) biotoxins are monitored as part of the PLOOM TCM program and the PLOOM ASWQS. Ministerial Conditions placed on the operation of the Beenyup WWTP by the EPA also require that a survey of metals and pesticides in marine biota be undertaken every three years (the most recent survey was in summer 2012–2013, and reported in BMT Oceanica (2013)).

The EQO, Maintenance of Seafood Safe for Human Consumption, is primarily concerned with the harvesting and consumption of raw shellfish (i.e. filter-feeding bivalve molluscs such as oysters, mussels, clams, pipis, scallops, cockles, and razor clams) and not other forms of seafood. Human health concerns relating to consumption of shellfish are not considered an issue at Ocean Reef as there is no aquaculture within 250 m of the diffuser and no known harvesting of shellfish in the waters 1–3 km offshore. The Department of Health (DoH) discourages the public from taking wild shellfish, recommending instead that shellfish are only consumed if harvested commercially and under a strict monitoring program. The DoH has further indicated that "it is impossible to guarantee the safety of eating wild shellfish without having a comprehensive monitoring program that tests the waterway concerned for harmful microorganisms and toxins" and has formally advised the Department of Environment and Conservation[7] that, in the absence of a full monitoring program, the application of the TTC criteria (EPA 2005b) is insufficient to protect those who wish to collect and eat wild shellfish.

3.2 Microbiological contaminants and algal biotoxins

The accepted method for determining whether the relevant EQC for maintenance of seafood for human consumption (Table 1.3) have been met is to monitor microbiological contaminants (measured as concentrations of thermotolerant coliforms (TTC)) and algal biotoxins (measured as concentrations of phytoplankton species) at the boundary of a pre-designated management zone. Such an approach has been developed for the ocean outlets at Sepia Depression (BMT Oceanica 2014a) and Alkimos (Oceanica 2011b).

Many disease-causing organisms are transferred from human and animal faeces to water via sewage effluent, from where they can be ingested by marine fauna and infect them, adversely affecting their suitability for human consumption. TTC are one such bacteria that primarily originate in the intestines of warm-blooded animals. By testing for TTC, it can be determined whether the ocean water around Ocean Reef has potentially been exposed to faecal contamination.

Nutrient enrichment as a result of TWW discharge could result in changes to the naturally occurring planktonic algal community. Although most algal blooms are considered harmless, some may contain species that produce toxins that have a potentially harmful effect on the surrounding marine environment. Species such as *Heterosigma akashiwo* and *Cryptosporidium parvum* are two such algae that cause fish mortalities.

As formal management zones have yet to be established for the Ocean Reef ocean outlets, sampling for the EQO Seafood for Human Consumption was undertaken at a series of fixed monitoring sites located at the boundary of an 'observed zone of influence' (OZI; Figure 3.1). The OZI was derived from ten years of monitoring data

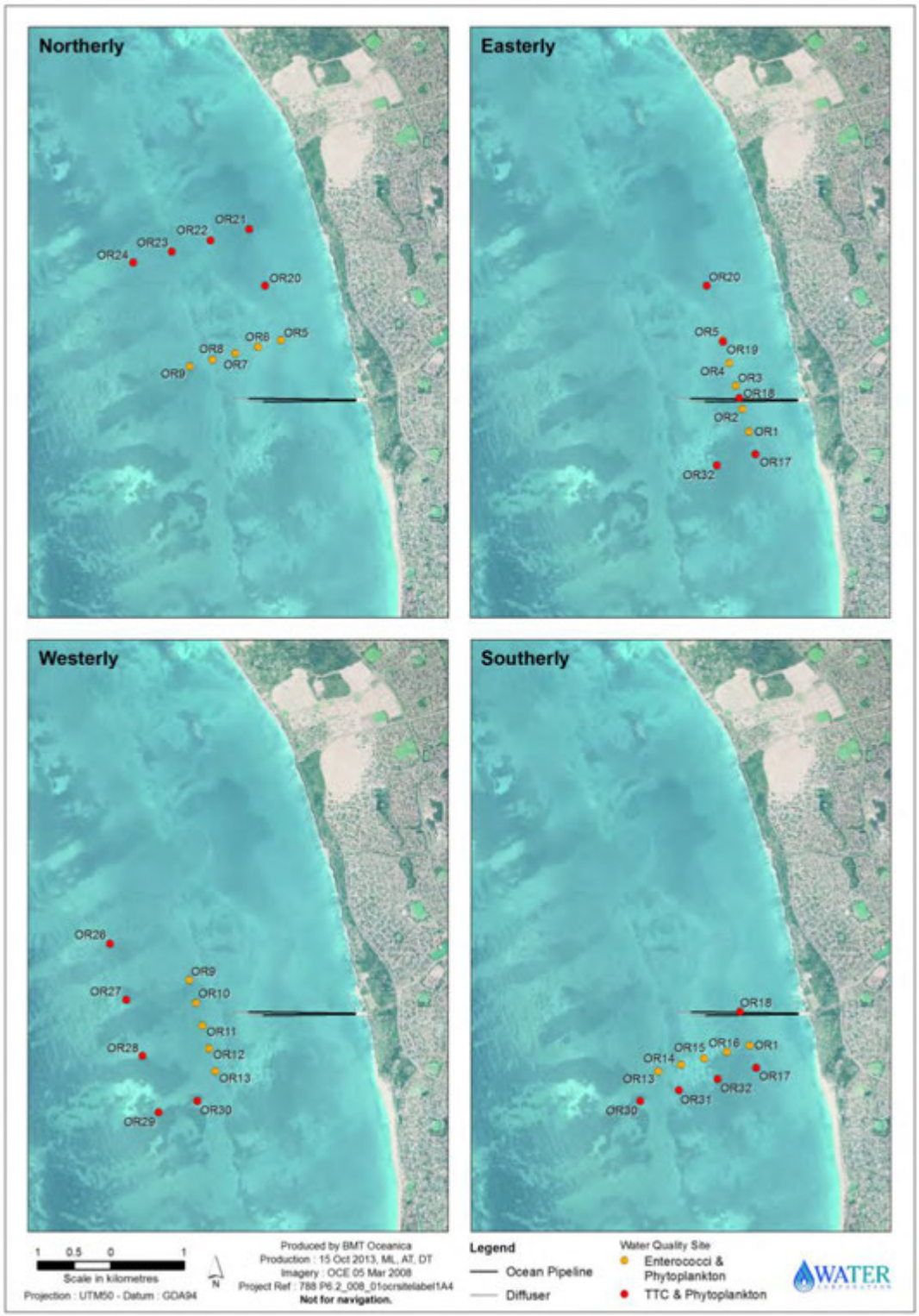
[7] *Now known as Department of Environment Regulation.*

collected at Ocean Reef. Data collected at the boundaries of the OZI are used in the assessment of the EQC. The OZI allow direct comparison with outlets where similar zones have been adopted as a requirement (i.e. Alkimos and Sepia Depression).

Samples were collected approximately fortnightly during the non-river flow period at five fixed sites located on the boundary of the OZI immediately down-current of the diffusers, with site selection based on the water current direction as indicated by the drogue (Figure 3.1, Figure 3.2). Composite water samples representative of the top half of the water column were collected and analysed for TTC and phytoplankton species.

For TTC, samples were collected in pre-sterilised bottles before being chilled in the dark to 4°C. Samples were subsequently transferred to PathWest Laboratories and analysed according to NATA-accredited methods (Appendix B).

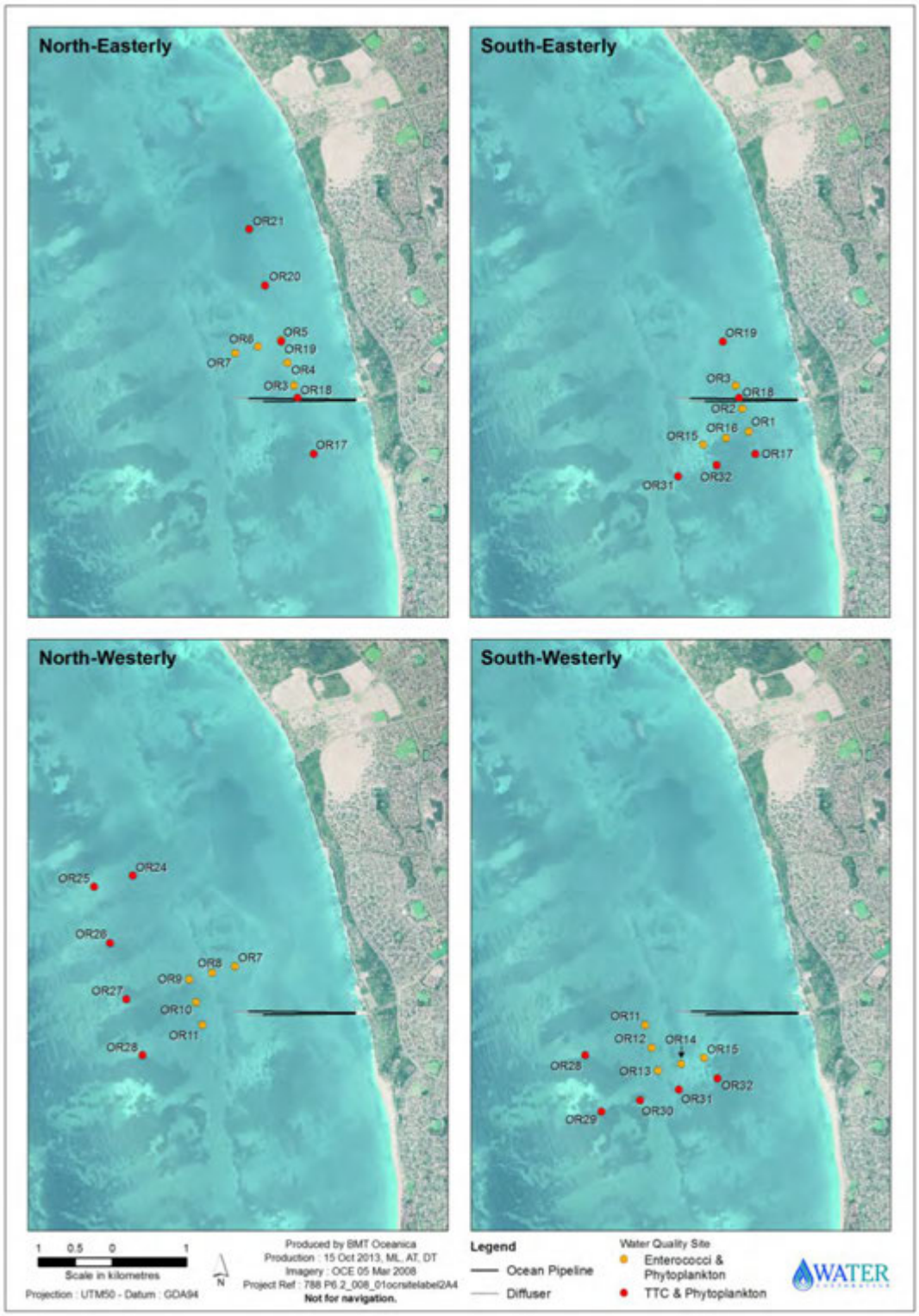
For phytoplankton, samples were preserved in Lugol's iodine solution and transported to Dalcon Environmental Laboratories for phytoplankton identification using the Utermöhl method. Phytoplankton were identified to the lowest taxonomic level possible. On each sampling date only one sample (i.e. in the direct path of the drogue) was analysed and the remaining four samples archived. In the event that toxic phytoplankton species are present at concentrations that exceed the recommended WASQAP guideline concentrations (DoF 2007), the full set of archived samples collected on that sampling occasion are also analysed (Table 3.1).



Notes:

1. Sites are located on the boundary of the observed zone of influence (OZI).

Figure 3.1 Fixed sites around the Ocean Reef outlet sampled for thermotolerant coliforms, *Enterococci* spp. and algal (phytoplankton) toxins during periods with northerly, easterly, westerly and southerly currents



Notes:

1. Sites are located on the boundary of the observed zone of influence (OZI).

Figure 3.2 Fixed sites around the Ocean Reef outlet sampled for thermotolerant coliforms, *Enterococci* spp. and algal (phytoplankton) toxins during periods with north-easterly, south-easterly, north-westerly and south-westerly currents

Table 3.1 Protocols for analysis of archived phytoplankton samples

Outcome of initial analysis	Further action
No exceedance of WASQAP[1] guideline concentrations	No analysis of archived samples
Exceedance of WASQAP guideline concentrations at both the reference site and the TCM[2] site	No analysis of archived samples
Exceedance of WASQAP guideline concentrations at the reference site, but not at the TCM site	No analysis of archived samples
Exceedance of WASQAP guideline concentrations at the TCM site but not at the reference site	Additional samples analysed

Notes:
1. Western Australian Shellfish Quality Assurance Program, DoF (2007).
2. Trial Compliance Monitoring.

3.2.1 Thermotolerant coliforms

The EQG for microbiological contaminants (measured as TTC) requires that median TTC concentrations, calculated from data collected at the boundary of the OZI, are not to exceed 14 CFU/100 mL, with ≤10% of samples to exceed 21 CFU/100 mL. The EQS requires that median TTC concentrations at the OZI boundary not exceed 70 CFU/100 mL, with ≤10% of samples exceeding 85 CFU/100 mL.

TTC were sampled for eight times over the 2014–2015 monitoring period (yielding a total of 40 samples). NHMRC (2008) guidelines and EPA (2005a) suggest that a minimum of 100 samples over the non-river flow period are needed for accurate assessment of microbial water quality EQC. If there are <100 samples in a given sampling year, data can be pooled from multiple years provided there is no reason to believe that local pollution conditions have changed (NHMRC 2008). We make the assumption that pollution conditions have not changed over the past 3 monitoring periods and present data collected since summer 2012–13 (pooled 3-season dataset), yielding a sample size of n=120 and thereby allowing an assessment against the EQC.

The median value for TTC derived from samples collected over the 2012–2013, 2013–2014 and 2014–2015 monitoring periods was at the limit of detection (<10 CFU/100 mL; Table 3.2, BMT Oceanica 2013, 2014b), meeting the EQG criterion for median concentrations. Over the three sampling periods, there were 12 instances where TTC exceeded 21 CFU/100 mL, representing 10% of the available samples and meeting the criteria for percentage of samples above 21 CFU/100 mL (Table 3.3).

Table 3.2 Median thermotolerant coliform concentration at the fixed monitoring sites for the Ocean Reef ocean outlet for 2012–2015 and comparison to the EQC

Date	Median (CFU/100 mL)	Compliance (EQG)
Dec 2012–Mar 2013 Dec 2013–Mar 2014 Dec 2015–Mar 2015 (n=120)	<10	■

Notes:
1. Green symbols (■) indicate the Environmental Quality Guidelines (EQGs) were met; amber (■) and red (■) symbols represent an exceedance of EQG and Environmental Quality Standard (EQS), respectively.
2. For site locations and GPS waypoints, see Figure 3.1, Figure 3.2 and Appendix H
3. Thermotolerant coliform results below the analytical detection limit (< 10 CFU/100 mL) were halved (= 5 CFU/100 mL) to calculate the median.
4. Environmental Quality Criteria (EQC) are based on ANZECC/ARMCANZ (2000) water quality guidelines for recreation waters.

Table 3.3 Thermotolerant coliform abundance for sites at the edge of the Ocean Reef OZI that exceeded concentrations of 21 CFU/100 mL and comparison to the EQC

Sampling season	Date	Site	CFU/100 mL	Compliance
2012–2013	25/03/2013	OR21	60	
		OR22	82	
2013–2014	03/12/2013	OR22	91	
	14/03/2014	OR22	70	
	19/03/2014	OR20	30	
		OR21	60	
		OR22	50	
		OR23	90	
2014–2015	22/01/2015	OR20	30	
	27/02/2015	OR17	140	
		OR18	50	
		OR19	240	
% total samples (n=120) >21 CFU/100 mL			10.0	
% total samples (n=120) >85 CFU/100 mL			3.3	

Notes:
1. Green symbols (■) indicate the Environmental Quality Guidelines (EQGs) were met; amber (■) and red (■) symbols represent an exceedance of EQG and Environmental Quality Standard (EQS), respectively.
2. Sites were located on the boundary of the observed zone of influence (OZI; see Figure 3.1, Figure 3.2 and Appendix H).
3. Environmental Quality Criteria (EQC) based on ANZECC/ARMCANZ (2000) water quality guidelines for recreation waters.

3.2.2 Toxic phytoplankton species

Monitoring of algal biotoxins aims to target concentrations of toxic phytoplankton species most likely to occur in local waters and involves a staged process, whereby phytoplankton species are identified and enumerated in the first instance (i.e. the EQG), and if this does not meet the required quality standards, a secondary assessment is required to assess toxin concentrations within sentinel mussels (i.e. EQS). The EQG for Seafood for Human Consumption is assessed against the WASQAP (DoF 2007) guideline values for toxic phytoplankton species (Table 3.4).

During fortnightly sampling over December 2014–March 2015, planktonic algae were collected at five fixed monitoring sites located on the border of the OZI (down-current from the outlets) and at four reference sites ~4 km south of the outlets. These data are collected for contextual purposes only, as presently there are no formal shellfish harvesting exclusion boundaries are established around the Ocean Reef ocean outlets. Analysis of phytoplankton cell density data from one monitoring site and one reference site per sampling occasion indicated that there were no instances where toxic phytoplankton species were present at densities in excess of WASQAP guideline values (Table 3.4).

Table 3.4 Estimated cell densities of phytoplankton species known to produce toxins and other potentially harmful (non-toxic) species

Date	Site[1]	Species	Estimated density (cells/L)	WASQAP guideline	Compliance[2]
03/12/2014	OR26 monitoring	*Nitzschia longissima*	732	n.d.	N/A
	ORR1 reference	No toxic species detected	n.d.	N/A	N/A
17/12/2014	OR22 monitoring	*Nitzschia longissima*	549	n.d.	N/A
	ORR2 reference	No toxic species detected	n.d.	N/A	N/A
08/01/2015	OR26 monitoring	*Nitzschia longissima*	183	n.d.	N/A
		Pseudo-nitzschia "delicatissima group"	1647	250 000	
	ORR4 reference	*Nitzschia longissima*	366	n.d.	N/A
		Pseudo-nitzschia "delicatissima group"	1281	250 000	
		Prorocentrum cordatum	183	n.d.	N/A
22/01/2015	OR22 monitoring	*Nitzschia longissima*	183	n.d.	N/A
		Pseudo-nitzschia "delicatissima group"	366	250 000	
	ORR4 reference	*Nitzschia longissima*	183	n.d.	N/A
		Pseudo-nitzschia "delicatissima group"	549	250 000	
		Nitzschia sp. 035	366	n.d.	N/A
		Nitzschia sp. 038	183	n.d.	N/A
13/02/2015	OR19 monitoring	No toxic species detected	n.d.	N/A	N/A
	ORR4 reference	*Nitzschia longissima*	549	n.d.	N/A
		Dinophysis acuminata	183	3000	
27/02/2015	OR19 monitoring	*Nitzschia longissima*	9699	n.d.	N/A
		Pseudo-nitzschia "delicatissima group"	3294	250 000	
		Pseudo-nitzschia "seriata group"	2745	250 000	
		Rhizosolenia setigera	732	n.d.	N/A
		Prorocentrum cordatum	366	n.d	N/A
	ORR4 reference	*Nitzschia longissima*	2928	n.d.	N/A
		Pseudo-nitzschia "delicatissima group"	915	250 000	
		Pseudo-nitzschia "seriata group"	366	250 000	
		Rhizosolenia setigera	366	n.d.	N/A
11/03/2015	OR26 monitoring	*Nitzschia longissima*	549	n.d.	N/A
		Pseudo-nitzschia "delicatissima group"	2562	250 000	
	ORR2 reference	*Nitzschia hungarica*	366	n.d.	N/A
		Nitzschia longissima	549	n.d.	N/A

Date	Site[1]	Species	Estimated density (cells/L)	WASQAP guideline	Compliance[2]
		Pseudo-nitzschia "delicatissima group"	2562	250 000	■
		Rhizosolenia setigera	366	n.d.	N/A
25/03/2015	OR26 monitoring	*Nitzschia longissima*	3843	n.d.	N/A
		Nitzschia spp.	366	n.d.	N/A
		Pseudo-nitzschia "delicatissima group"	5673	250 000	■
		Pseudo-nitzschia "seriata group"	1281	250 000	■
		Rhizosolenia setigera	183	n.d.	N/A
	ORR1 reference	*Pseudo-nitzschia "delicatissima* group"	3843	250 000	■

Notes:

1. Samples were analysed for one monitoring site and one reference site per sampling occasion.
2. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS), respectively.
3. For site locations and GPS waypoints, see Figure 3.1, Figure 3.2and Appendix H.
4. n.d. = no data available or threshold limit to trigger testing flesh, N/A = not applicable.
5. Full list of WASQAP toxic algae guideline concentrations (DoF 2007):
   Alexandrium spp. (100 cells/L)
   Gymnodinium spp. (1000 cells/L)
   Karenia spp. (1000 cells/L)
   Dinophysis spp. (500 cells/L)
   Dinophysis acuminta (3000 cells/L)
   Prorocentrum lima (500 cells/L)
   Psuedo-nitzschia spp. (250 000 cells/L)
   Gonyaulax cf *spinifera* (100 cells/L)
   Protoceratium reticulatum (Gonyaulax grindleyi) (500 cells/L).

3.3 Compliance summary

The EQC for microbiological contaminants (as TTC) were assessed based on pooled data from three sampling seasons (2012–2013, 2013–2014 and 2014–2015), with a sample size (n=120) that allowed for an accurate EQC comparison (EPA 2005a). The median value for TTC concentrations was at the limit of detection (<10 CFU/100 mL). Over the three seasons, there were 12 instances where TTC exceeded 21 CFU/100 mL (representing 10.0% of the available samples; Table 3.5). The EQG criteria for microbiological contaminants (as TTC) were therefore met.

The EQG for algal biotoxins requires that toxic phytoplankton species at the fixed monitoring sites are not present in numbers that exceed the criteria listed in WASQAP (DoF 2007). There were no instances where toxic phytoplankton species exceeded WASQAP guideline values, thus meeting the EQG (Table 3.5).

Table 3.5 Compliance against EQC relevant to the EQO 'Maintenance of Seafood for Human Consumption'

Environmental quality indicator		Comments	Compliance
Microbiological contaminants	Thermotolerant coliforms (TTC)	The median value for TTC derived from 120 samples collected over the 2012–2013, 2013–2014 and 2014–2015 sampling seasons was at the limit of detection (<10 CFU/100 mL)	■
		There were 10.0% of TTC samples that exceeded 21 CFU/100 mL over the 3-season pooled dataset (n=120)	■
Algal biotoxins	Potentially toxic phytoplankton species	Results of the 2014–2015 monitoring program found no instances where toxic phytoplankton species were recorded in excess of WASQAP guideline values (DoF 2007)	■

Note:

1. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS), respectively.
2. EQO = Environmental Quality Objective.

4. Maintenance of Primary and Secondary Contact Recreation

4.1 Environmental Quality Objective

The EQOs for the EV 'Recreation and Aesthetics' are aimed at ensuring Perth's coastal waters are safe for primary and secondary contact recreation activities such as swimming and boating. To meet this objective, water quality around the Ocean Reef outlets is to be maintained so that:

- primary contact recreation (e.g. swimming) is safe in all waters except areas designated otherwise
- secondary contact recreation (e.g. boating) is safe in all waters except areas designated otherwise.

A formal area where contact recreation is not recommended has not been established for the area surrounding the Ocean Reef outlets. Sampling for this EQO was therefore undertaken at a series of fixed monitoring sites located at the boundary of the OZI, as described in Section 3.2. As the maintenance of primary contact recreation EQO requires a higher water quality standard to be maintained than secondary contact recreation EQO, by default, it is assumed that if primary contact recreation EQSs are met, secondary contact recreation EQSs will also be achieved.

4.2 Microbiological contaminants and algal biotoxins

The accepted method for determining whether the EQC for primary and secondary contact recreation (Table 1.4) have been met is to monitor microbiological contaminants (measured as numbers of faecal streptococci) and algal toxins (measured as numbers of phytoplankton cells) at the boundary of a pre-designated management zone. Such an approach has been developed for the ocean outlets at Sepia Depression and Alkimos.

Disease-causing microorganisms (pathogens) associated with bathing areas include salmonellae, shigellae, enteropathogenic *Escherichia coli*, cysts of *Entamoeba histolytica*, parasite ova, enteroviruses and infectious hepatitis (Hart 1974, McNeill 1985; cited in ANZECC/ARMCANZ 2000). The most common types of diseases associated with water-borne pathogens are eye, ear, nose and throat infections, skin diseases and gastrointestinal disorders (ANZECC/ARMCANZ 2000). Detecting faecal pathogens within routine water samples is difficult and often 'indicator' micro-organisms (such as *Enterococci* spp.) are used to assess the health risks associated with pathogens in recreational waters (Elliot & Colwell 1985; cited in ANZECC/ARMCANZ 2000).

Algal blooms can be harmful to human/animal health if encountered via ingestion or skin contact. For this reason, phytoplankton cell concentrations are monitored in the TCM program to ensure concentrations are within acceptable guidelines limits (EPA 2005b).

Microbial contaminants were sampled for approximately fortnightly at a series of fixed monitoring sites on the OZI boundary (refer Section 3.2, Figure 3.1 and Figure 3.2). Samples were collected during the non-river flow period at five fixed sites located immediately down-current of the diffusers, with site selection based on the water current direction as indicated by the drogue (Appendix H). Composite water samples representative of the top half of the water column were collected for faecal streptococci (*Enterococci* spp.) and phytoplankton cell concentrations.

Enterococci spp. samples were collected in pre-sterilised bottles before being chilled to 4°C and placed in the dark. On completion of sampling, the samples were transferred to PathWest laboratories and analysed according to NATA-accredited methods (Appendix B).

For phytoplankton, samples were collected, preserved and analysed in the manner described in Section 3.2.

4.2.1 Faecal streptococci (*Enterococci* spp.)

The EQG is assessed against the 95th percentile value of faecal streptococci (*Enterococci* spp.) concentrations sampled over the bathing season. To meet the EQG for primary contact recreation, the 95th percentile is not to exceed 200 MPN/100 mL at the OZI boundary. To meet the EQG for secondary contact recreation, the 95th percentile is not to exceed 2000 MPN/100 mL (EPA 2005b).

Enterococci spp. were sampled for eight times over the December–March monitoring period (yielding a total of 40 samples). NHMRC (2008) guidelines and EPA (2005a) suggest that a minimum of 100 samples over the non-river flow period are needed for accurate assessment of microbial water quality EQC. If there are less than 100 samples in a given sampling year, data can be pooled from multiple years provided there is no reason to believe that local pollution conditions have changed (NHMRC 2008). We make the assumption that pollution conditions have not changed over the past 3 sampling years and present data collected since summer 2012–13 (pooled 3-season dataset), yielding a total sample size of n=120 and thereby allowing an assessment against the EQC.

The 95th percentile of *Enterococci* spp. concentrations based on 120 samples was 10 MPN/100 mL (Table 4.1), thus meeting the EQG for both primary and secondary contact recreation for this interim assessment.

Table 4.1 The 95th percentile of *Enterococci* spp. concentrations at the boundary of the observed zone of influence for the Ocean Reef ocean outlets and comparison to the EQC

Date	95th percentile (MPN/100 mL)	Compliance (primary contact)	Compliance (secondary contact)
Dec 2012–Mar 2013 Dec 2013–Mar 2014 Dec 2014–Mar 2015 (n=120)	10	■	■

Notes:
1. Green symbols (■) indicate the Environmental Quality Guidelines (EQGs) were met; amber (■) and red (■) symbols represent an exceedance of EQG and Environmental Quality Standard (EQS), respectively.
2. For site locations and GPS waypoints, see Figure 3.1, Figure 3.2 and Appendix H.
3. *Enterococci* spp. results below the analytical detection limit (<10 CFU/100 mL) were halved (= 5 CFU/100 mL) to calculate the 95th percentile.
4. Environmental Quality Criteria (EQC) based on ANZECC/ARMCANZ (2000) water quality guidelines for recreation waters.

4.2.2 Phytoplankton cell concentrations

The EQG for algal biotoxins at Ocean Reef requires the median total phytoplankton cell concentration for the area of concern (either from one sampling run or from a single site over an agreed period of time) should not exceed 15 000 cells/mL or there should be no reports of skin or eye irritation or potential algal poisoning in swimmers considered by a medical practitioner as potentially resulting from toxic algae when less than 15 000 cells/mL is present in the water column.

From December 2014 to March 2015, total estimated phytoplankton cell densities at the OZI boundary ranged from 12.4 to 433.0 cells/mL, with a median of 25.2 cells/mL (Table 4.2). The requirements for the EQG were therefore met.

Table 4.2 Estimated phytoplankton total cell densities collected at one of the fixed monitoring sites for contact recreation down-current of the Ocean Reef outlets

Date	Site	Total density (cells/mL)	Compliance
03/12/2014	OR9	28.4	
17/12/2014	OR7	22.0	
08/01/2015	OR9	14.8	
22/01/2015	OR7	12.4	
13/02/2015	OR1	123.9	
27/02/2015	OR5	286.9	
11/03/2015	OR9	17.4	
25/03/2015	OR9	433.0	
	Median (all data)	25.2	■

Notes:
1. Green symbols (■) indicate the Environmental Quality Guidelines (EQGs) were met; amber (■) and red (■) symbols represent an exceedance of EQG and Environmental Quality Standard (EQS), respectively.
2. For site locations and GPS waypoints, see Figure 3.1, Figure 3.2 and Appendix H.

4.3 Compliance summary

The EQG for microbiological contaminants (95th percentile of *Enterococci* spp. concentrations) was assessed based on pooled data (n=120) from three sampling seasons (2012–2013, 2013–2014 and 2014–2015), and equalled 10 MPN/100 mL. This met the EQG for both primary and secondary contact recreation.

The EQG for algal biotoxins requires the median total phytoplankton cell concentration for the area of concern should not exceed 15 000 cells/mL or there should be no reports of skin or eye irritation or potential algal poisoning in swimmers considered by a medical practitioner as potentially resulting from toxic algae when less than 15 000 cells/mL is present in the water column. The median phytoplankton cell density at the contact recreation boundary was 25.2 cells/mL, meeting the EQG requirements (Table 4.3).

Table 4.3 Compliance against EQC relevant to the EQO 'Maintenance of Primary and Secondary Contact Recreation'

Environmental quality indicator		Comments	EQC	Compliance
Faecal streptococci	*Enterococci* spp.	The 95th percentile of *Enterococci* spp. concentrations was 10 MPN/100 mL	EQG (primary contact)	■
			EQG (secondary contact)	■
Algal biotoxins	Phytoplankton (cell concentration)	The median total phytoplankton cell concentration was 25.2 cells/mL	EQG	■

Note:
1. Green symbols (■) indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) and Environmental Quality Standard (EQS), respectively.

References

Anon (2003) Memorandum of Understanding (MoU) for the Management of TWW Discharges to the Marmion Marine Park. Anonymous author, Perth, Western Australia

ANZECC/ARMCANZ (2000) National Water Quality Management Strategy: Paper No 4 – Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1 – The Guidelines (Chapters 1–7). Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australian Capital Territory, October 2000

BMT Oceanica (2013) Perth Long Term Ocean Outlet Monitoring Program (PLOOM) 2012–2013 Annual Report: Ocean Reef. Prepared for Water Corporation by BMT Oceanica Pty Ltd, Report No. 788_03_004/3_Rev0, Perth, Western Australia, November 2013

BMT Oceanica (2014a) Sepia Depression Ocean Outlet – Monitoring and Management Plan. Prepared for Water Corporation by BMT Oceanica Pty Ltd, Report No. 821_001/1_Rev4, Perth, Western Australia, January 2014

BMT Oceanica (2014b) Perth Long Term Ocean Outlet Monitoring Program (PLOOM) 2013–2014 Annual Report: Ocean Reef. Prepared for Water Corporation by BMT Oceanica Pty Ltd, Report No. 788_04_006/2_Rev0, Perth, Western Australia, June 2014

BMT Oceanica (2015) Perth Long Term Ocean Outlet Monitoring (PLOOM) Program: 2015 Summer Water Quality Survey – Ocean Reef: 3 February 2015, Swanbourne: 20 January 2015, Sepia Depression: 17 February 2015. Prepared for Water Corporation by BMT Oceanica Pty Ltd, Report No. 1120_006/1_RevB, Perth, Western Australia, June 2015

DALSE (2003) Perth Long-Term Ocean Outlet Monitoring Programme 2001–2002 (PLOOM 3). Prepared for Water Corporation of Western Australia by DAL Science & Engineering Pty Ltd, Report No. 241/01, Perth, Western Australia, April 2003

DoF (2007) Western Australian Shellfish Quality Assurance Program (WASQAP) Operations Manual. Department of Fisheries, Perth, Western Australia

EPA (2002) Implementation Framework for Western Australia for the Australian and New Zealand Guidelines for Fresh and Marine Water Quality and Water Quality Monitoring and Reporting (Guidelines 4 & 7: National Water Quality Management Strategy). Environmental Protection Authority, Report No. 1078, Perth, Western Australia

EPA (2005a) Manual of Standard Operating Procedures – For Environmental Monitoring against the Cockburn Sound Environmental Quality Criteria (2003 – 2004) – A Supporting Document to the State Environmental (Cockburn Sound) Policy 2005. Environmental Protection Authority, Report No. 21, Perth, Western Australia

EPA (2005b) Environmental Quality Criteria Reference Document for Cockburn Sound (2003–2004) – A Supporting Document to the State Environmental (Cockburn Sound) Policy 2005. Environmental Protection Authority, Report No. 20, Perth, Western Australia

EPA (2015) Environmental Assessment Guideline for Protecting the Quality of Western Australia's Marine Environment. Environmental Protection Authority, Report No. EAG 15, Perth, Western Australia, March 2015

Govt of WA (2003) Hope for the Future: The Western Australian State Sustainability Strategy. Government of Western Australia, Department of the Premier and Cabinet, Perth, Western Australia

McAlpine KW, Wenziker KJ, Apte SC, Masini RJ (2005) Background Quality for Coastal Marine Waters of Perth, Western Australia. Department of Environment, Report No. 117, Perth, Western Australia

NHMRC (2008) Guidelines for Managing Risks in Recreational Water. National Health and Medical Research Council, Canberra, Australian Capital Territory

Oceanica (2011a) Perth Long Term Ocean Outlet Monitoring Program (PLOOM) 6.1 – 2010/2011 Annual Report: Ocean Reef. Prepared for Water Corporation by Oceanica Consulting Pty Ltd, Report No. 788_01_004/1, Perth, Western Australia, November 2011

Oceanica (2011b) Alkimos Wastewater Treatment Plant – Marine Treated Wastewater Discharge Monitoring and Management Plan (2010 to 2020). Prepared for Water Corporation by Oceanica Consulting Pty Ltd, Report No. 635_001/1, Perth, Western Australia, January 2011

Appendices on CD

Appendix D – National Measurement Institute Laboratory results

Appendix F – Ecotox Australasia Laboratory results

Appendix G – Marine and Freshwater Research Laboratory results

Appendix I – PathWest Microbiological Laboratory results

Appendix J – Dalcon Environmental Laboratory results

Appendices listed above are available on CD by contacting BMT Oceanica Pty Ltd

Appendix A – Beenyup wastewater treatment plant License conditions and Ministerial statement

Government of Western Australia
Department of Environment and Conservation

Your ref: L7882/1991/14
Our ref: DEC625-02
Enquiries: Bhabesh Das
Phone: 9333 7521
Fax: 9333 7550
Email: bhabesh.das@dec.wa.gov.au

The Manager
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

Dear Sir/Madam

Environmental Protection Act 1986
Licence L7882/1991/14
Occupier: Water Corporation
Premises: Beenyup Wastewater Treatment Plant, Lot8278 on Plan 30778 Ocean Reef Road, CRAIGIE WA6025

You are hereby advised that a licence under the *Environmental Protection Act 1986* (the Act) has been granted for the above premises. The Department of Environment and Conservation will advertise the issuing of this licence in the public notices section of The West Australian newspaper.

The licence is subject to the attached conditions. Under section 58 of the Act, it is an offence to contravene a licence condition. This offence carries a penalty of up to $125,000, with a daily penalty of up to $25,000.

In accordance with section 102(1)(c) of the Act, you are afforded 21 days to appeal the conditions of the licence. Under section 102(3)(a) of the Act, any other person may also appeal the conditions of the licence.

To make an appeal or check if any appeals have been made, contact the Office of the Appeals Convenor on 6467 5190. Please direct all other inquiries to the Licensing Officer above.

Yours faithfully,

Carissa Aitken
A/Manager, Works Approval & Emissions Licensing Section

Thursday, 29 September 2011

enc: Environmental Protection Act 1986 Licence 7882/1991/14
copy to: Local Government Authority: City of Joondalup

Government of Western Australia
Department of Environment and Conservation

LICENCE FOR PRESCRIBED PREMISES
Environmental Protection Act 1986

LICENCE NUMBER: L7882/1992/14 **FILE NUMBER** DEC625 - 02

LICENSEE
Water Corporation
629 New Castle Street
LEEDERVILLE WA 6007
ABN: 28 003 434 917

PREMISES
Beenyup Wastewater Treatment Plant
Lot 8278 on Plan 30778, Ocean Reef Road
CRAIGIE WESTERN AUSTRALIA 6025
(as depicted in Attachment 1)

PRESCRIBED PREMISES CATEGORY
Schedule 1 of the *Environmental Protection Regulations 1987*

CATEGORY NUMBER	CATEGORY DESCRIPTION	CATEGORY PRODUCTION OR DESIGN CAPACITY	PREMISES PRODUCTION OR DESIGN CAPACITY
54	Sewage facility: premises – (a) On which sewage is treated (excluding septic tanks); or (b) From which treated sewage is discharged onto land or into waters.	100 cubic metres or more per day	135,000 cubic metres per day
61	Liquid waste facility: premises on which liquid waste produced on other premises (other than sewage waste) is stored, reprocessed, treated or irrigated.	100 tonnes or more per year	50,000 tonnes per year

CONDITIONS OF LICENCE
Subject to the conditions of licence set out in the attached pages.

Officer delegated under Section 20
of the *Environmental Protection Act 1986*

ISSUE DATE Friday, 30 September 2011
COMMENCEMENT DATE: Tuesday, 1 November 2011
EXPIRY DATE: Monday, 31 October 2016

DEFINITIONS

"APHA-AWWA-WEF" means American Public Health Association; American Water Works Association; Water Environment Federation;

"Biological wastes category 1.02 and 1.05" means biological wastes under category 1.02 and 1.05 within Appendix A – Controlled Waste Categories and Descriptions of the *Environmental Protection (Controlled Waste) Regulations 2004;*

"Director" means Director, Environmental Regulation Division of the Department of Environment and Conservation for and on behalf of the Chief Executive Officer as delegated under Section 20 of the *Environmental Protection Act 1986*;

"Director" for the purpose of correspondence means-

Regional Leader, Industry Regulation
Booragoon Office, Swan Region
Department of Environment and Conservation
Locked Bad 104 Telephone: (08) 9333 7510
Bentley Delivery Centre WA 6983 Facsimile: (08) 9333 7550;

"chemical scrubbing system" means a chemical scrubbing system for the removal of odorous compounds;

"continuous monitor" means a monitor that measures the instantaneous concentration of exit gas every fifteen minute;

"covers" means metallic or non-metallic covers used to cover the pre-treatment, primary treatment and secondary aeration areas of the treatment plant;

"histogram" means a chart, graph or table showing the results of specified monitoring over a specified interval;

"Inspector" means person appointed to be an inspector under section 88 of the *Environmental Protection Act 1986;*

"licensed" means licensed or registered under the *Environmental Protection Act 1986* unless otherwise specified;

"monitoring period" means 1 July to 30 June;

"NATA" means National Association of Testing Authorities;

"plant" means the Beenyup WWTP;

"sewage treatment" means the activity under which the premises is prescribed, and includes the treatment of sewage and the discharge of treated wastewater onto land or into waters;

"sensitive receptor' means any land or building that is used as a residence, guest house, hotel, motel, caravan park, school, church, hospital, or as an office or consulting rooms, where such office or consulting rooms are not located in an industrial area;

"STP, dry" means standard temperature and pressure (0°C and 101.325 kilopascals);

"scrubber stack 1" means the stack from the chemical scrubbing system;

"scrubber stack 2" means the stack from the carbon scrubbing system;

"Ocean Reef Outlet" means Ocean Reef Outlet extending 1.8 kilometres off the shore; and

"USEPA" means United States Environmental Protection Agency.

ANNUAL ENVIRONMENTAL REPORT

1 The licensee shall submit to the Director, by **1 September** each year, an Annual Environmental Report providing the following information obtained during the monitoring period from 1 July to 30 June:

(i) A histogram showing the monthly recorded average flow rate, temperature and concentration of hydrogen sulphide being emitted through the scrubber stack, measured in accordance with condition 4;

(ii) A histogram showing the daily maximum and daily average concentrations of hydrogen sulphide emitted through the scrubber stack, as measured in accordance with condition 5;

(iii) A histogram showing the reliability of the continuous monitor against the bench marks of 90% of the time in a calendar month and 95% of the time over monitoring period of a year;

(iv) A histogram showing the volumes of treated wastewater discharged each month through the Beenyup Ocean Outlet;

(v) A histogram showing the monthly average loadings for total phosphorus and total nitrogen in treated wastewater discharged to the ocean from BeenyupWWTP through the Beenyup Ocean Outlets in kg/day;

(vi) A histogram showing the results of treated wastewater monitoring as per condition 10(b) including duplicate NATA accredited laboratory results;

(vii) A histogram showing the number of complaints received by the licensee over the reporting period.

ANNUAL AUDIT COMPLIANCE REPORT

2 The licensee shall by 1 September in each year, provide to the Director an Annual Audit Compliance Report in the form in Attachment 2 to this licence, signed and certified in the manner required by Section C of the form, indicating the extent to which the licensee has complied with the conditions of this licence, and any previous licence issued under Part V of the Act for the premises, during the period beginning 1 July the previous year and ending on 30 June in that year.

COMPLAINTS

3 The licensee shall keep a written record of all complaints received at the premises. The record must be dated and provide the following information (if known):

(i) date and time of complaint;
(ii) location about which the complaint was made;
(iii) general description of the nature of complaint;
(iv) wind direction, wind speed and temperature at the time of the complaint;
(v) likely source of the reported problem; and
(vi) action taken in response to the complaint.

This record, or copies thereof, shall be made available to the inspector on request.

OPERATIONAL ODOUR EMISSION MONITORING

4 The licensee shall operate and maintain a continuous hydrogen sulphide monitor in accordance with the manufacturer's instructions to measure and record the concentration of hydrogen sulphide emitted from the scrubber located within the premises.

ODOUR CONTROL STACK - MANUAL MONITORING

5 The licensee shall monitor each of the parameters stated in column 1 of Table 1, at the locations stated in column 2 of Table 1, at the frequency stated in column 3 of Table 1 using the methods specified in column 4 of Table 1, and record the results in the units specified in column 5 of Table 1.

Table 1: Odour control stack – manual monitoring

Column 1	Column 2	Column 3	Column 4	Column 5
Parameters	**Measurement and sampling locations**	**Monitoring frequency**	**Sampling method**	**Units**
Hydrogen sulphide	Scrubber slack 1 and scrubber stack 2	March, June, September and December	NATA accredited method for the measurement and analysis of hydrogen sulphide emissions from stationary sources	mg/ m^3 at STP, dry
Volumetric flow rate			USEPA method 2	m^3/s at STP, dry and at STP, wet
Stack exit temperature			n/a	°C

ODOUR CONTROL STACK- TARGET

6 The licensee shall operate the plant to achieve a hydrogen sulphide emission target of less than 1.5 ppm at the stack outlet as monitored in accordance with the condition 4 of this licence.

ODOUR CONTROL STACK– LIMITS

7 The licensee shall ensure that the emission of the parameter specified in Column 1 of Table 2, from the locations stated in column 2 of Table 2, do not exceed the concentration limits specified in column 3 and 4 of Table 2.

Table 2: Odour Control stack emission limits

Column 1	Column 2	Column 3	Column 4
Parameter	**Location**	**Concentration limit**	**Mass emission rate limit**
Hydrogen sulphide	Scrubber stack 1	5mg/m³ at STP, dry	0.20g/s at STP, dry
	Scrubber Stack 2		0.19g/s at STP, dry

8 The licensee shall notify the Director, in writing, before 5pm on the next usual business day after becoming aware of any confirmed measurement which indicates that an emission target as specified in condition 6 or an emission limit as specified in condition 7 has been exceeded and the notification shall include:

(i) the date and time of the exceedance;
(ii) production rate at time of exceedance;
(iii) the cause of the exceedance;
(iv) an estimate of the period over which the limit was exceeded;
(v) an indication of known or potential environmental impacts;
(vi) corrective actions taken or planned to mitigate environmental consequences resulting from the exceedance; and
(vii) corrective action taken or planned to prevent a recurrence of the exceedance.

ODOUR CONTROL CONDITIONS

9 The licensee shall ensure that odour emitted from the premises does not unreasonably interfere with the health, welfare, convenience, comfort or amenity of any person at a sensitive receptor.

DISCHARGE TO WATER

MONITORING OF DISCHARGED TREATED WASTEWATER

10(a) The licensee shall monitor and record the cumulative monthly volumes of treated wastewater being discharged to the ocean via Ocean Reef ocean outlet.

10(b) The licensee shall monitor the concentration of the parameters stated in column 1 of Table 3, at the monitoring frequency stated in column 2 of Table 3, within treated wastewater being discharged from the Beenyup WWTP to the ocean through the Ocean Reef Ocean Outlet at the treated wastewater sampling point and the results shall be recorded in the units stated in column 3 of Table 3.

Table 3: Monitoring of discharged treated wastewater

Column 1 **Parameters**	Column 2 **Monitoring frequency**	Column 3 **Units**
Total Nitrogen, Total Phosphorus	Monthly	Kilograms per day (monthly average)
pH	Six monthly	pH unit
E.Coli		Most probable number per 100 ml
Total dissolved solids, Total suspended solids, 5-Day Biochemical Oxygen Demand (filtered), Oil and Grease, Arsenic, Cadmium, Copper, Chromium, Lead, Mercury, Nickel and Zinc		mg/l

10(c) The licensee shall ensure that all water samples are collected, handled and preserved in accordance with the relevant parts of the Australian Standard 5667.

10(d) The licensee shall ensure that all water samples are analysed in accordance with the current "Standard Methods for Examination of Water and Wastewater," APHA-AWWA-WEF.

10(e) The licensee shall analyse all water samples, required to be monitored by any condition of this licence, in its own laboratory, or ensure that samples are analysed in a laboratory holding NATA accreditation for the analyses specified. If the licensee uses its own laboratory, then at least one set of samples per year shall also be submitted to a laboratory holding NATA accreditation for the analysis specified.

TOTAL PHOSPHORUS AND NITROGEN LOAD LIMIT

11(a) The licensee shall ensure that the load for total phosphorus in treated wastewater discharged from the Beenyup WWTP to the ocean through the Ocean Reef ocean outlet does not exceed an annual average of 1500 kilograms per day recorded over the financial year.

11(b) The licensee shall ensure that the load for total nitrogen in treated wastewater discharged from the Beenyup WWTP to the ocean through the Ocean Reef ocean outlet does not exceed an annual average of 3600 kilograms per day recorded over the financial year.

TANKERED WASTE

12 The licensee may accept biological wastes category 1.02 and 1.05 (from other Water Corporation assets) tankered into the premises at the pre-treatment works of the sewage treatment plant. The waste shall be delivered to the plant via an enclosed pipeline.

DISCHARGE TO LAND

MANAGEMENT OF PROCESS SOLID WASTES

13(a) The licensee shall dispose of all collected grit and screenings from the pre-treatment area to a licensed or registered landfill.

13(b) The licensee shall dispose of sludge and biosolids in accordance with the document *Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products*, Department of Environmental Protection, Water and Rivers Commission and Department of Health (February, 2002) (as amended).

PLAN OF PREMISES

BeenyupWWTP

LICENCE NUMBER: L7882/1992/14 **FILE NUMBER:** DEC625-02

ANNUAL AUDIT COMPLIANCE REPORT

SECTION A

LICENCE DETAILS

Licence Number:	Licence File Number:
Company Name: Trading as:	ABN:
Reporting period: _____ to _____	

STATEMENT OF COMPLIANCE WITH LICENCE CONDITIONS

1. Were all conditions of licence complied with within the reporting period? (please tick the appropriate box)

Yes □ Please proceed to Section C
No □ Please proceed to Section B

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:_____

LICENCE NUMBER: L7882/1992/14 **FILE NUMBER:** DEC625-02

SECTION B - DETAILS OF NON-COMPLIANCE WITH LICENCE CONDITION.

Please use a separate page for each licence condition that was not complied with.

a) Licence condition not complied with?
b) Date(s) when the non compliance occurred, if applicable?
c) Was this non compliance reported to DEC?
☐ Yes ☐ Reported to DEC verbally Date _____ ☐ No ☐ Reported to DEC in writing Date _____
d) Has DEC taken, or finalised any action in relation to the non compliance?
e) Summary of particulars of non compliance, and what was the environmental impact?
f) If relevant, the precise location where the non compliance occurred (attach map or diagram)
g) Cause of non compliance
h) Action taken or that will be taken to mitigate any adverse effects of the non compliance
i) Action taken or that will be taken to prevent recurrence of the non compliance

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:_____

LICENCE NUMBER: L7882/1992/14 **FILE NUMBER:** DEC625-02

SECTION C - SIGNATURE AND CERTIFICATION

This Annual Audit Compliance Report may only be signed by a person(s) with legal authority to sign it. The ways in which the Annual Audit Compliance Report must be signed and certified, and the people who may sign the statement, are set out below.
Please tick the box next to the category that describes how this Annual Audit Compliance Report is being signed. If you are uncertain about who is entitled to sign or which category to tick, please contact the licensing officer for your premises.

If the licence holder is		The Annual Audit Compliance Report must be signed and certified:
an individual	☐	by the individual licence holder, or
	☐	by a person approved in writing by the Chief Executive Officer of the Department of Environment and Conservation to sign on the licensee's behalf.
A firm or other unincorporated company	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
A corporation	☐	by affixing the common seal of the licensee in accordance with the Corporations Act 2001; or
	☐	by two directors of the licensee; or
	☐	by a director and a company secretary of the licensee, or
	☐	if the licensee is a proprietary company that has a sole director who is also the sole company secretary – by that director, or
	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
A public authority (other than a local government)	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
a local government	☐	by the chief executive officer of the licensee; or
	☐	by affixing the seal of the local government.

It is an offence under section 112 of the *Environmental Protection Act 1986* for a person to give information on this form that to their knowledge is false or misleading in a material particular. There is a maximum penalty of $50,000 for an individual or body corporate.

I/We declare that the information in this annual audit compliance report is correct and not false or misleading in a material particular.

SIGNATURE: _____ SIGNATURE: _____

NAME: (printed) _____ NAME: (printed) _____

POSITION: _____ POSITION: _____

DATE: ____/____/____ DATE: ____/____/____

SEAL (if signing under seal)

LICENCE NUMBER:L7882/1991/14
LICENCE FILE NUMBER: DEC625-02
APPLICATION DATE: 31/08/2011
EXPIRY DATE: 31 October 2016

PREMISES DETAILS

LICENSEE AND OCCUPIER
Water Corporation
629 New Castle Street
LEEDERVILLE WA 6007
ABN: 28 003 434 917

PREMISES
Beenyup Wastewater Treatment Plant (WWTP)
Lot 8278 on Plan 30778
Ocean Reef Road
CRAIGIE WA 6025

PRESCRIBED PREMISES SUMMARY

Table 1: Prescribed premises summary

Category number*	Category Description*	Category Production or Design Capacity*	Premises Production or Design Capacity#	Premises Fee Component**
54	Sewage facility: premises – a) on which sewage is treated (excluding septic tanks); or b) from which treated sewage is discharged onto land or into waters.	100 cubic metres or more per day	135,000 cubic metres per day	More than 2000 cubic metres per day
61	Liquid waste facility: premises on which liquid waste produced on other premises (other than sewerage waste) is stored, reprocessed, treated or irrigated	100 tonnes or more per year	50,000 tonnes per year	More than 10,000 but not more than 100,000 tonnes per year

* From Schedule 1 of the Environmental Protection Regulations 1987
# From application
** From Schedule 4 of the Environmental Protection Regulations 1987

This Environmental Assessment Report (EAR) has been drafted for the purposes of detailing information on the management and mitigation of emissions and discharges from the prescribed premises. The objective of the EAR is to provide a risk assessment of emissions and discharges, and information on the management of other activities occurring onsite which are not related to the control of emissions and discharges from the prescribed premises activity. This does not restrict the Department of Environment and Conservation (DEC) to assessing only those emissions and discharges generated from the activities that cause the premises to become prescribed premises.

Basis of Assessment
Beenyup WWTP, which has been assessed as a "prescribed premises" under category numbers 54 and 61, within Schedule 1 of the *Environmental Protection Regulations 1987*.

- Category 54: sewage facility: premises – (a) on which sewage is treated (excluding septic tanks); or (b) from which treated sewage is discharged onto land or into waters; and
- Category 61: liquid waste facility: premises on which liquid waste produced on other premises (other than sewerage waste) is stored, reprocessed, treated or irrigated.

The Beenyup WWTP serve's Perth's rapidly developing northern suburbs from Quinns Rock through to Scarborough and inland through Dianella and Bayswater to the foothills east of Midland. Sewage enters the WWTP via pipelines by gravity. The current throughput of the facility is about 122 ML (Mega litres) per day. At present, the facility is licensed to accept 135 ML per day. With the recent upgrade of the plant, the annual throughput may go up to 150 ML.

1.0 BACKGROUND

1.1 GENERAL COMPANY DESCRIPTION

The Water Corporation (WC) provides water and wastewater services to Perth and hundreds of towns and communities spread over 2.5 million square kilometres of Western Australia. They also provide drainage and irrigation services to thousands of households, businesses and farms across the state. WC holds many licences for WWTP's with DEC.

WC has an environmental policy available on its website and operates to an environmental management system which enables the systematic identification of environmental risks, setting of targets and development of environment improvement plans to reduce risks and ensure its activities are sustainable. WC is heavily involved with a diverse range of environmental programs and ongoing sponsorship programs.

1.2 LOCATION OF PREMISES

Beenyup WWTP is located at Lot 8278 on Plan 30778 Ocean Reef Road, Craigie, Western Australia. The plant has been operating at this premises since 1972. A major upgrade of the plant in terms of odour control has been completed recently. The site is bounded by the Mitchell Freeway to the east, Ocean Reef Road to the north, the residential suburb of Craigie to the west and Craigie Open Space, an area of regionally significant bushland, to the south. The site has a number of land uses, including its primary function, wastewater treatment.

1.3 EXISTING ENVIRONMENT

1.3.1 Adjacent land use

Beenyup WWTP is located directly south of the Groundwater Replenishment Trial facility. Other land uses on site include areas of Radiata Pine, Bush Forever Site 303 and bushland areas outside of the Bush Forever site. These bushland areas consist of a mixture of vegetation communities varying in condition from quite good to highly degraded. Commercial land at the northern boundary of the Beenyup site occupies 5 ha and includes a depot site with workshops and a bitumen lay-down storage area. Additionally, WC's Construction Branch occupies 0.6ha south of the commercial area, which consists of a bitumen lay-down hardstand area for the storage of pipes and equipment used in water and sewer reticulation mains repairs.

1.3.2 Bush Forever Site 303

The Beenyup site contains 24.5ha of land designated Bush Forever (site 303). This area occurs as a number of remnant bush islands that accompany a greater area of bushland along the eastern boundary of the site. The surrounding bushland varies in quality from quite good to highly degraded. Currently the Beenyup Site Management Plan provides management planning and actions to manage the potential effect of WC activities on the Bush Forever land.

1.3.3 Geology

The sub-surface geology of the site is generally made up of Quaternary Age sands of the Bassendean sand unit (Bennett Environmental Consulting, 2006). The sands are typically pale to darker olive yellow in colour and are medium to course with evidence of sub-rounded quartz and trace quantities of moderately sorted residual feldspar. They are derived from local weathering of the underlying Tamala Limestone.

A large stretch of the Quindalup dune system occurs along the western margin of Beenyup site and the Craigie Open Space, commencing at the southern boundary of Warrandyte Reserve to the north through to Whitfords Avenue to the south. WC has acquired 2.7ha of the dune, from Warrandyte Reserve southwards to the pine log steps. The remaining section of the dune, in addition to Craigie Open Space, is vested to the City of Joondalup for management. Remnant vegetation covers the dune, but it is relatively disturbed by human impacts such as rubbish dumping, weed invasion and localised erosion.

1.3.4 Flora, Vegetation and Fauna

The Beenyup site is included in the Karrakatta Vegetation Complex – Central and South. The vegetation of the Karrakatta Complex – Central and South is described as predominantly an Open Forest of *Eucalyptus gomphocephala*, *Eucalyptus marginate* subsp. *marginate* and *Corymbia calphylla* and a Woodland of *Eucalyptus marginate* subsp. *marginate* – Banksia species (Bennett Environmental Consulting, 2005).

A flora, vegetation and fauna survey was conducted for the general Beenyup site (including the Bush Forever Site) for the Beenyup Site Management Plan (Bennett Environmental Consulting, 2006). No Declared Rare or Priority Flora was recorded in the survey area and there is no known *Phytophthora* dieback at the site.

1.3.5 Contaminated Sites

A site approximately 150m to the north of the Beenyup site was reported to DEC in May 2007 as a 'suspected site', the assessment is still ongoing. The proposed construction works for the upgrade does not disturb the suspected contamination to the north.

1.3.6 Groundwater

The Perth Groundwater Atlas indicates the historical maximum water table level at the site is at 4.0m AHD, corresponding to 17-19m below current ground level. A dissipation test at the site indicated that the water table was present at 18.1m below ground level (3.6m AHD) (Worley Parsons, 2007); therefore, interference of plant structural and civil elements by groundwater is not expected.

The Beenyup site is located in a Priority 3 Perth Coastal Underground Water Pollution Control Area.

1.4 PROCESS DESCRIPTION

Sewage entering the plant passes through bar screens that remove materials such as paper, rags and other large objects from the flow and mechanically rake the material into a screw conveyor. The material is then pressed and disposed of in a DEC licensed landfill.

After screening, the wastewater flows into circular grit removal tanks, aerated to allow the inorganic material to settle and the organic material to pass through very slowly to large rectangular primary sedimentation tanks allowing about 50 per cent of the suspended solids to settle out as sludge. Sludge is collected by scraper mechanism and pumped to the solids handling area for thickening and digestion.

The treated wastewater leaving the primary tanks called primary treated wastewater passes to secondary treatment tanks. Secondary treatment is achieved in aeration tanks by the activated sludge process where ideal conditions are provided for microbiological life to grow rapidly and consume the organic material in the wastewater. Microorganisms require oxygen to survive and this is provided by blowers which inject air through fine bubble dome diffusers on the floor of the tanks.

Following aeration, the treated wastewater passes slowly through circular clarifiers in which the activated sludge settles leaving a high quality secondary effluent.

The settled sludge containing micro-organisms is rapidly removed using scrapers and is returned to the aeration tanks.

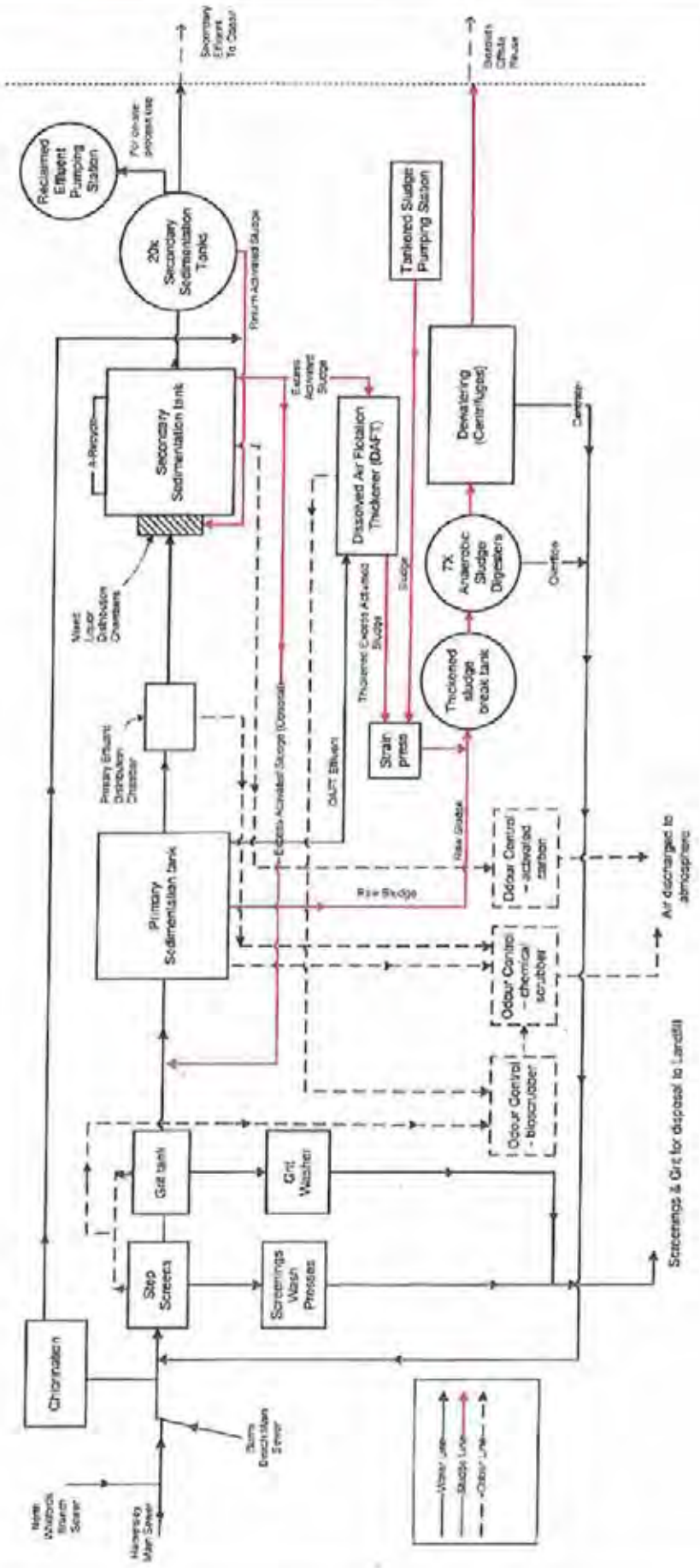
Solids removed from the primary sedimentation tanks and excess solids produced by the activated sludge process are thickened and fed to the anaerobic digesters. Following digestion, the sludge is mechanically dewatered to produce a biosolid suitable for use as a soil conditioner.

Secondary treated wastewater flows by gravity to the Indian Ocean in the vicinity of the Marmion Marine Park and is discharged into 10 metres of water via two outlets, one 1850 metres and the other one 1650 metres offshore where it is rapidly diluted and dispersed.

The throughput of the plant may increase to 135 mega litres per day with the recent upgrade of the plant (W4090/1991/1). The upgrade to the plant includes the following:

1. Construction of four secondary sedimentation tanks;
2. building three sludge thickeners;
3. construction of three sludge digesters;
4. installation of sludge dewatering centrifuge;
5. building additional grit washer;
6. construction of an odour scrubber system;
7. installation of an enclosed sludge load out facility;
8. installation of additional covers and duct work

Beenyup WWTP flow chart is shown below in Figure 1.



Beenyup WWTP_Basic Plant Flow Diagram

Odour Control
The Beenyup WWTP has the potential for causing odour emissions which can affect health, welfare, amenity of people if not properly managed.

The facility services northern suburbs, thus wastewater will travel in the sewers for hours before it reaches the treatment plant. Biological activity in sewers decomposes some of the organic material present in sewage and the wastewater arriving at the WWTP is odourous. Hydrogen sulphide and other sulphur-containing compounds will cause most of the odour from the inlet sewer and primary treatment tanks.

The plant odour control incorporates mechanical, chemical and biological treatment approaches. Mechanical odour control is to be through coverings and ventilation ducts. The inlet sewer, screening, primary treatment tanks, secondary treatment tanks are covered and ventilated in order to prevent fugitive emissions of odorous gases. Covers on the tanks and connecting channels have access hatches for operations and monitoring purposes. The covers are designed to minimise odour leakage and ensure negative pressure under the covers during normal operation. Odourous air will be extracted from beneath the covers and conveyed to scrubbers in fibreglass reinforced plastic ducts. A system of dampers at each extraction point will control the amount of air extracted. In addition key mechanical equipment such as extraction fans, odour scrubbers, chemical pumps are installed with stand-by capacity.

The odour treatment system incorporates biological and chemical air treatment to remove odour causing compounds. The odourous air from the odour sources will be ducted to the odour treatment system for the removal of odourous compounds. Odourous air from the secondary tanks will be treated with carbon column prior to its discharge to the environment via 50 m tall stack.

Overall, the odour treatment system will significantly remove hydrogen sulphide and reduce the odour level of the air before it is discharged to the environment through a nominal 50 metre tall emission stack.

Sludge Out-loading Facility:
The WWTP has been upgraded with a new sludge load out facility. The design of the new sludge load out facility allows for the steel lids to be retracted within the odour enclosure, ensuring the system provides full containment of odour. Trucks will remain in the enclosure for 1 complete air-change after the steel lids are closed. The doors are then opened allowing the trucks to exit.

Additional Stack:
A new 50m tall and 2.6m diameter stack has been constructed in addition to the existing 50 m tall and 2m diameter stack which will have a combined capacity of 342,000m3/h air flow and plant capacity to treat 135 ML/day.

Odour model predications suggest the highest predicted ground level concentrations from the two stacks of 2 Odour Units (OU) occurs within a small zone to the west and north-west, and on the south boundary of the treatment plant. There is a zone above 1.5 OU to the west of the plant and a smaller zone above 1.5 OU to the south-east. All predicted concentrations of the contribution from the new larger stack are below 5 OU.

Ocean Outlet
The Beenyup ocean outlet will discharge average flows of treated wastewater of up to 135ML/day in approximately 10m of water via a 200m long diffuser. This will be located at

the end of the discharge pipe. The outlet is designed to maximise the efficient dilution of the treated wastewater by spreading the discharge along the diffuser via 50 individual ports (~125mm diameter) located laterally along the last 200 metres of the pipe. As the effluent rises to the surface from each port, it mixes with surrounding seawater. The initial dilution is about 50 times and further dilution is achieved by dispersion by wind driven currents. Under the Ministerial statement 569, July 2001, the nutrients load discharged to the ocean shall not be more than 3600 kg per day for nitrogen and 1700 kg per day for phosphorus.

1.5 REGULATORY CONTEXT

1.5.1 Part IV Environmental Protection Act 1986, Environmental Impact Assessment

Beenyup WWTP has been assessed under Part IV of the *Environmental Protection Act 1986*. The Office of the Environmental Protection Authority (OEPA) assessed two proposals from WC relating to Beenyup WWTP. They are as follows:

- Beenyup wastewater Ocean Outlet Duplication into Marmion Marine Park. OEPA assessment Bulletin 393, Statement 101, January 1990;
- Change of Environmental Conditions – Beenyup Ocean Outfall Duplication into Marmion Marine Park. OEPA assessment Bulletin 762, Statement No. 382, March 1995; and
- Change of Environmental Conditions - Beenyup Ocean Outfall Duplication into Marmion Marine Park, Statement No. 569, July 2001.

This premises is bound by Ministerial Conditions for its operation, which should be considered in conjunction with this licence. The Ministerial Conditions were amended in July 2001 to allow the load of phosphorus discharged at the ocean outlet to be greater. The increase was approved because it has been demonstrated that nitrogen is the limiting factor in algal growth in the particular body of water subject to the discharge.

1.5.2 Part V Environmental Protection Act 1986, Environmental Management

The Beenyup WWTP has been assessed as a "prescribed premises" under Category 54 within Schedule 1 of the *Environmental Protection Regulations 1987* and requires a licence for the operation of the WWTP.

DEC will also administer the following regulations to regulate various activities associated with the WWTP:

- *Environmental Protection (Controlled Waste) Regulations 2004*
- *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*
- *Environmental Protection (Noise) Regulations 1997*
- *Environmental Protection (Unauthorised Discharges)Regulations 2004*

The guidelines that also apply to this premises include:

- *Limits and Targets for Prescribed Premises Policy*, Department of Environment and Conservation (April, 2006).
- *Regulatory Monitoring Requirements for Prescribed Premises*, Department of Environment and Conservation (April, 2006).
- *A Guide to Clearing Permits under the Environmental Protection Act 1986*, Department of Environment and Conservation, June 2005.
- *A Guide to the Exemptions and Regulations for Clearing Native Vegetation under the Environmental Protection Act 1986*, Department of Environment and Conservation, June 2005.

- *Land development sites and impacts on air quality - A Guideline for the Prevention of Dust and Smoke Pollution from Land Development Sites in Western Australia* (Department of Environment and Conservational Protection, 1996)
- *Australian Guidelines for Sewerage Systems – Effluent Management* (ANZECC 1997).
- *EPA Guidance Statement No. 3 – Separation Distances between Industrial and Sensitive Land Uses*
- *EPA Draft Guidance Statement No. 8 – Environmental Noise*
- *EPA Draft Guidance Statement No. 47 – Interim guidance on odour as a relevant environmental Factor*
- *EPA Guide – Interim industry consultation guide to community consultation*
- *Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products*, Department of Environmental Protection, Water and Rivers Commission and Department of Health (February, 2002)

1.5.3 Other Decision Making Authorities' Legislation which applies

Department of Mines and Petroleum (DMP) for the storage of chemicals;
Local Government Act 1995; and
Health Act 1911.

1.5.4 Local Government Authority

Beenyup WWTP is located within the City of Joondalup.

2.0 STAKEHOLDER AND COMMUNITY CONSULTATION

SUBMISSIONS RECEIVED DURING 21 DAY PUBLIC COMMENT PERIOD

The Application for licence for this facility was advertised in the West Australian newspaper on 19/09/2011 as a means of advising stakeholders and to seek public comments. No submissions were received.

3.0 EMISSIONS AND DISCHARGES RISK ASSESSMENT

DEC considers that conditions should focus on regulating emissions and discharges of significance. Where appropriate, emissions and discharges which are not significant should be managed and regulated by other legislative tools or management mechanisms.

The following section assesses the environmental risk of potential emissions from the Beenyup WWTP facility. In order to determine the site's appropriate environmental regulation, an emissions and discharges risk assessment was conducted of the Beenyup WWTP facility using the environmental risk matrix outlined in Appendix B. The results of this are summarised in Table 2.

Table 2: Risk assessment and regulatory response summary table.

Risk factor	Significance of emissions	Socio-Political Context of Each Regulated Emission	Risk Assessment	DEC Regulation (EP Act - Part V)	EAR Reference	Other management (legislation,tools,agencies)
Dust emissions	1. Dust emission from the plant is insignificant	No interest	E – No regulation	LIC – no condition	N/A	General provisions of the *Environmental Protection Act 1986* relating to pollution and environmental harm.
Odour emissions	5 –Significant. Odours will primarily be in the form of hydrogen sulfide and volatile organic compounds. Odourous air will be extracted from the inlet works, primary tanks, secondary treatment tanks, and sludge storage facilities, sludge loading and unloading area, passed through a biological scrubber and chemical scrubber and vented to a nominal 50 metre tall stack. Odour control is managed by covering and sealing inlet , primary treatment tanks, secondary treatment tanks, sludge storage, biosolids loading and unloading raeas and directing odourous gas from these odour sources to biological and chemical odour scrubbing system. Most of the odourous compounds (hydrogen sulphide and volatile organic compounds) are removed from the exiting gas by the scrubbers before the gas exits through a 50m tall stack.	High. Community concern is strong. Distance to interested parties is approximately 200m	B – condition (LIC – limits condition) (setting targets) (emission management condition)	LIC– require condition	Apendix A Section 1.1	General provisions of the Environmental Protection Act 1986.
Noise emissions	1. Not significant	No community interest	E – No regulation	LIC– No condition is required	N/A	EP Noise Regulations, Code of Practice, EMP or EMS
Light emissions	1. Not significant	No community concern	E – No regulation	LIC– No licence condition is required	N/A	DEC, EMP or EMS, General provisions of the EP Act

Discharges to water	3 – Somewhat significant. Secondary treated wastewater will be discharged via two ocean outlets (1850m & 1650 m) offshore into the marine environment of the Indian Ocean at a depth of 10m into deep water and open ocean conditions. Under the Ministerial Statement No. 569, nitrogen and phosphorus load discharged into the ocean shall not be more than 3600 kg and 1700 kg per day respectively. WC is also required to monitor heavy metals, BOD and coliform	There is some community interest	B – condition (Limits for nitrogen and phosphorus), monitoring of heavy metals and bacteria	LIC – require conditions	Appendix A Section 1.2	Ministerial Condition for nutrients (nitrogen and Phosphorus) load discharged to the ocean via ocean outlet. UD Regulations, Code of Practice EMP or EMS
Discharges to land	1. Not significant. WC irrigates its plantation areas within the premises	No community concern	E – No regulation	LIC – No condition is required	N/A	UD Regulations, Code of Practice EMP or EMS
Solid / liquid wastes	1. Not significant. Disposal of biosolids will be in accordance with *WA Guidelines for Direct Land Application of Biosolids and Biosolids Products 2002.*	No community concern	E – no regulation	LIC – No condition is required.		Controlled Waste Regs, EMS
Hydrocarbon/ chemical storage	1. Chemical storages have been constructed in accordance with the dangerous goods regulations.	No community concern	D – regulation is required	LIC – require conditions	N/A	Dangerous Goods storage licence and relevant legislation (DOCEP), EMS
Native vegetation clearing	N/A	N/A	N/A	LIC – No conditions	N/A	Clearing permit pending (DMP), EMS
Contaminated site identification	NA	N/A	N/A	LIC – No conditions	N/A	Contaminated Sites Branch (DEC), Tenement Conditions and Closure Plan (DOIR), EMS

4.0 GENERAL SUMMARY AND COMMENTS

Beenup WWTP is an existing sewage facility servicing northern suburbs since 1972. The WWTP has been recently upgraded to increase the daily throughput from 120 ML to 135 ML per day. The plant has been substantially upgraded in terms of odour emission control which includes among others:

- a biological odour scrubber system coupled with the existing chemical scrubber;
- a carbon column odour scrubbing system dedicated to the secondary tanks;
- two new digesters in addition to five existing digesters;
- enclosed biosolid storage and loading area; and
- a 50m tall and 2.6m diameter stack.

The existing licence for Beenyup WWTP has been reviewed and a new licence drafted for the premises. However, the WWTP has the potential to cause odour emission and it requires regulation. Licence conditions have been set to minimise odour emissions from the premises. DEC considers that WC is required to adhere to its odour management plan to ensure odour does not does not unreasonably interfere with the health, welfare, convenience, comfort or amenity of any person at a sensitive receptor.

Secondary treated water will be discharged to the ocean via Beenyup ocean outlet. As per Ministerial statement 569, July 2001, the nutrients load discharged to the ocean shall not be more than 3600 kg per day for nitrogen and 1700 kg per day for phosphorus. Licence conditions have been set to reflect the nutrient limits.

OFFICER PREPARING REPORT

Dr Bhabesh Das

Position: Senior Environmental Officer
Booragoon Office, Swan Region
Department of Environment and Conservation
9333 7521

13/09/2011

ENDORSEMENT

Marko Pasalich

Position: Team Leader
Booragoon Office, Swan Region
Department of Environment and Conservation
9333 7528

13/09/2011

APPENDIX A: EMISSIONS AND DISCHARGES OF SIGNIFICANCE

1.1 ODOUR EMISSIONS

Beenyup WWTP has the potential to generate odour emissions from the site. Unless an adequate odour management system is in place, odour may impact the amenity of land users surrounding the plant.

The sources of odour at the plant include but not limited to the following:

- inlet;
- screening;
- primary tanks;
- secondary tanks;
- sludge loading and unloading area;
- digesters and bio gas; and
- fugitives from leaks, opening of covers.

The main constituent of odour from the WWTP is hydrogen sulphide with minor percent of sulphur containing compounds. Majority of hydrogen sulphide will be removed from odourous air by biological and acid scrubber system before exiting through 50m tall stack.

At Beenyup WC's environmental objective for odour reduction at the WWTP is to ensure that the 5 OU contour (99.9th percentile, 1-hour average, Australian Standard threshold certainty Odour Unit), predicted using the specific odour model developed to simulate conditions at the Beenyup WWTP, falls within 600m buffer distance. At Beenyup residential development has been encroached within just over 200 metres from the premises boundary.

Odour model predications suggest the highest predicted ground level concentrations from the two stacks of 2 Odour Units (OU) occurs within a small zone to the west and north-west, and on the south boundary of the treatment plant. There is a zone above 1.5 OU to the west of the plant and a smaller zone above 1.5 OU to the south-east. All predicted concentrations of the contribution from the new larger stack are below 5 OU.

ODOUR EMISSIONS RISK ASSESSMENT

The environmental risk of odour emission is set at medium high considering community concern about odour from the premises and in accordance with Appendix B: Emissions and Discharges risk assessment matrix.

RECOMMENDED STRATEGY FOR MANAGING ODOUR EMISSIONS

The issue of odour emissions require regulation. Accordingly, licence conditions have been set requiring continuous monitoring of hydrogen sulphide on the exiting air from the scrubber system before discharging through 50m tall stack, stack monitoring to meet licence criteria. WC is required to adhere to its Odour Management Plan.

1.2 DISCHARGES TO WATER

Secondary treated water is discharged to the ocean via Beenyup ocean outlet. Secondary treated wastewater is also directed to WC's groundwater replenishment plant.

DISCHARGES TO WATER RISK ASSESSMENT

WC has been monitoring marine environment surrounding the discharge point and provides the report to the Marine Branch of DEC. The impact on the marine environment appears to be insignificant.

RECOMMENDED STRATEGY FOR MANAGING DISCHARGES TO WATER

The issue of water discharges require regulation. Under the Ministerial statement 569, July 2001, the nutrients load discharged to the ocean shall not be more than 3600 kg per day for nitrogen and 1700 kg per day for phosphorus. Licence conditions have been set to reflect the nutrient limits.

APPENDIX B: EMISSIONS AND DISCHARGES RISK ASSESSMENT MATRIX

Table 3: Measures of Significance of Emissions

Emissions as a percentage of the relevant emission or ambient standard		Worst Case Operating Conditions (95th Percentile)			
		>100%	50 – 100%	20 – 50%	<20%*
Normal Operating Conditions (50th Percentile)	>100%	5	N/A	N/A	N/A
	50 – 100%	4	3	N/A	N/A
	20 – 50%	4	3	2	N/A
	<20%*	3	3	2	1

*For reliable technology, this figure could increase to 30%

Table 4: Socio-Political Context of Each Regulated Emission

		Relative proximity of the interested party with regards to the emission				
		Immediately Adjacent	Adjacent	Nearby	Distant	Isolated
Level of Community Interest or Concern*	5	High	High	Medium High	Medium	Low
	4	High	High	Medium High	Medium	Low
	3	Medium High	Medium High	Medium	Low	No
	2	Low	Low	Low	Low	No
	1	No	No	No	No	No

Note: These examples are not exclusive and professional judgement is needed to evaluate each specific case

*This is determined by DEC using the DEC "Officer's Guide to Emissions and Discharges Risk Assessment" May 2006.

Table 5: Emissions Risk Reduction Matrix

		Significance of Emissions				
		5	4	3	2	1
Socio-Political Context	High	A	A	B	C	D
	Medium High	A	A	B	C	D
	Medium	A	B	B	D	E
	Low	A	B	C	D	E
	No	B	C	D	E	E

PRIORITY MATRIX ACTION DESCRIPTORS
A = Do not allow (fix)
B = licence condition (setting limits + EMPs - short timeframes)(setting targets optional)
C = licence condition (setting targets + EMPs - longer timeframes)
D= EIPs, other management mechanisms/licence conditions (monitoring/reporting)/other regulatory tools
E = No regulation, other management mechanisms

Note: The above matrix is taken from the DEC Officer's Guide to Emissions and Discharges Risk Assessment May 2006.

Ass # 912
Bull # 762
State # 382

WESTERN AUSTRALIA

MINISTER FOR THE ENVIRONMENT

STATEMENT TO AMEND CONDITIONS APPLYING TO A PROPOSAL (PURSUANT TO THE PROVISIONS OF SECTION 46 OF THE ENVIRONMENTAL PROTECTION ACT 1986)

PROPOSAL:	BEENYUP WASTEWATER OCEAN OUTLET DUPLICATION INTO MARMION MARINE PARK (079 / 912)
CURRENT PROPONENT:	WATER AUTHORITY OF WESTERN AUSTRALIA
CONDITIONS SET ON:	13 JULY 1990

The implementation of this proposal is now subject to the following conditions which replace all previous conditions:

1 Implementation

The proponent must adhere in substance to the proposal as assessed. However, changes to the proposal which are not substantial may be carried out with the approval of the Minister for the Environment.

1-1 Subject to these conditions, the manner of detailed implementation of the proposal shall conform in substance with that set out in any designs, specifications, plans or other technical material submitted by the proponent to the Environmental Protection Authority with the proposal. Where, in the course of that detailed implementation, the proponent seeks to change those designs, specifications, plans or other technical material in any way that the Minister for the Environment determines on the advice of the Environmental Protection Authority, is not substantial, those changes may be effected.

2 Target Loads for Nitrogen and Phosphorus

2-1 The proponent shall not permit the combined mean monthly nutrient loadings within both the original and second pipelines from the Beenyup Wastewater Treatment Plant to exceed the maximum loads set for total phosphorus (plus 10 per cent) and total nitrogen for the original single outfall.

The maximum load set for total phosphorus is 913 kg per day and for total nitrogen 3.6 tonnes per day.

2-2 The proponent shall refer to the Environmental Protection Authority any proposal to increase the levels of nutrients discharged beyond the levels referred to in condition 2-1 .

2-3 Prior to 31 August each year, the proponent shall submit monitoring reports to the Department of Environmental Protection, giving details of the plant performance, in relation to the mean monthly nutrient concentrations and loads in the wastewater.

Published on

13 MAR 1995

12th FLOOR, DUMAS HOUSE, 2 HAVELOCK STREET, WEST PERTH, 6005 TELEPHONE (09) 321 2222 FAX (09) 322 5149

3 Nutrient Impact Studies

The proponent should undertake studies to determine the impacts of nutrients from the Beenyup outfalls.

3-1 Prior to 31 July 1990, the proponent shall commence a study to examine water circulation in the region of the outlets of both pipelines in order to determine the flushing characteristics of the receiving waterbody, in consultation with and to the requirements of the Department of Environmental Protection on advice of the Department of Conservation and Land Management. A complete range of conditions shall be sampled to enable calibration of an appropriate numerical model.

3-2 Prior to 31 July 1990, the proponent shall commence a study to examine the effects of nutrient loadings on the local marine communities, in consultation with and to the requirements of the Department of Environmental Protection on advice of the Department of Conservation and Land Management. This study shall involve at least three years of intensive effort (Phase 1) and two years of reduced effort (Phase 2).

3-3 Prior to commencement of the studies required by conditions 3-1 and 3-2, the proponent shall establish a Technical Advisory Group, which includes representatives from the Water Authority of Western Australia, the Department of Environmental Protection, the Fisheries Department and the Department of Conservation and Land Management, to co-ordinate the studies.

3-4 In the event that, due to excessive nutrient loading, the effluent causes an unacceptable environmental impact in the opinion of the Minister for the Environment on advice of the Department of Environmental Protection, the proponent shall undertake additional treatment of the effluent to further remove nutrients to a level acceptable to the Minister for the Environment.

4 Monitoring Programme

4-1 The proponent shall continue with the existing monitoring programme as described in the Public Environmental Report, to the requirements of the Department of Environmental Protection in consultation with the Department of Conservation and Land Management and the Fisheries Department.

4-2 The proponent shall submit reports on the monitoring programme referred to in condition 4-1 to the Department of Environmental Protection as outlined in the Public Environmental Report.

5 Water Quality

Condition deleted. (Matter addressed by Procedures 3 and 4).

6 Bacterial Concentrations

6-1 In the event that water quality criteria for bacteria in the prescribed beneficial use zones are exceeded, the proponent shall further treat the effluent to reduce bacterial concentrations.

7 Effects on Marine Biota

7-1 In the event that concentrations of bacteria or other contaminants introduced into the receiving water by the proponent are unacceptable, in the opinion of the Minister for the Environment, because of demonstrable effects on marine biota (especially mammals), the proponent shall take action to ensure that concentrations of contaminants are reduced to levels which are acceptable to the Minister for the Environment on advice of the Departments of Environmental Protection and Conservation and Land Management.

8 Surveys of Biota Contamination

8-1 The proponent shall undertake surveys, to the requirements of the Department of Environmental Protection in consultation with the Department of Conservation and Land Management and the Fisheries Department, to investigate contamination of biota (particularly the harvestable fish species of the area) by heavy metals, pesticides and by-products of the chlorination process.

These surveys shall:

1 incorporate an initial survey, commencing as soon as possible and to be completed before the second pipeline becomes operational, to establish current levels of contamination in a range of species; and

2 include follow-up surveys, to take place every three years, with a major review after 12 years.

The proponent shall forward results to the Department of Environmental Protection within six months of completion of sampling.

8-2 In the event that levels of contamination of biota are found to be unacceptable in the opinion of the Minister for the Environment, the proponent shall reduce concentrations of contaminants to levels which are acceptable to the Minister for the Environment on advice of the Department of Environmental Protection.

9 Approval of Pipeline Alignment

Condition deleted. (Alignment now approved and pipeline constructed).

10 Alternative to Underwater Blasting for Rock Removal

Condition deleted. (Alternative approved and rock removed).

11 Rehabilitation of On-shore Site

11-1 Following the completion of construction and launching of the pipeline, the proponent shall rehabilitate the onshore site to the requirements of the Department of Environmental Protection on advice of the Ministry for Planning.

12 Studies to Predict Loads and Impacts by 2040

12-1 Prior to 31 March 1995, the proponent shall undertake and complete studies to the requirements of the Environmental Protection Authority which:

1 predict the wastewater discharges and characteristics likely to occur by the year 2040 from Metropolitan Perth (including discharges from the area between Mandurah and Yanchep, inclusive); and

2 determine whether the waters off Metropolitan Perth have the assimilative capacity for the combined wastewater discharges predicted to occur by 2040.

13 Studies of Alternatives to Ocean Disposal

13-1 Prior to 31 March 1995, the proponent shall undertake and complete a study to the requirements of the Environmental Protection Authority which investigates alternatives to ocean disposal of wastewater.

14 Decommissioning

14-1 The proponent shall achieve satisfactory decommissioning, and if necessary, removal of the pipeline and rehabilitation of the site and its environs.

14-2 At least six months prior to decommissioning, the proponent shall prepare a decommissioning and rehabilitation plan.

14-3 The proponent shall implement the plan required by condition 14-2.

Procedure

1 The Department of Environmental Protection is responsible for verifying compliance with the conditions contained in this statement, with the exception of conditions stating that the proponent shall meet the requirements of either the Minister for the Environment or any other public authority.

2 If the Department of Environmental Protection, other public authority or proponent is in dispute concerning compliance with the conditions contained in this statement, that dispute will be determined by the Minister for the Environment.

3 Prior to commencing operations, the Department of Environmental Protection, on advice of the Water Authority of Western Australia, the Departments of Conservation and Land Management and Health and the Fisheries Department will identify beneficial uses and beneficial use zones for the waters in the locality of the outlets and determine a mixing zone, to the requirements of the Minister for the Environment. The water quality criteria for the beneficial use zones will be those published in Environmental Protection Authority Bulletin No 103, Water Quality Criteria for Marine and Estuarine Waters of Western Australia, April 1981, or as revised from time to time.

4 The allocation of beneficial uses and beneficial use zones and the mixing zone will be periodically reviewed in the light of monitoring data, to the requirements of the Minister for the Environment on advice of the Department of Environmental Protection.

Peter Foss, MLC
MINISTER FOR THE ENVIRONMENT

13 MAR 1995

Appendix B – Analytical laboratories and methods

Analytical Laboratories

Analytes determined and analytical laboratories used for treated wastewater characterisation

Analytes	Analytical Laboratory	Analytical Method	Reporting Limit	Unit
Microbiological				
E.coli	PathWest Laboratory Medicine WA	Membrane filtration	Dilution dependent(1)	CFU 100 mL^{-1}
Enterococci	PathWest Laboratory Medicine WA	Membrane filtration	Dilution dependent(1)	MPN 100 mL^{-1}
Nutrients				
Ortho-phosphate	Murdoch University Marine and Freshwater Research Laboratory (MAFRL) and/or National Measurement Institute (NMI)	Lachat-Automated Flow Injection Analyser (4100)	2(2)	µg P L^{-1}
Ammonia		Lachat-Automated Flow Injection Analyser (2000)	3(2)	µg N L^{-1}
Nitrate + Nitrite		Lachat-Automated Flow Injection Analyser (2100)	2(2)	µg N L^{-1}
Total Nitrogen		Lachat-Automated Flow Injection Analyser (2700)	50(2)	µg N L^{-1}
Total Phosphorus		Lachat-Automated Flow Injection Analyser (4700)	5(2)	µg P L^{-1}
Metals and Metalloids				
Arsenic filtered	National Measurement Institute (NMI)	Inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectrometry (NT2.47.251)	1	µg L^{-1}
Arsenic total		NT2.47.251	1	µg L^{-1}
Cadmium filtered		Inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectrometry (NT2.47)	0.1	µg L^{-1}
Cadmium total		NT2.47	0.1	µg L^{-1}
Chromium filtered		NT2.47	2	µg L^{-1}
Chromium total		NT2.47	2	µg L^{-1}
Copper filtered		NT2.47	1	µg L^{-1}
Copper total		NT2.47	1	µg L^{-1}
Lead filtered		NT2.47	1	µg L^{-1}
Lead total		NT2.47	1	µg L^{-1}
Mercury filtered		Inductively coupled plasma mass spectrometry and inductively coupled plasma atomic emission spectrometry (NT2.47.244)	0.1	µg L^{-1}
Mercury total		NT2.47.244	0.1	µg L^{-1}
Nickel filtered		NT2.47	2	µg L^{-1}
Nickel total		NT2.47	2	µg L^{-1}
Selenium filtered		NT2.47.251	1	µg L^{-1}
Selenium total		NT2.47	1	µg L^{-1}
Silver filtered		NT2.47	0.8	µg L^{-1}
Silver total		NT2.47	0.8	µg L^{-1}
Zinc filtered		NT2.47	2	µg L^{-1}
Zinc total		NT2.47	2	µg L^{-1}

Analytes	Analytical Laboratory	Analytical Method	Reporting Limit	Unit
Phenoxy Acid Herbicides				
Dicamba	National Measurement Institute (NMI)	Electron Impact Full Scan or Selected Ion Monitoring (NGCMS_1117)	1	$\mu g\ L^{-1}$
MCPA		NGCMS_1117	1	$\mu g\ L^{-1}$
Dichlorprop		NGCMS_1117	1	$\mu g\ L^{-1}$
2,4-D		NGCMS_1117	1	$\mu g\ L^{-1}$
2, 4, 5-T		NGCMS_1117	1	$\mu g\ L^{-1}$
2 4, 5 –TP		NGCMS_1117	1	$\mu g\ L^{-1}$
2, 4-DB		NGCMS_1117	1	$\mu g\ L^{-1}$
MCPP		NGCMS_1117	1	$\mu g\ L^{-1}$
Trichlopyr		NGCMS_1117	1	$\mu g\ L^{-1}$
Triazine Herbicides				
Atrazine	National Measurement Institute (NMI)	Extraction, Cleanup and Analysis (NR_19)	0.1	$\mu g\ L^{-1}$
Hexazinone		NR_19	0.1	$\mu g\ L^{-1}$
Metribuzine		NR_19	0.1	$\mu g\ L^{-1}$
Prometryne		NR_19	0.1	$\mu g\ L^{-1}$
Simazine		NR_19	0.1	$\mu g\ L^{-1}$
Organophosphate Pesticides				
Azinphos-Methyl	National Measurement Institute (NMI)	NR_19	0.1	$\mu g\ L^{-1}$
Azinphos-Ethyl		NR_19	0.1	$\mu g\ L^{-1}$
Chlorpyrifos		NR_19	0.1	$\mu g\ L^{-1}$
Chlorpyrifos Methyl		NR_19	0.1	$\mu g\ L^{-1}$
Chlorfenvinophos (E)		NR_19	0.1	$\mu g\ L^{-1}$
Chlorfenvinphos (Z)		NR_19	0.1	$\mu g\ L^{-1}$
Demeton-S-Methyl		NR_19	0.1	$\mu g\ L^{-1}$
Dichlorvos		NR_19	0.1	$\mu g\ L^{-1}$
Diazinon		NR_19	0.1	$\mu g\ L^{-1}$
Dimethoate		NR_19	0.1	$\mu g\ L^{-1}$
Ethion		NR_19	0.1	$\mu g\ L^{-1}$
Fenthion		NR_19	0.1	$\mu g\ L^{-1}$
Fenitrothion		NR_19	0.1	$\mu g\ L^{-1}$
Malathion		NR_19	0.1	$\mu g\ L^{-1}$
Parathion (Ethyl)		NR_19	0.1	$\mu g\ L^{-1}$
Parathion Methyl		NR_19	0.1	$\mu g\ L^{-1}$
Pirimiphos-Ethyl		NR_19	0.1	$\mu g\ L^{-1}$
Pirimiphos-Methyl		NR_19	0.1	$\mu g\ L^{-1}$
Organochlorine Pesticides				
Aldrin	National Measurement Institute (NMI)	NR_19	0.01	$\mu g\ L^{-1}$
trans-Chlordane		NR_19	0.01	$\mu g\ L^{-1}$
cis-Chlordane		NR_19	0.01	$\mu g\ L^{-1}$
Oxychlordane		NR_19	0.01	$\mu g\ L^{-1}$
BHC (other than lindane)		NR_19	0.01	$\mu g\ L^{-1}$
DDD		NR_19	0.01	$\mu g\ L^{-1}$
DDE		NR_19	0.01	$\mu g\ L^{-1}$
DDT		NR_19	0.01	$\mu g\ L^{-1}$
Dieldrin		NR_19	0.01	$\mu g\ L^{-1}$
Endrin		NR_19	0.01	$\mu g\ L^{-1}$
Endrin Aldehyde		NR_19	0.01	$\mu g\ L^{-1}$
Endrin Ketone		NR_19	0.01	$\mu g\ L^{-1}$
alpha-Endosulfan		NR_19	0.01	$\mu g\ L^{-1}$
beta-Endosulfan		NR_19	0.01	$\mu g\ L^{-1}$
Endosulfan Sulfate		NR_19	0.01	$\mu g\ L^{-1}$
HCB		NR_19	0.01	$\mu g\ L^{-1}$

Analytes	Analytical Laboratory	Analytical Method	Reporting Limit	Unit
Heptachlor		NR_19	0.01	µg L^{-1}
Heptachlor epoxide		NR_19	0.01	µg L^{-1}
Lindane		NR_19	0.01	µg L^{-1}
Methoxychlor		NR_19	0.01	µg L^{-1}
Phthalates				
Dimethyl phthalate	National Measurement Institute (NMI)	Electron Impact or Selected Ion Monitoring (NGCMS_1111)	10	µg L^{-1}
Diethyl phthalate		NGCMS_1111	10	µg L^{-1}
Di-n-butyl phthalate		NGCMS_1111	10	µg L^{-1}
Benzyl butyl phthalate		NGCMS_1111	10	µg L^{-1}
Bis(2-ethylhexyl)phthalate		NGCMS_1111	20	µg L^{-1}
Di-n-octyl phthalate		NGCMS_1111	10	µg L^{-1}
PCB Aroclors				
Aroclor 1016	National Measurement Institute (NMI)	NR_19	0.1	µg L^{-1}
Aroclor 1221		NR_19	0.1	µg L^{-1}
Aroclor 1232		NR_19	0.1	µg L^{-1}
Aroclor 1242		NR_19	0.1	µg L^{-1}
Aroclor 1248		NR_19	0.1	µg L^{-1}
Aroclor 1254		NR_19	0.1	µg L^{-1}
Aroclor 1260		NR_19	0.1	µg L^{-1}
Total PCBs (as above)		NR_19	0.1	µg L^{-1}
Chlorinated Hydrocarbons				
2-Chloronaphthalene	National Measurement Institute (NMI)	Extraction, Filtration and Analysis using a modified USEPA 8270 method (NGCMS_1122)	20	µg L^{-1}
1,4-Dichlorobenzene		NGCMS_1122	20	µg L^{-1}
1,2-Dichlorobenzene		NGCMS_1122	20	µg L^{-1}
1,3-Dichlorobenzene		NGCMS_1122	20	µg L^{-1}
Hexachlorobenzene		NGCMS_1122	20	µg L^{-1}
1,2,4-Trichlorobenzene		NGCMS_1122	20	µg L^{-1}
Hexachloroethane		NGCMS_1122	20	µg L^{-1}
Hexachlorocyclopentadiene		NGCMS_1122	20	µg L^{-1}
Hexachloro-1,3-butadiene		NGCMS_1122	20	µg L^{-1}
Ethers				
4-Bromophenyl phenyl ether	National Measurement Institute (NMI)	NGCMS_1122	20	µg L^{-1}
4-Chlorophenyl phenyl ether		NGCMS_1122	20	µg L^{-1}
Bis(2-chloroethyl)ether		NGCMS_1122	20	µg L^{-1}
Bis(2-chloroethoxy)methane		NGCMS_1122	20	µg L^{-1}
Bis(2-chloroisopropyl)ether		NGCMS_1122	20	µg L^{-1}
Amines, Nitroaromatics & Nitrosamines				
Azobenzene	National Measurement Institute (NMI)	NGCMS_1122	20	µg L^{-1}
2,4-Dinitrotoluene		NGCMS_1122	20	µg L^{-1}
2,6-Dinitrotoluene		NGCMS_1122	20	µg L^{-1}
Nitrobenzene		NGCMS_1122	20	µg L^{-1}
NNitrosodimethylamine		NGCMS_1122	20	µg L^{-1}
N-Nitrosodiphenylamine		NGCMS_1122	20	µg L^{-1}
N-Nitrosodi-n-		NGCMS_1122	20	µg L^{-1}

Analytes	Analytical Laboratory	Analytical Method	Reporting Limit	Unit
propylamine				
Aniline		NGCMS_1122	20	µg L^{-1}
4-Chloroaniline		NGCMS_1122	20	µg L^{-1}
2-Nitroaniline		NGCMS_1122	20	µg L^{-1}
3-Nitroaniline		NGCMS_1122	20	µg L^{-1}
4-Nitroaniline		NGCMS_1122	20	µg L^{-1}
Other Organics				
Dichlorobenzidine	National Measurement Institute (NMI)	NGCMS_1122	20	µg L^{-1}
2-Methylnaphthalene		NGCMS_1122	10	µg L^{-1}
Isophorone		NGCMS_1122	20	µg L^{-1}
Benzyl alcohol		NGCMS_1122	20	µg L^{-1}
Carbazole		NGCMS_1122	20	µg L^{-1}
Dibenzofuran		NGCMS_1122	20	µg L^{-1}
BTEX				
Benzene	National Measurement Institute (NMI)	Purge and trap technique with GC/FID (WL244)	1	µg L^{-1}
Toluene		WL244	1	µg L^{-1}
Ethylbenzene		WL244	1	µg L^{-1}
Xylene		WL244	2	µg L^{-1}
Total BTEX		WL244	5	µg L^{-1}
TPH				
TPH C6-C9	National Measurement Institute (NMI)	WL244	25	µg L^{-1}
TPH C10-C14		Gas chromatography with flame ionisation detection (WL203)	25	µg L^{-1}
TPH C15-C28		WL203	100	µg L^{-1}
TPH C29-C36		WL203	100	µg L^{-1}
Total Petroleum Hydrocarbons (TPH)		WL203	250	µg L^{-1}
PAHs				
Naphthalene	National Measurement Institute (NMI)	NGCMS_1111	0.1	µg L^{-1}
Acenaphthylene		NGCMS_1111	0.1	µg L^{-1}
Acenaphthene		NGCMS_1111	0.1	µg L^{-1}
Fluorene		NGCMS_1111	0.1	µg L^{-1}
Phenanthrene		NGCMS_1111	0.1	µg L^{-1}
Anthracene		NGCMS_1111	0.1	µg L^{-1}
Fluoranthene		NGCMS_1111	0.1	µg L^{-1}
Pyrene		NGCMS_1111	0.1	µg L^{-1}
Benzo(a)anthracene		NGCMS_1111	0.1	µg L^{-1}
Chrysene		NGCMS_1111	0.1	µg L^{-1}
Benzo(b)&(k)fluoranthene		NGCMS_1111	0.1	µg L^{-1}
Benzo(a)pyrene		NGCMS_1111	0.1	µg L^{-1}
Indeno(1,2,3-cd)pyrene		NGCMS_1111	0.1	µg L^{-1}
Dibenz(ah)anthracene		NGCMS_1111	0.1	µg L^{-1}
Benzon(ghi)perylene		NGCMS_1111	0.1	µg L^{-1}
Surfactants				
methylene blue active substances (MBAS) *	SGS Australia	Methylene dye added, extraction and colorimetrically measured based on test APHA 5540C	n/a	n/a
Miscellaneous Other				
Chlorine-Free	National Measurement Institute (NMI)	Colour test by comparision with coloured disc (WL146)	0.02	mg/L
Chlorine-Total		WL146	0.02	mg/L
Dissolved Organic		Split Sample and Compare	n/a	mg/L

Analytes	Analytical Laboratory	Analytical Method	Reporting Limit	Unit
Carbon (after filtering)		Total Carbon and Inorganic Carbon measured with Infrared Detector – Based on Method APHA 5310B (WL240)		
Total Organic Carbon		WL240	n/a	mg/L
Total Suspended Solids		Gravimetric Procedure – Based on APHA Methods 2540D and E (WL126)	5	mg/L
5-day Biological Oxygen Demand		5 Day Incubation of Neutralised, Chlorine Free Sample – Based on APHA Method 5210B (WL189)	5	mg/L
pH		Measured Potentiometrically Using a Combination Electrode (WL120)	0.1	pH unit

Notes:

1. The upper and lower detection limits for microbiological indicators are dependent on the dilution of the original sample.
2. Method detection limit determined from 3.2 x standard deviation of 10 standard samples.
   n/a = information not available

Analytical methods and reporting limits for water quality parameters

Parameter	Analytical Method(1)	Reporting Limit	Unit
Nutrients			
Ortho-phosphate	Lachat-Automated Flow Injection Analyser (4100)	2(2)	µg P L^{-1}
Ammonia	Lachat-Automated Flow Injection Analyser (4100)	3(2)	µg P L^{-1}
Nitrate + Nitrite	Lachat-Automated Flow Injection Analyser (4100)	2(2)	µg P L^{-1}
Primary Production			
Chlorophyll-a	Acetone extraction (3000)	0.1(2)	µg P L^{-1}
Phaeophytin	Acetone extraction (3000)	0.1(2)	µg P L^{-1}
Microbiological Indicators			
E.coli	Membrane filtration	Dilution dependent(3)	CFU 100 ml^{-1}
Enterococci	Membrane filtration	Dilution dependent(3)	CFU 100 ml^{-1}

Notes:

1. Numbers in brackets refer to the MAFRL analysis method number.
2. Method detection limit determined from 3.2 x standard deviation of 10 standard samples.
3. The upper and lower detection limits for microbiological indicators are dependent on the dilution of the original sample.

Appendix C – Treated wastewater characterisation results

Parameter	Ocean Reef	ANZECC/ARMCANZ (2000a) guidelines (µg/L)[1]				
	TWW	Level of protection				Low reliability value (LRV)
	3 Feb 2015	99%	95%	90%	80%	
Microbiological						
Confirmed *Enterococci* (MPN/100 mL)[2]	16 000	n/a[3]	n/a	n/a	n/a	n/a
Presumptive thermotolerant coliforms (TTC; CFU/100 mL)[4]	250 000	n/a	n/a	n/a	n/a	n/a
Confirmed TTC (CFU/100 mL)[4]	250 000	n/a	n/a	n/a	n/a	n/a
Escherichia coli (CFU/100 mL)	250 000	n/a	n/a	n/a	n/a	n/a
Nutrients (µg/L)						
Ammonia-N	**2400**	**500**	910	1200	1700	-
Nitrate-N+Nitrite-N	8 000	ID[5]	ID	ID	ID	13,000
Nitrogen-Total N	11 000	n/a	n/a	n/a	n/a	n/a
Phosphate-Ortho as P	6 100	n/a	n/a	n/a	n/a	n/a
Phosphorous-Total P	6 600	n/a	n/a	n/a	n/a	n/a
'Dissolved' (0.45 µm filtered) (µg/L)						
Arsenic (As)	<1	ID	ID	ID	ID	2.3 (As III) 4.5 (As V)
Cadmium (Cd)	<0.1	0.7	5.5	14	36	-
Chromium (Cr)	1	7.7 (Cr III) 0.14 (Cr VI)	27.4 (Cr III) 4.4 (Cr VI)	48.6 (Cr III) 20 (Cr VI)	90.6 (Cr III) 85 (Cr VI)	-
Copper (Cu)	**7**	**0.3**	1.3	3	8	-
Lead (Pb)	<1	2.2	4.4	6.6	12	-
Mercury (Hg)	<0.1	0.1	0.4	0.7	1.4	-
Nickel (Ni)	2	7	70	200	560	-
Selenium (Se)	<1	ID	ID	ID	ID	3
Silver (Ag)	<0.8	0.8	1.4	1.8	2.6	-
Zinc (Zn)	**62**	**7**	15	23	43	-
Total metals (acid extractable; unfiltered) (µg/L)						
Arsenic (As)	<1	ID	ID	ID	ID	2.3 (As III) 4.5 (AsV)
Cadmium (Cd)	<0.1	0.7	5.5	14	36	-
Chromium (Cr)	1.2	7.7 (Cr III) 0.14 (Cr VI)	27.4 (Cr III) 4.4 (Cr VI)	48.6 (Cr III) 20 (Cr VI)	90.6 (Cr III) 85 (Cr VI)	-
Copper (Cu)	**6.4**	**0.3**	1.3	3	8	-
Lead (Pb)	<1	2.2	4.4	6.6	12	-
Mercury (Hg)	<0.1	0.1	0.4	0.7	1.4	-
Nickel (Ni)	2	7	70	200	560	-
Selenium (Se)	<1	ID	ID	ID	ID	3
Silver (Ag)	<0.8	0.8	1.4	1.8	2.6	-
Zinc (Zn)	**52**	**7**	15	23	43	-
Triazine herbicides (µg/L)						
Atrazine	<0.1	ID	ID	ID	ID	13
Hexazinone	<0.1	ID	ID	ID	ID	75
Metribuzine	<0.1	n/a	n/a	n/a	n/a	n/a
Prometryne	<0.1	n/a	n/a	n/a	n/a	n/a

Parameter	Ocean Reef	ANZECC/ARMCANZ (2000a) guidelines (µg/L)[1]				
	TWW	Level of protection				Low reliability value (LRV)
	3 Feb 2015	99%	95%	90%	80%	
Simazine	<0.1	ID	ID	ID	ID	3.2
Phenoxy acid herbicides (µg/L)						
Dicamba[6]	<1	n/a	n/a	n/a	n/a	n/a
MCPA	<1	ID	ID	ID	ID	1.4
Dichlorprop	<1	n/a	n/a	n/a	n/a	n/a
2,4-D	<1	ID	ID	ID	ID	280
2,4,5-T	<1	n/a	n/a	n/a	n/a	n/a
2,4,5-TP	<1	n/a	n/a	n/a	n/a	n/a
2,4-DB	<1	n/a	n/a	n/a	n/a	n/a
MCPP	<1	n/a	n/a	n/a	n/a	n/a
Triclopyr[7]	<1	n/a	n/a	n/a	n/a	n/a
Organophosphate pesticides (µg/L)						
Azinphos-Methyl	<0.1	ID	ID	ID	ID	0.01
Azinphos-Ethyl	<0.1	n/a	n/a	n/a	n/a	n/a
Chlorpyrifos	<0.1	0.0005	0.009	0.04	0.3	-
Chlorfenvinphos (E)	<0.1	n/a	n/a	n/a	n/a	n/a
Chlorfenvinphos (Z)	<0.1	n/a	n/a	n/a	n/a	n/a
Demeton-S-Methyl	<0.1	ID	ID	ID	ID	4
Dichlorvos	<0.1	n/a	n/a	n/a	n/a	n/a
Diazinon	<0.1	ID	ID	ID	ID	0.01
Dimethoate	<0.1	ID	ID	ID	ID	0.15
Ethion	<0.1	n/a	n/a	n/a	n/a	n/a
Fenthion	<0.1	n/a	n/a	n/a	n/a	n/a
Fenitrothion	<0.1	ID	ID	ID	ID	0.001
Malathion	<0.1	ID	ID	ID	ID	0.05
Parathion (Ethyl)	<0.1	ID	ID	ID	ID	0.004
Parathion Methyl	<0.1	n/a	n/a	n/a	n/a	n/a
Pirimiphos-Ethyl[8]	<0.1	n/a	n/a	n/a	n/a	n/a
Pirimiphos-Methyl[9]	<0.1	n/a	n/a	n/a	n/a	n/a
Organochlorine pesticides (µg/L)						
Aldrin	<0.001	ID	ID	ID	ID	0.003
Trans-Chlordane[10]	<0.001	ID	ID	ID	ID	0.001
Cis-Chlordane[10]	<0.001	ID	ID	ID	ID	0.001
Oxychlordane[10]	<0.001	ID	ID	ID	ID	0.001
Gamma-BHC (Lindane)	<0.001	ID	ID	ID	ID	0.007
alpha-BHC	<0.001	n/a	n/a	n/a	n/a	n/a
beta-BHC	<0.001	n/a	n/a	n/a	n/a	n/a
delta-BHC	<0.001	n/a	n/a	n/a	n/a	n/a
p,p-DDD	<0.001	n/a	n/a	n/a	n/a	n/a
p,p-DDE	<0.001	ID	ID	ID	ID	0.0005

Parameter	Ocean Reef	ANZECC/ARMCANZ (2000a) guidelines (µg/L)[1]				
	TWW	Level of protection				Low reliability value (LRV)
	3 Feb 2015	99%	95%	90%	80%	
p,p-DDT	<0.001	ID	ID	ID	ID	0.0004
Dieldrin	<0.001	ID	ID	ID	ID	0.01
Endrin	<0.001	0.004	0.008	0.01	0.02	-
Endrin Aldehyde	<0.001	n/a	n/a	n/a	n/a	n/a
Endrin ketone	<0.001	n/a	n/a	n/a	n/a	n/a
alpha-Endosulfan	<0.001	ID	ID	ID	ID	0.0002
beta-Endosulfan	<0.001	ID	ID	ID	ID	0.007
Endosulfan Sulfate[11]	<0.001	0.005	0.01	0.02	0.05	-
HCB (Hexachlorobenzene)	<0.001	ID	ID	ID	ID	0.05
Heptachlor	<0.001	ID	ID	ID	ID	0.0004
Heptachlor epoxide	<0.001	n/a	n/a	n/a	n/a	n/a
Methoxychlor	<0.001	ID	ID	ID	ID	0.004
Phenol (µg/L)						
Phenol	–	280	400	520	720	–
Nonylphenol	–	ID	ID	ID	ID	1
2-Chorophenol	–	ID	ID	ID	ID	340
2-Methylphenol	–	n/a	n/a	n/a	n/a	n/a
2,4-Dichlorophenol	–	ID	ID	ID	ID	120
2-Nitrophenol	–	n/a	n/a	n/a	n/a	n/a
4-Chloro-3-methylphenol	–	n/a	n/a	n/a	n/a	2
2,4,6-Trichlorophenol	–	ID	ID	ID	ID	34
4-Nitrophenol	–	ID	ID	ID	ID	2
2,4,5-Trichlorophenol	–	n/a	n/a	n/a	n/a	n/a
2,3,4,6-Trichlorophenol	–	ID	ID	ID	ID	10
Pentachlorophenol (PCP)	–	11	22	33	55	-
Phthalates (µg/L)						
Dimethyl phthalate	<10	ID	ID	ID	ID	3700
Diethyl phthalate	<10	ID	ID	ID	ID	900
Di-n-butyl phthalate	<10	ID	ID	ID	ID	25
Butyl benzyl phthalate	<10	n/a	n/a	n/a	n/a	n/a
Bis(2-ethylhexyl) phthalate	<20	ID	ID	ID	ID	1
PCB aroclors						
Aroclor 1016	<0.1	ID	ID	ID	ID	0.009
Aroclor 1221	<0.1	ID	ID	ID	ID	1
Aroclor 1232	<0.1	ID	ID	ID	ID	0.3
Aroclor 1242	<0.1	ID	ID	ID	ID	0.3
Aroclor 1248	<0.1	ID	ID	ID	ID	0.03
Aroclor 1254	<0.1	ID	ID	ID	ID	0.01
Aroclor 1260	<0.1	ID	ID	ID	ID	n/a
Total PCB's (as above)[12]	<0.1	ID	ID	ID	ID	n/a

Parameter	Ocean Reef	ANZECC/ARMCANZ (2000a) guidelines (µg/L)[1]				
	TWW	Level of protection				Low reliability value (LRV)
	3 Feb 2015	99%	95%	90%	80%	
Chlorinated hydrocarbons (µg/L)						
2-Chloronaphthalene	–	n/a	n/a	n/a	n/a	n/a
1,4-Dichlorobenzene	–	ID	ID	ID	ID	60
1,2-Dichlorobenzene	–	ID	ID	ID	ID	160
1,3-Dichlorobenzene	–	ID	ID	ID	ID	260
Hexachlorobenzene	–	ID	ID	ID	ID	0.05
1,2,4-Trichlorobenzene	–	20	80	140	240	-
Hexachloroethane	–	ID	ID	ID	ID	290
Hexachlorocyclopentadiene	–	ID	ID	ID	ID	0.05
Hexachloro-1,3-butadiene[13]	–	ID	ID	ID	ID	0.03
Ethers (µg/L)						
4-Bromophenyl phenyl ether[14]	–	n/a	n/a	n/a	n/a	n/a
4-Chlorophenyl phenyl ether	–	n/a	n/a	n/a	n/a	n/a
Bis(2-chloroethyl)ether	–	n/a	n/a	n/a	n/a	n/a
Bis(2-chloroethoxy)methane	–	n/a	n/a	n/a	n/a	n/a
Bis(2-chloroisopropyl)ether	–	n/a	n/a	n/a	n/a	n/a
Amines, nitroaromatics nitrosamines (µg/L)						
Azobenzene	–	n/a	n/a	n/a	n/a	n/a
2,4-Dinitrotoluene	–	ID	ID	ID	ID	16
2,6-Dinitrotoluene	–	n/a	n/a	n/a	n/a	0.3
Nitrobenzene	–	ID	ID	ID	ID	550
N-Nitrosodimethylamine	–	n/a	n/a	n/a	n/a	n/a
N-Nitrosodiphenylamine	–	ID	ID	ID	ID	6
N-Nitrosodi-n-propylamine	–	n/a	n/a	n/a	n/a	n/a
Aniline	–	ID	ID	ID	ID	8
4-Chloroaniline	–	n/a	n/a	n/a	n/a	n/a
2-Nitroaniline	–	n/a	n/a	n/a	n/a	n/a
3-Nitroaniline	–	n/a	n/a	n/a	n/a	n/a
4-Nitroaniline	–	n/a	n/a	n/a	n/a	n/a
Other organics (µg/L)						
Dichlorobenzidine[15]	–	ID	ID	ID	ID	0.5
2-Methylnaphthalene	–	n/a	n/a	n/a	n/a	n/a
Isophorone	–	ID	ID	ID	ID	130
Benzyl alcohol	–	n/a	n/a	n/a	n/a	n/a
Carbazole	–	n/a	n/a	n/a	n/a	n/a
Dibenzofuran	–	n/a	n/a	n/a	n/a	n/a
BTEX (µg/L)						
Benzene	<1.0	500	700	900	1300	500
Toluene	<1.0	ID	ID	ID	ID	180
Ethylbenzene	<1.0	ID	ID	ID	ID	5

Parameter	Ocean Reef	ANZECC/ARMCANZ (2000a) guidelines (µg/L)[1]				
	TWW	Level of protection				Low reliability value (LRV)
	3 Feb 2015	99%	95%	90%	80%	
Xylene[16]	<2.0	ID	ID	ID	ID	75
Total BTEX[12]	<5.0	n/a	n/a	n/a	n/a	n/a
Total petroleum hydrocarbons (TPH) (µg/L)						
TPH C6 - C9[17]	<25	ID	ID	ID	ID	n/a
TPH C10 - C14[17]	<25	ID	ID	ID	ID	n/a
TPH C15 - C28[17]	<100	ID	ID	ID	ID	n/a
TPH C29 - C36[17]	<100	ID	ID	ID	ID	n/a
Total TPH[17,18]	<250	ID	ID	ID	ID	n/a
Poly aromatic hydrocarbons (PAHs) (µg/L)						
Naphthalene	<0.01	50	70	90	120	-
Acenaphthylene	<0.01	n/a	n/a	n/a	n/a	n/a
Acenaphthene	<0.01	n/a	n/a	n/a	n/a	n/a
Fluorene	<0.01	n/a	n/a	n/a	n/a	n/a
Phenanthrene	<0.01	ID	ID	ID	ID	2
Anthracene	<0.01	ID	ID	ID	ID	0.4
Fluoranthene	<0.01	ID	ID	ID	ID	1.4
Pyrene	<0.01	n/a	n/a	n/a	n/a	n/a
Benz(a)anthracene	<0.01	n/a	n/a	n/a	n/a	n/a
Chrysene	<0.01	n/a	n/a	n/a	n/a	n/a
Benzo(b,k)fluoranthene	<0.02	n/a	n/a	n/a	n/a	n/a
Benzo(a)pyrene	<0.01	n/a	n/a	n/a	n/a	n/a
Indeno(1,2,3-cd)pyrene	<0.01	n/a	n/a	n/a	n/a	n/a
Dibenz(a,h)anthracene	<0.01	n/a	n/a	n/a	n/a	n/a
Benzo(g,h,i)perylene	<0.01	50	70	90	120	-
Surfactants (mg/L)						
Methylene blue active substances (MBAS)[19]	0.09	n/a	n/a	n/a	n/a	n/a
Miscellaneous other (mg/L unless indicated)						
Chlorine-Free	<0.01	ID	ID	ID	ID	3
Chlorine-Total	<0.01	ID	ID	ID	ID	3
Dissolved Organic Carbon (DOC)	11	n/a	n/a	n/a	n/a	n/a
Total Organic Carbon (TOC)	12	n/a	n/a	n/a	n/a	n/a
Total Suspended Solids (TSS)[20]	11	n/a	n/a	n/a	n/a	n/a
Biological Oxygen Demand (BOD)	6	n/a	n/a	n/a	n/a	n/a
pH[21]	7.6	n/a	n/a	n/a	n/a	n/a

Notes:

1. The trigger values for marine waters are from Table 3.4.1 in ANZECC/ARMCANZ (2000a). The EPA has provided advice that in WA waters where a high level of protection applies, that the 99% species protection levels should be used, with the exception of cobalt, where the 95% species protection levels is used. **Grey bold** text represents the relevant ANZECC/ARMCANZ (2000a) guideline values and **amber bold** text represents an exceedance of ANZECC/ARMCANZ (2000a) guideline values prior to initial dilution.
2. Primary and secondary contact guideline for recreational marine waters are 35 and 230 *Enterococci* organisms/100 mL, respectively (ANZECC/ARMCANZ 2000a).
3. n/a = ANZECC/ARMCANZ (2000a) guideline or LRV not available for this parameter.

4. Primary and secondary contact guidelines for recreational marine waters 150 and 1000 faecal coliforms/100 mL (ANZECC/ARMCANZ 2000a), respectively.
5. ID = insufficient data to derive a reliable national trigger value.
6. Recreational guideline for Dicamba = 300 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000a).
7. Recreational guideline for Triclopyr = 20 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000a).
8. Recreational guideline for Pirimiphos-ethyl = 1 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000a).
9. Recreational guideline for Pirimiphos-methyl = 60 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000a).
10. Guideline values are for total chlordane though cis-chlordane is around 7 times more toxic than transchlordane (ANZECC/ARMCANZ 2000a).
11. Values for Endosulphan, not Endosulphan sulfate (Table 3.4.1; ANZECC/ARMCANZ 2000a).
12. ANZECC/ARMCANZ (2000b) recommends using a formula to calculate total toxicity of the mixture if using total PCBs and BTEX (page 8.3-65; ANZECC/ARMCANZ 2000b).
13. Environmental Concern Level (ECL) for Hexachloro-1,3-butadiene (not LRV) (definition of ECL on page 8.3-35; page 8.3-231; ANZECC/ARMCANZ 2000b).
14. Recommended ECL for 4-Bromophenyl phenyl ether = 12 µg L^{-1} (page 8.3-232; ANZECC/ARMCANZ 2000b).
15. ECL for Dichlorobenzidine (not LRV) (page 8.3-187; ANZECC/ARMCANZ 2000b).
16. Guideline for o-Xylene = 350 µg/L, for m-xylene = 75 µg/L and for p-xylene = 200 µg L^{-1} (ANZECC/ARMZANC 2000a).
17. Guideline values are for generic oils and petroleum hydrocarbons (Table 3.4.1; ANZECC/ARMCANZ 2000a).
18. A generic estimate of 7 µg/L for a total petroleum hydrocarbon chronic value has been estimated using USEPA methods (page 8.3-297; ANZECC/ARMCANZ 2000b).
19. Recreational guideline for MBAS = 0.2 mg/L (ANZECC/ARMCANZ 2000a).
20. Suspended solids guidelines for the protection of saltwater aquaculture species = <10,000 µg/L (Table 4.4.2; ANZECC/ARMCANZ 2000a).
21. pH guideline range for slightly disturbed inshore marine ecosystems in south-west Australia = 8.0 to 8.4 (Table 3.3.6; ANZECC/ARMCANZ 2000a).

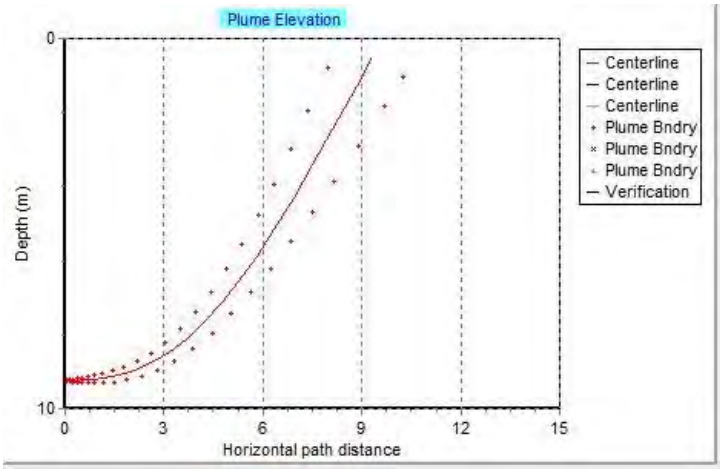
References

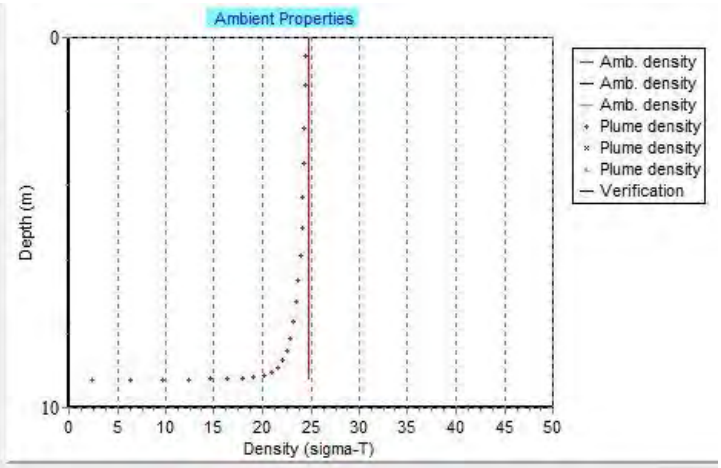
ANZECC/ARMCANZ (2000a) National Water Quality Management Strategy: Paper No 4 − Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1 − The Guidelines (Chapters 1-7). Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australian Capital Territory, October 2000

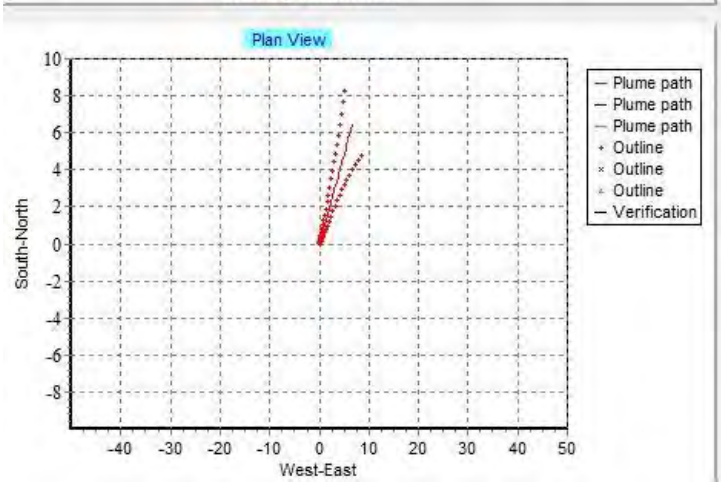
ANZECC/ARMCANZ (2000b) National Water Quality Management Strategy: Paper No 4 − Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 2 − Aquatic Ecosystems − Rationale and Background Information (Chapter 8). Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australian Capital Territory, October 2000

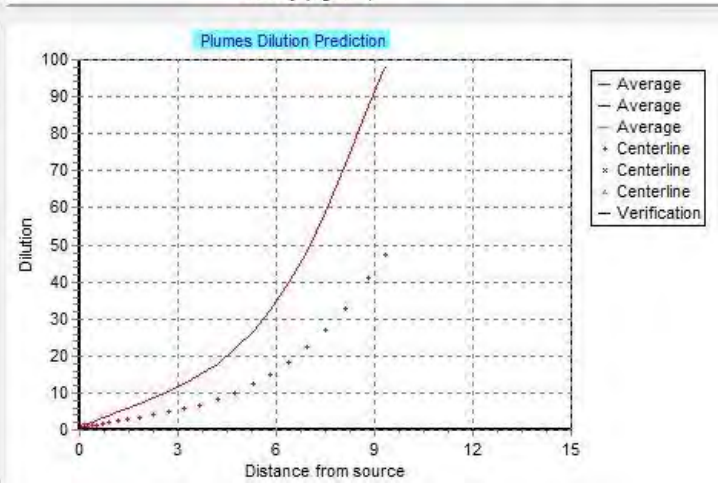
Appendix E – Initial dilution output

```
/ Windows UM3. 4/06/2015 1:01:42 PM
Case 1; ambient file c:\plumes\VP plume 3.001.db; Diffuser table record 1: ----------------------------------
      Depth    Amb-cur    Amb-dir    Amb-sal    Amb-tem    Amb-pol      Decay    Far-spd    Far-dir    Disprsn
          m        m/s        deg        psu          C       kg/kg         s-1        m/s        deg   m0.67/s2
        0.0       0.07       44.0       35.97      22.81         0.0         0.0  2.1416E+8  2.1416E+8        0.0
       9.24      0.062       44.0       35.98      22.93         0.0         0.0  2.1416E+8  2.1416E+8        0.0
   P-dia  P-elev V-angle H-angle   Ports Spacing AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()     (m)     (m)     (m)     (m)   (MLD)   (psu)     (C) (kg/kg)
   0.125    0.76     0.0    46.0    50.0     4.0   100.0   150.0    9.24   129.0     0.6    25.0     0.1
Froude number:      13.32
        Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln    x-posn    y-posn
Step      (m)   (cm/s)      (m)  (kg/kg)       ()       ()       (m)       (m)
   0     9.24      6.2    0.125     0.1      1.0      1.0       0.0       0.0; 
 100    9.046    6.216    0.812  0.0138    7.079    3.398      1.31     1.265; axial vel 0.00903
 192    4.975    6.562    2.735 0.00236    41.24    19.46     4.652     4.492; axial vel  0.0287 max dilution reached
 200    4.311    6.619    3.017 0.00202    48.31    22.77     4.977     4.806; 
 224    2.017    6.816    4.049 0.00125    77.69    36.37     6.033     5.826; merging,
 236    0.481    6.946    4.838 0.000988   98.53    48.67     6.711     6.481; axial vel   0.434 surface,
  ;
1:01:42 PM. amb fills: 2
```

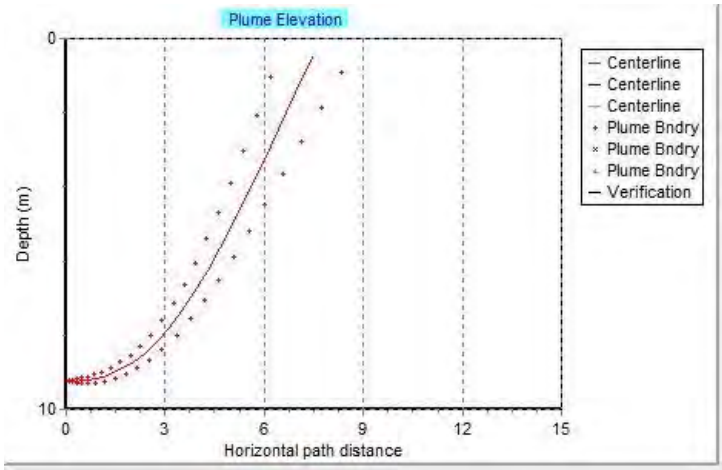


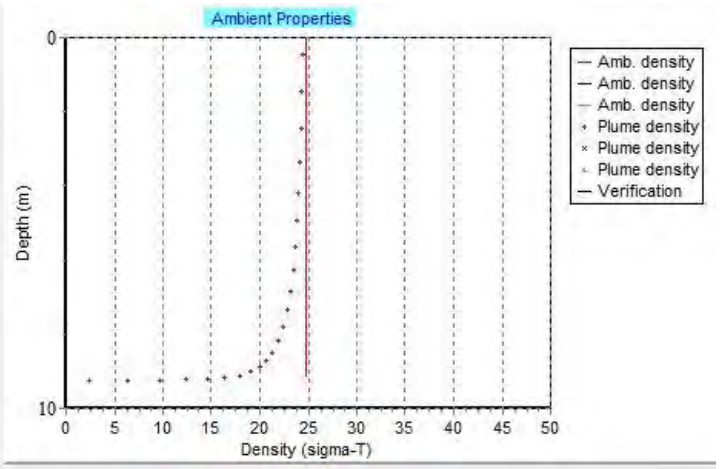


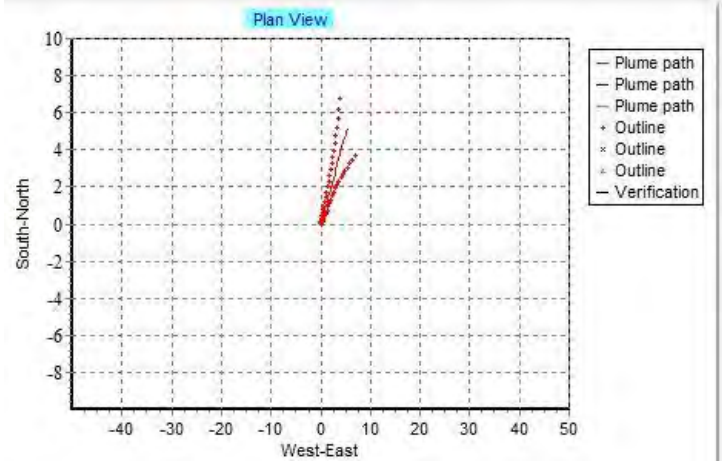


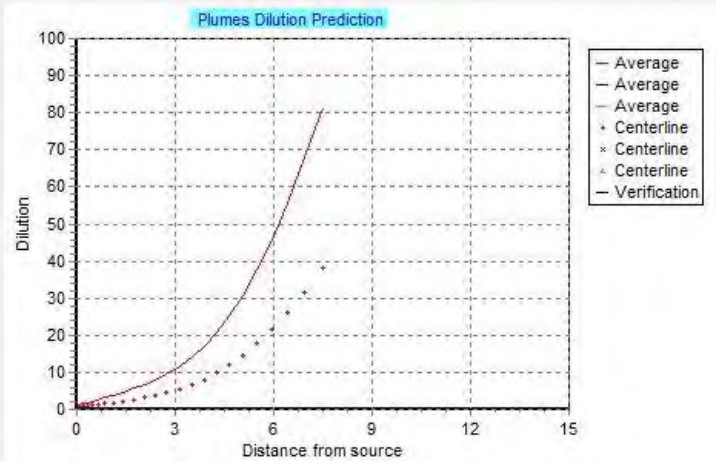


```
/ Windows UM3. 4/06/2015 12:59:24 PM
Case 1; ambient file c:\plumes\VP plume 3.001.db; Diffuser table record 1: ----------------------------------
      Depth     Amb-cur     Amb-dir     Amb-sal     Amb-tem     Amb-pol       Decay     Far-spd     Far-dir     Disprsn
          m         m/s         deg         psu           C        kg/kg         s-1         m/s         deg    m0.67/s2
        0.0        0.07        44.0        35.97       22.81          0.0         0.0  2.1416E+8  2.1416E+8         0.0
       9.16       0.062        44.0        35.98       22.93          0.0         0.0  2.1416E+8  2.1416E+8         0.0
   P-dia  P-elev V-angle H-angle   Ports Spacing AcuteMZ ChrncMZ P-depth Ttl-flo Eff-sal    Temp Polutnt
     (m)     (m)   (deg) (N-deg)      ()      (m)     (m)     (m)     (m)   (MLD)   (psu)     (C) (kg/kg)
    0.16    0.84     0.0    46.0    48.0     4.0   100.0   150.0    9.24   129.0     0.6    25.0     0.1
Froude number:      7.485
        Depth  Amb-cur    P-dia  Polutnt   Dilutn  CL-diln   x-posn   y-posn
Step      (m)   (cm/s)      (m)  (kg/kg)       ()       ()      (m)      (m)
   0     9.24      6.2     0.16      0.1      1.0      1.0      0.0      0.0;
 100     8.72    6.237    0.891   0.0147    6.629     3.16    1.467    1.417;
 194    3.853    6.656     2.77   0.0024    40.65    19.48     4.08     3.94; axial vel  0.0375 max dilution reached
 200    3.343      6.7    2.981  0.00213    45.77    21.89    4.279    4.132;
 224    1.027    6.901    4.001  0.00132    73.61    34.76    5.167     4.99; axial vel   0.177 merging,
 229    0.452     6.95    4.278   0.0012    81.26    39.02    5.389    5.204; surface,
 ;
12:59:24 PM. amb fills: 2
```









Appendix H – Site coordinates

Site Coordinates

Ocean Reef trial compliance monitoring (TCM) reference and seasonal monitoring site location details and water quality parameters measured at the different sites

Site Code	Location with Respect to Outlet	Parameters Measured	Easting	Northing
Intensive Summer Water Quality ('Trial Compliance') Monitoring				
ORR1	Reference Site ≈ 4,000 m south	Nutrients; Phytoplankton; Water column profiles	377208	6482301
ORR2	Reference Site ≈ 4,000 m south	Nutrients; Phytoplankton; Water column profiles	377456	6482302
ORR3	Reference Site ≈ 4,000 m south	Nutrients; Phytoplankton; Water column profiles	377215	6482054
ORR4	Reference Site ≈ 4,000 m south	Nutrients; Phytoplankton; Water column profiles	377461	6482053

Datum: UTM WGS84 Zone 50

Ocean Reef trial compliance monitoring (TCM) sites and their relative distances from the outlet diffuser

Date	Site code - distance from outlet diffuser	Easting	Northing
03/12/2014	ORT-0	377880	6485136
	ORT-100	377712	6485189
	ORT-350	377474	6485266
	ORT-1000	376849	6485449
	ORT-1500	376374	6485614
17/12/2014	ORT-0	377880	6485139
	ORT-100	377818	6485241
	ORT-350	377696	6485459
	ORT-1000	377364	6486018
	ORT-1500	377103	6486447
08/01/2015	ORT-0	377749	6485227
	ORT-100	377542	6485369
	ORT-350	377004	6485735
	ORT-1000	376589	6486011
	ORT-1500	377749	6485227
22/01/2015	ORT-0	377878	6485135
	ORT-100	377829	6485242
	ORT-350	377707	6485452
	ORT-1000	377400	6486038
	ORT-1500	377181	6486483
13/02/2015	ORT-0	377879	6485139
	ORT-100	378027	6484992
	ORT-350	378205	6484814
	ORT-1000	378665	6484352
	ORT-1500	379020	6484004
27/02/2015	ORT-0	377878	6485138
	ORT-100	377889	6485242
	ORT-350	377916	6485490
	ORT-1000	377971	6486132
	ORT-1500	378024	6486631
11/03/2015	ORT-0	377880	6485138
	ORT-100	377749	6485227
	ORT-350	377542	6485369
	ORT-1000	376999	6485727
	ORT-1500	376594	6486028
25/03/2015	ORT-0	377876	6485139
	ORT-100	377721	6485204
	ORT-350	377487	6485298
	ORT-1000	376887	6485548
	ORT-1500	376418	6485735

Datum: UTM WGS84 Zone 50

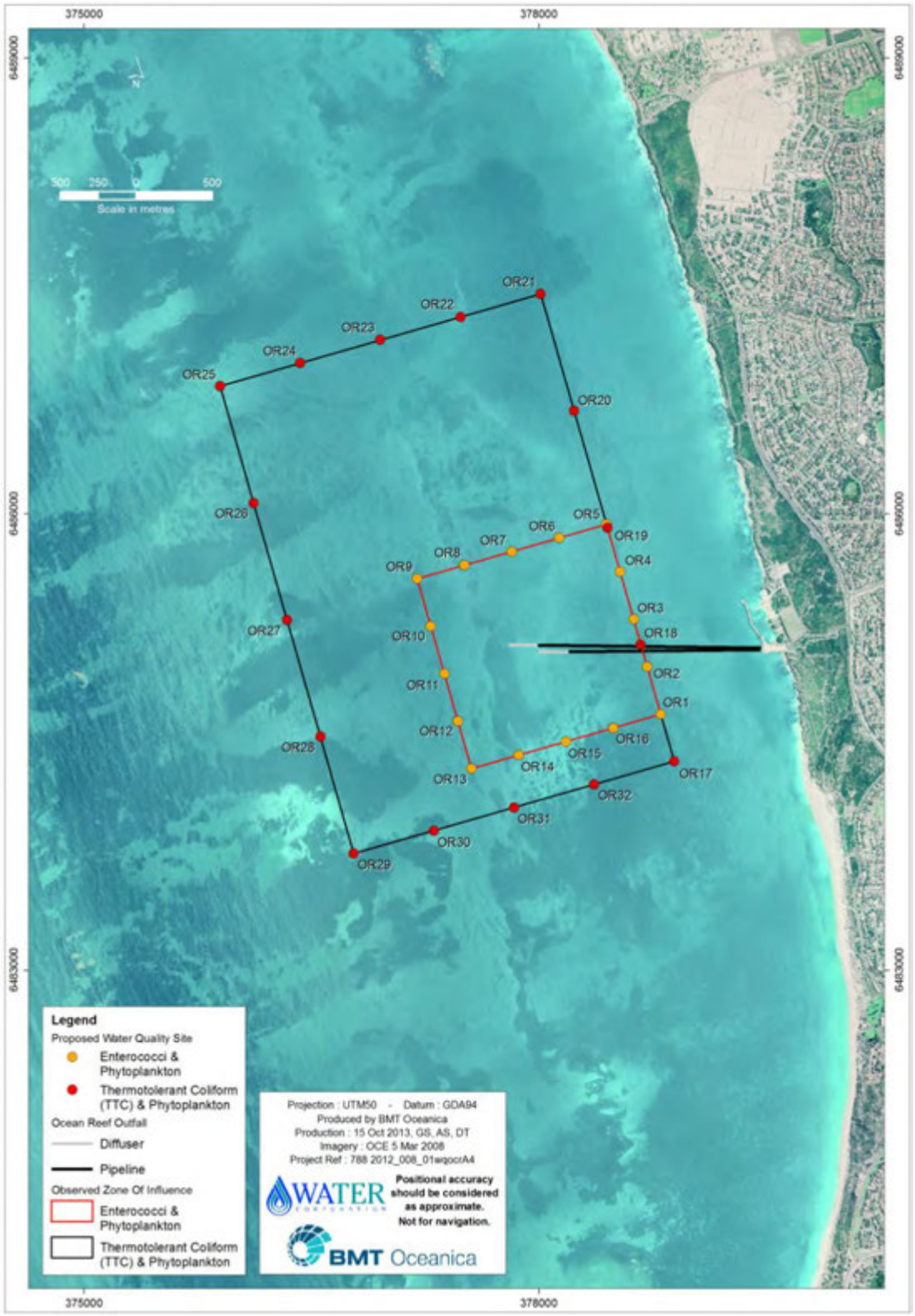
Notes:

1. The location of TCM potential impact sites are determined based on the direction of the surface current on the sampling day

Ocean Reef microbial and phytoplankton monitoring sites at the boundary of the observed zone of influence for contact recreation (1-16) and human consumption (17-32)

Site	Easting	Northing
OR1	378806	6484682
OR2	378717	6484995
OR3	378627	6485307
OR4	378537	6485620
OR5	378448	6485932
OR6	378135	6485842
OR7	377823	6485753
OR8	377511	6485663
OR9	377198	6485574
OR10	377288	6485261
OR11	377378	6484949
OR12	377467	6484637
OR13	377557	6484324
OR14	377869	6484414
OR15	378181	6484503
OR16	378494	6484593
OR17	378895	6484373
OR18	378674	6485142
OR19	378454	6485911
OR20	378233	6486680
OR21	378013	6487449
OR22	377484	6487297
OR23	376956	6487145
OR24	376427	6486994
OR25	375898	6486842
OR26	376119	6486073
OR27	376339	6485304
OR28	376560	6484535
OR29	376780	6483766
OR30	377309	6483918
OR31	377838	6484069
OR32	378366	6484221

Datum: UTM WGS84 Zone 50



Note:

On each sampling occasion, samples are collected down-current of the diffuser at a sub-set of five fixed monitoring sites located at the observed zone of influence boundary. The sites are selected based on the water current direction as indicated by a drogue release.

Fixed sites around the Ocean Reef ocean outlets sampled for thermotolerant coliforms, *Enterococci* spp. and algal (phytoplankton) toxins in relation to the observed zone of influence

BMT Oceanica Pty Ltd
PO Box 462, Wembley,
WA 6913, Australia
Tel: +61 8 6272 0000
Fax: +61 8 6272 0099
bmtoceanica@bmtoceanica.com.au
www.bmtoceanica.com.au