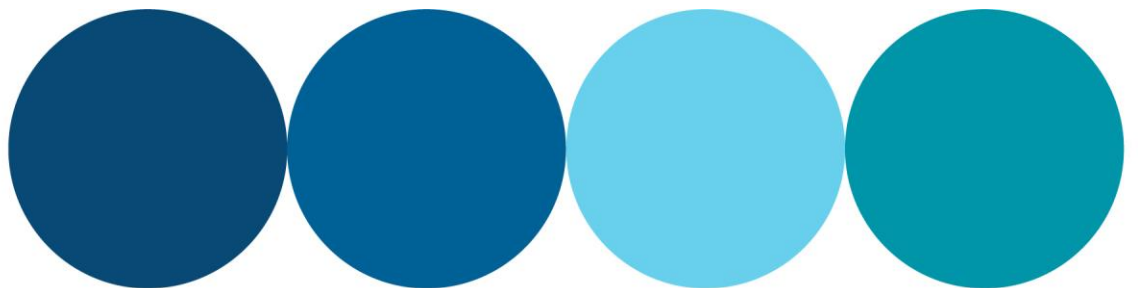


# Perth Long Term Ocean Outlet Monitoring Program (PLOOM)

2022–2023 Annual Report

Beenyup Water Resource Recovery Facility





This report has been prepared for Water Corporation by BMT, September 2023, Report Number R-000932-1.

## Document history

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## Quality Assurance



BMT Commercial Australia Pty Ltd has prepared this report in accordance with our Integrated Management System, in compliance with ISO9001, ISO45001 and ISO14001.

## 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 Commercial Australia Pty Ltd (BMT) 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: 21/09/2023

**Director (or delegate)**

Date: 21/09/2023



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## Acronyms

|        |                                                                             |
|--------|-----------------------------------------------------------------------------|
| ANZG   | Australian and New Zealand Guidelines for Fresh and Marine Water Quality    |
| CFU    | Colony forming unit                                                         |
| DO     | Dissolved oxygen                                                            |
| DoH    | Western Australian Department of Health                                     |
| DPIRD  | Western Australia Department of Primary Industries and Regional Development |
| 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                                              |
| LoR    | Limit of reporting                                                          |
| MMP    | Marine Management Plan                                                      |
| MPN    | Most probable number                                                        |
| NATA   | National Association of Testing Authorities                                 |
| NOEC   | No observed effect concentration                                            |
| PLOOM  | Perth Long Term Ocean Outlet 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                                                  |



|      |                                  |
|------|----------------------------------|
| WRRF | Water Resource Recovery Facility |
| WWTP | Wastewater Treatment Plant       |



## Executive summary

This report documents the findings of the 2022–2023 Ocean Reef monitoring program. The report outlines the findings of three environmental monitoring programs:




- trial compliance monitoring (TCM)
- whole of effluent toxicity (WET) testing
- comprehensive treated wastewater characterisation (CTWWC).

Results are reported in the context of the Environmental Quality Management Framework (EQMF) described in EPA (2017) for the following Environmental Quality Objectives (EQOs):

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

The results are summarised in Report Card format (Table ES 1). The report card contains colour-coded results, with the individual colours representing the extent to which the Environmental Quality Criteria (EQC) were met (Table ES 2 – Table ES 4).

**Table ES 1 Summary report card legend**

| Management response                                           | Colour                                                                               |
|---------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <b>Monitor:</b> EQG or EQS met (continue monitoring)          |  |
| <b>Investigate:</b> EQG not met (investigate against the EQS) |  |
| <b>Action:</b> 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 relates to the total toxicity of the mixture (TTM) and EQG 4 the results of WET testing.



To meet EQG 1, bioaccumulating toxicant (specifically, cadmium and mercury) concentrations must be below their respective ANZG (2018) 80% species protection guidelines prior to discharge and 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 their ANZG (2018) 99% species protection guidelines at the LEPA boundary, 100 m from the diffuser. Initial dilution modelling for conditions on 14/02/2023 found that the Ocean Reef outlets were achieving a worst-case average initial dilution of 1:303. 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 0.49, which is below the ANZG (2018) guideline value and meets 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. WET tests were undertaken in July 2022, October 2022, January 2023 and April 2023. The lowest NOEC recorded during the four sampling events was 12.5%, thus meeting EQG 4. (Table ES 2).

Water quality monitoring – receiving environment: Ocean water quality was assessed fortnightly between December 2022 to March 2023 as part of the TCM program. Samples were collected at fixed distance intervals down-current of the outlets. Current direction was determined using a drogue to select the current vector. 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 2022–2023 monitoring period indicated that all EQGs bar EQG1 for nutrient enrichment and organic enrichment (dissolved oxygen) and EQGs 1 and 2 for phytoplankton biomass were met. (Table ES 2). The EQS for nutrient enrichment was triggered as median chlorophyll-a values in both consecutive years 2021–22 and 2022-23 were above 80<sup>th</sup> percentile of reference sites. Assessment against the EQS suggest that the EQS 1 and 2 criteria for phytoplankton biomass were not met (Table ES 2).

An approved management plan is not yet in place for the Ocean Reef outlets and there is no requirement for Water Corporation to formally report any of the EQG or EQS exceedances. Nevertheless, Water Corporation may wish to consider an investigation into discharge composition and background variability over time to determine the potential for ongoing exceedances.











**Table ES 2 Summary report card for the Environmental Quality Objective ‘Maintenance of Ecosystem Integrity’**

| Environmental quality indicator       |                                                    | EQC   | Comments                                                                                                                                                                                                      | Compliance |
|---------------------------------------|----------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Toxicants in treated wastewater (TWW) | Bioaccumulating toxicants                          | EQG 1 | Concentrations of cadmium and mercury in the undiluted TWW stream were below the limit of reporting and the ANZG (2018) 80% species protection guidelines (36 and 1.4 µg/L, respectively)                     |            |
|                                       | Non-bioaccumulating toxicants and initial dilution | EQG 2 | Initial dilution on 14/02/2023 (1:303 at Ocean Outlet B) was sufficient to reduce non-bioaccumulating contaminant concentrations to below their ANZG (2018) 99% species protection guidelines.                |            |
|                                       | Total toxicity of the mixture (TTM)                | EQG 3 | The TTM for the additive effect of ammonia, copper and zinc after initial dilution (0.49) was below the ANZG (2018) guideline value of 1.0                                                                    |            |
|                                       | Whole of effluent toxicity testing                 | EQG 4 | The lowest NOEC during the reporting period was 12.5%. Only 4 dilutions with background seawater are required to achieve this NOEC which is lower than the dilutions typically achieved at the LEPA boundary. |            |
| Nutrient enrichment                   | Chlorophyll-a                                      | EQG 1 | Median chlorophyll-a concentration within the high ecological protection area (HEPA) (0.6 µg/L) was higher than the 80 <sup>th</sup> percentile of historical reference site concentrations (0.4 µg/L).       |            |
|                                       | Chlorophyll-a                                      | EQS 1 | Median chlorophyll-a concentration within the high ecological protection area (HEPA) was higher than the 80 <sup>th</sup> percentile of historical reference sites in two consecutive years                   |            |
|                                       | Light attenuation coefficient (LAC)                | EQG 1 | Median LAC within the HEPA (0.090 Log <sub>10</sub> /m) was lower than the 80 <sup>th</sup> percentile of historical reference sites (0.093 Log <sub>10</sub> /m).                                            |            |
| Phytoplankton biomass                 | Phytoplankton biomass                              | EQG 1 | Median chlorophyll-a concentrations exceeded three times the median of reference sites on three occasions                                                                                                     |            |



| Environmental quality indicator |                             | EQC   | Comments                                                                                                                                                                                                            | Compliance                                                                            |
|---------------------------------|-----------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
|                                 | (measured as chlorophyll-a) |       | (14 December 2022, 14 February 2023 and 9 March 2023)                                                                                                                                                               |                                                                                       |
|                                 |                             | EQG 2 | Phytoplankton biomass measured as chlorophyll-a exceeded three times median chlorophyll-a concentration of historical reference sites, on three 37.5% of occasions during non-river flow period.                    |    |
|                                 |                             | EQS 1 | Median chlorophyll-a concentration exceeded three times the median of reference sites on three occasions in the 2022–2023 non-river flow period and twice in the 2021–2022 non-river flow period.                   |    |
|                                 |                             | EQS 2 | Chlorophyll-a concentration exceeded three-times the median chlorophyll-a concentration of reference sites on 37.5% and 25% of occasions during the non-river flow period in 2022–2023 and 2021–2022, respectively. |    |
| Physical chemistry              | Organic enrichment          | EQG   | Dissolved oxygen saturation within the HEPA, fell below 90% saturation at ORT-1500m the period between 17/01/2023 and 20/02/2023.                                                                                   |  |
|                                 |                             | EQS   | Dissolved oxygen saturation within the HEPA was above 60% saturation at all times.                                                                                                                                  |  |
|                                 | Salinity                    | EQG   | Median salinity was between the 20 <sup>th</sup> and 80 <sup>th</sup> percentiles of the natural salinity range within the notional HEPA (at 100, 350, 1000 and 1500 m from the outlet).                            |  |

Notes:

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



### ***EQO 'Maintenance of Seafood for Human Consumption'***

There are two 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 ANZG (2018) EQG for Maintenance of Seafood for Human Consumption states that median TTC concentrations at sites at the boundary of the Observed Zone of Influence (OZI) are not to exceed 14 CFU/100 mL and the 90<sup>th</sup> percentile of TTC concentrations must not exceed 21 CFU/100 mL.

For the present reporting period, the EQC for TTC were assessed based on pooled data from three sampling seasons (2020–21, 2021–22 and 2022–23), with a sample size (n=120) that allowed for appropriate comparison with the EQC (EPA 2005)<sup>1</sup>. Median TTC concentration was at the limit of detection (<10 CFU/100 mL), and therefore below the 14 CFU/100 mL EQG. Over the three seasons, the 90<sup>th</sup> percentile was equal to the limit of detection (<10 CFU/100 mL), and less than the 21 CFU/100 mL criteria. As the 90<sup>th</sup> percentile was below the criteria, the EQG was met (Table ES 3).




The EQG for 'Maintenance of Seafood for Human Consumption' states that concentrations of potentially toxic algae at sites at the boundary of the OZI must not exceed the Western Australian Shellfish Quality Assurance Program (WASQAP, DoH, DPIRD and Industry, 2020) concentrations. Densities of toxic phytoplankton were below relevant WASQP guidelines meeting the EQG for toxic phytoplankton species (Table ES 3).

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<sup>1</sup> NHMRC (2008) guidelines and EPA (2005) 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.



**Table ES 3 Summary report card for the Environmental Quality Objective ‘Maintenance of Seafood for Human Consumption’**

| Environmental quality indicator |                                | Comments                                                                                                                                                                                                | Compliance                                                                          |
|---------------------------------|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Faecal pathogens                | Thermotolerant coliforms (TTC) | Median TTC concentrations derived from 120 samples collected over the 2020–21, 2021–22 and 2022–23 sampling seasons was at the limit of detection (<10 CFU/100 mL) and below the 14 CFU/100 mL criteria |  |
|                                 |                                | The 90 <sup>th</sup> percentile was equal to the limit of detection (<10 CFU/100 mL), and less than the 21 CFU/100 mL criteria                                                                          |  |
| Algal biotoxins                 | Toxic phytoplankton species    | During the 2022-2023 monitoring period, there were no recorded instances of toxic phytoplankton species exceeding the Western Australian Shellfish Quality Guidelines.                                  |  |

Notes:

1. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met
2. represent an exceedance of the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS), respectively.
3. TTC results below the analytical detection limit (<10 CFU/mL) were halved (=5 CFU/mL) to calculate median value.
4. TTC = Thermotolerant coliforms.



**EQO 'Maintenance of Primary and Secondary Recreation'**



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

The EQG for primary contact recreation requires that the 95<sup>th</sup> percentile of faecal pathogens (*Enterococci* spp.) does not exceed 200 MPN/100 mL outside the OZI boundary. To meet the EQG for secondary contact recreation, the 95<sup>th</sup> 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 (2020–2021, 2021–2022 and 2022-2023). The 95<sup>th</sup> percentile of *Enterococci* spp. concentrations was <10 MPN/100 mL and met the EQG for both primary and secondary contact recreation (Table ES 4).

To evaluate the 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 requires that the median total phytoplankton cell concentration for the area of concern not to exceed 10 000 cells/mL. Phytoplankton densities at individual sites during 2022–2023 were below 10 000 cells/mL, meeting the EQG (Table ES 4).

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

| Environmental Quality Indicator |                                    | EQC                      | Comments                                                                                                                                                      | Compliance                                                                            |
|---------------------------------|------------------------------------|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Faecal pathogens                | <i>Enterococci</i> spp.            | EQG1 (primary contact)   | The 95 <sup>th</sup> percentile of <i>Enterococci</i> spp. concentrations (10 MPN/100 mL) was lower than the 200 MPN/100 mL (EQG1) and 2000 MPN/100 mL (EGQ2) |  |
|                                 |                                    | EQG2 (secondary contact) |                                                                                                                                                               |                                                                                       |
| Algal biotoxins                 | Phytoplankton (cell concentration) | EQG                      | Estimated total Phytoplankton cell count at individual sites were < 10 000 cells/mL at each site and sampling occasion during 2022–2023 monitoring            |  |

Note:

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










### **EQO ‘Maintenance of Aesthetic Values’**

The EQO for the EV ‘Recreation and Aesthetics’ is to ensure that Perth’s coastal waters are aesthetically pleasing and that the aesthetic value is protected. To ensure this EQO is being met, monitoring routinely assesses the quality of surface water appearance. The EQG for maintenance of aesthetic values requires that questionnaires are completed by field personnel on eight occasions during the non-river flow period to determine aesthetic appearance. Water clarity at sites around and at distance from the ocean outlet is measured and the presence of fish tainting substances in the TWW is also determined and a complaints register regarding aesthetic values is maintained by the Water Corporation.

The results of the measurements for aesthetics, water clarity and fish tainting substances demonstrated that all EQGs for aesthetics were (Table ES 1).

**Table ES 1 Summary report card for the Environmental Quality Objective ‘Maintenance of Aesthetic Values’**

| <b>Environmental Quality Indicator</b> | <b>EQC</b> | <b>Comments</b>                                                                                                                         | <b>Compliance<sup>1</sup></b>                                                         |
|----------------------------------------|------------|-----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Nuisance organisms                     | EQG        | Nuisance organisms were not present in excessive amounts.                                                                               |   |
| Faunal deaths                          | EQG        | There were no instances of dead marine organisms observed.                                                                              |  |
| Water clarity                          | EQG        | Measurements of light attenuation determined that the natural visual clarity of the water was reduced by ~4% (i.e. > 20%).              |  |
| Colour                                 | EQG        | There was a slight noticeable colour variation on 2 sampling occasions. No noticeable colour was recorded on any other sampling events. |  |
| Surface films                          | EQG        | No surface films or oil were recorded on any sampling event.                                                                            |  |
| Surface debris                         | EQG        | No floating debris or matter was visible on the surface on any sampling occasion.                                                       |  |
| Odour                                  | EQG        | No noticeable odour was detected on any sampling occasion.                                                                              |  |

Note:

1. Green (■) symbols indicate the Environmental Quality Guideline (EQG) was met
2. represent an exceedance of the EQG or Environmental Quality Standard (EQS), respectively.



# 1 Introduction

## 1.1 Document purpose

This annual report documents the findings of the 2022–2023 ocean monitoring around the Ocean Reef ocean outlets. Monitoring was completed according to Western Australia’s Environmental Quality Management Framework (EQMF; EPA 2016).

## 1.2 Wastewater treatment plant infrastructure and discharge

Water Corporation operates the Beenyup Water Resource Recovery Facility (WRRF) in metropolitan Perth, which treats approximately ~116 ML wastewater per day to produce advanced secondary treated wastewater (TWW). The TWW is traditionally discharged to the sea through two ocean outlets at Ocean Reef (Figure 1). 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). Discharge commenced from Outlet A in 1978 and Outlet B in 1992.

Stage 1 of Water Corporation’s Perth Groundwater Replenishment Scheme (GWRS) consists of a 14 GL/year capacity plant. Secondary TWW from the Beenyup WRRF is diverted into the Advanced Water Recycling Plant (AWRP) and further treated via ultrafiltration (UF), reverse osmosis (RO) and ultraviolet (UV) disinfection processes to drinking water standard for recharge of the confined aquifers.

The AWRP reduces the environmental impact of potable water extraction from the aquifer but with a corresponding reduction in the volume and change to the composition of the TWW being discharged to the marine environment through the ocean outlets. A proposed expansion (Stage 2 of the GWRS) will increase the capacity of the AWRP to 28 GL/year, treat a larger proportion of the secondary TWW from the Beenyup WRRF for groundwater recharge and further reduce/alter the discharge to the ocean.

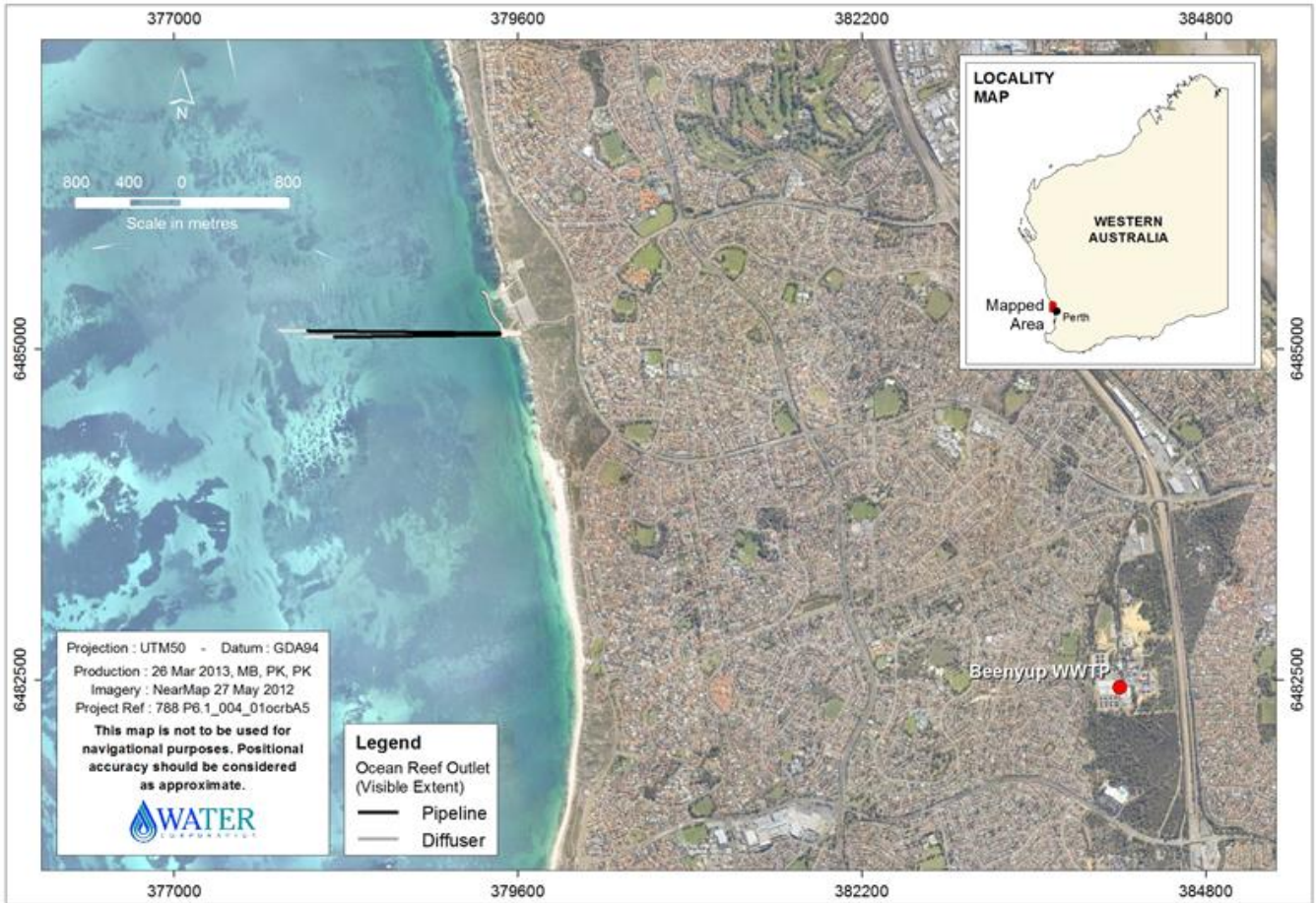
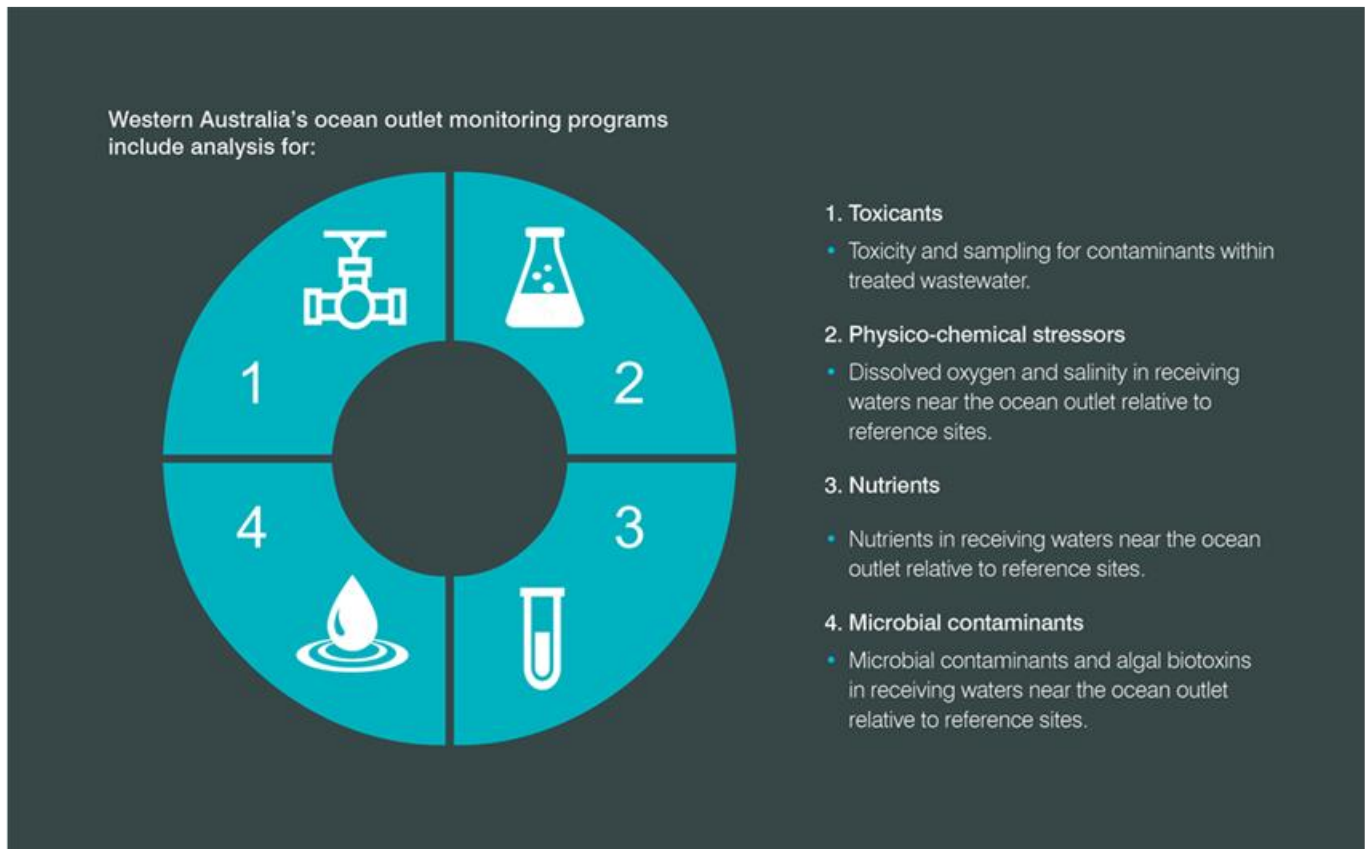


Figure 1 Location of Beenyp WRRF and Ocean Reef ocean outlets





## 1.3 Potential stressors in treated wastewater



### 1.3.1 Toxicants

Metals and persistent organic compounds may be directly toxic to marine biota and/or may accumulate in marine biota at concentrations sufficient to pose a risk to humans if consumed. Under the PLOOM program, TWW is screened for bioaccumulating and non-bioaccumulating toxicants and the concentrations are compared to relevant environmental guidelines. To account for the synergistic effects of multiple toxicants and toxicants without guidelines, the overall toxicity of the TWW is determined using whole of effluent toxicity (WET) testing.

### 1.3.2 Physico-chemical stressors

TWW contains organic matter, decomposition of which by microorganisms uses oxygen. If more dissolved oxygen (DO) is consumed than is produced, DO levels decline. Measurements of DO saturation in receiving waters near the outlets provide an indication of the risk posed by deoxygenation.

Reduced salinity near the outfall, resulting from freshwater in the TWW plume may cause osmotic stress in marine biota. Measurements of salinity in receiving waters near the outfall are compared to the salinity at appropriate reference sites. The comparison allows evaluation of whether salinity near the outfall is within the range of natural variation.

### 1.3.3 Nutrients

TWW contains elevated concentrations of the biologically available nutrients ammonia, nitrite, nitrate and orthophosphate. Nutrients can stimulate phytoplankton growth beyond natural levels, which can lead to shading of photosynthetic organisms such as seagrasses and/or macroalgae. The potential for shading



is determined using in-water measures of chlorophyll-a (a proxy for phytoplankton biomass) and light attenuation (a measure of water clarity).

Although most algal blooms are harmless, some contain species that produce toxins that may be harmful to swimmers (via ingestion or skin contact) or poison seafood. Phytoplankton species composition and cell concentrations are monitored to ensure concentrations are within acceptable limits.

#### 1.3.4 Microbial contaminants

Disease-causing organisms in the TWW pose a risk to humans if exposed during primary and/or secondary contact activities (i.e. swimming and boating). The same organisms if ingested by marine fauna may reduce their suitability for human consumption. To assess the risk, concentrations of indicator organisms are routinely compared to the Environmental Protection Authority's (EPA's; EPA 2017) criteria for primary and secondary contact recreation and for seafood for human consumption.

### 1.4 Environmental management approach

Water Corporation's formal environmental commitments for the Beenyup WRRF discharge are outlined in Ministerial Statements 382 and 569. To maintain consistency with the other metropolitan ocean outfall programs, the Ocean Reef outlets (Figure 2) are monitored as part of the Perth Long-Term Ocean Outlet Monitoring (PLOOM) program. The ocean monitoring program is consistent with the approach advocated under the State Government's EQMF, which is applied to Western Australia's coastal waters (EPA 2016).



Source: Nearmap Pty Ltd

**Figure 2** Aerial image of the Ocean Reef ocean outlets

Stage 1 of the AWRP/GWRS operates under existing approvals. The change in discharge characteristics associated with Stage 2 requires a change to proposal/conditions under Sections 45c and 46 of the *Environmental Protection Act 1986* (EP Act). The approvals process includes development of an Environmental Monitoring and Management Plan (EMMP), which will bring the management



framework into line with contemporary Department of Water and Environmental Regulation policy (EPA 2017) and establish formal management areas around the outlets. The EMMP and associated management zones do not apply until the stage 2 facility reaches full capacity and the existing monitoring approach will remain in place until then.

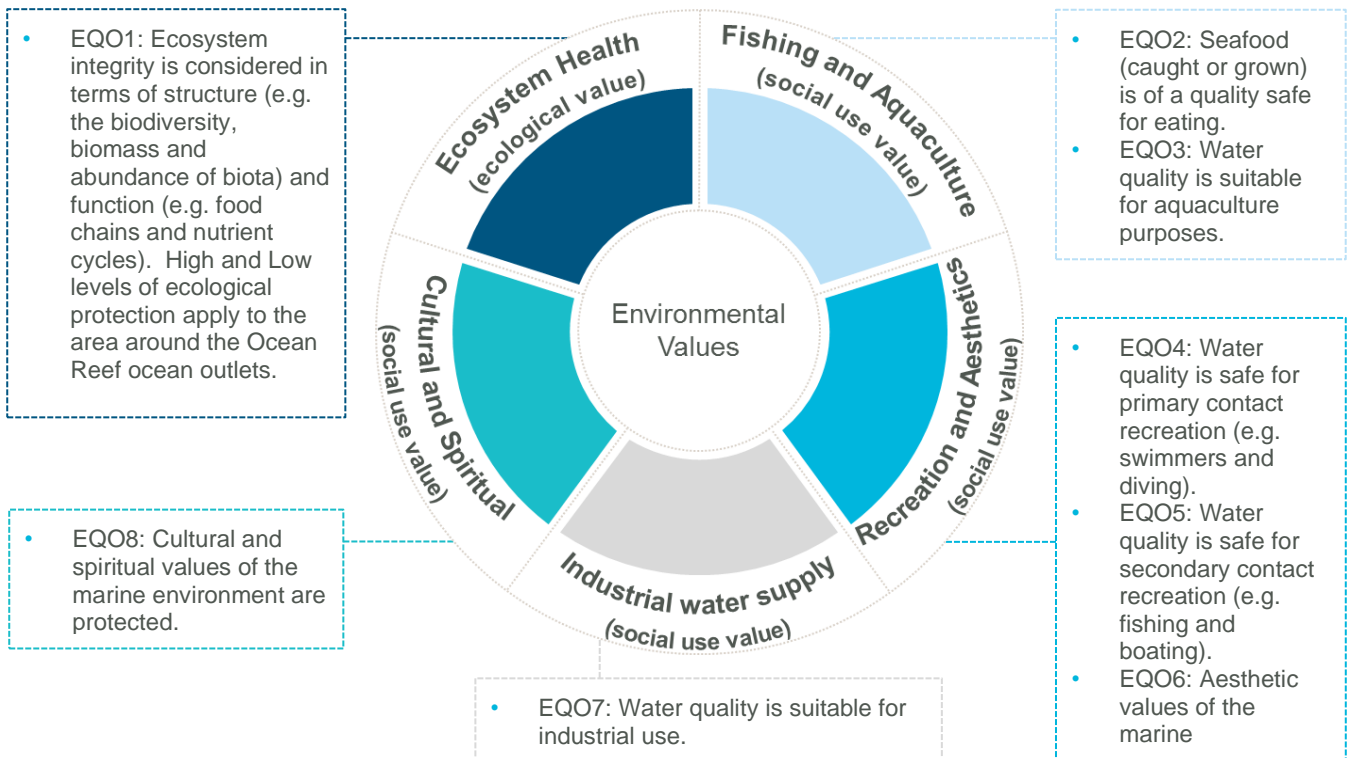
## 1.5 Environmental Quality Management Framework (EQMF)

The EQMF is based on:

- identifying Environmental Values (EVs) (Figure 3)
- establishing and spatially defining Environmental Quality Objectives (EQOs) that need to be maintained to ensure the associated EVs are protected (Figure 3)
- 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.

There are two levels of EQC:

1. **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 a more detailed assessment against the EQS is triggered.
2. **Environmental Quality Standards (EQSs)** are management triggers which, if exceeded, signify that the EQO is at risk of not being met and that a management response may be required.

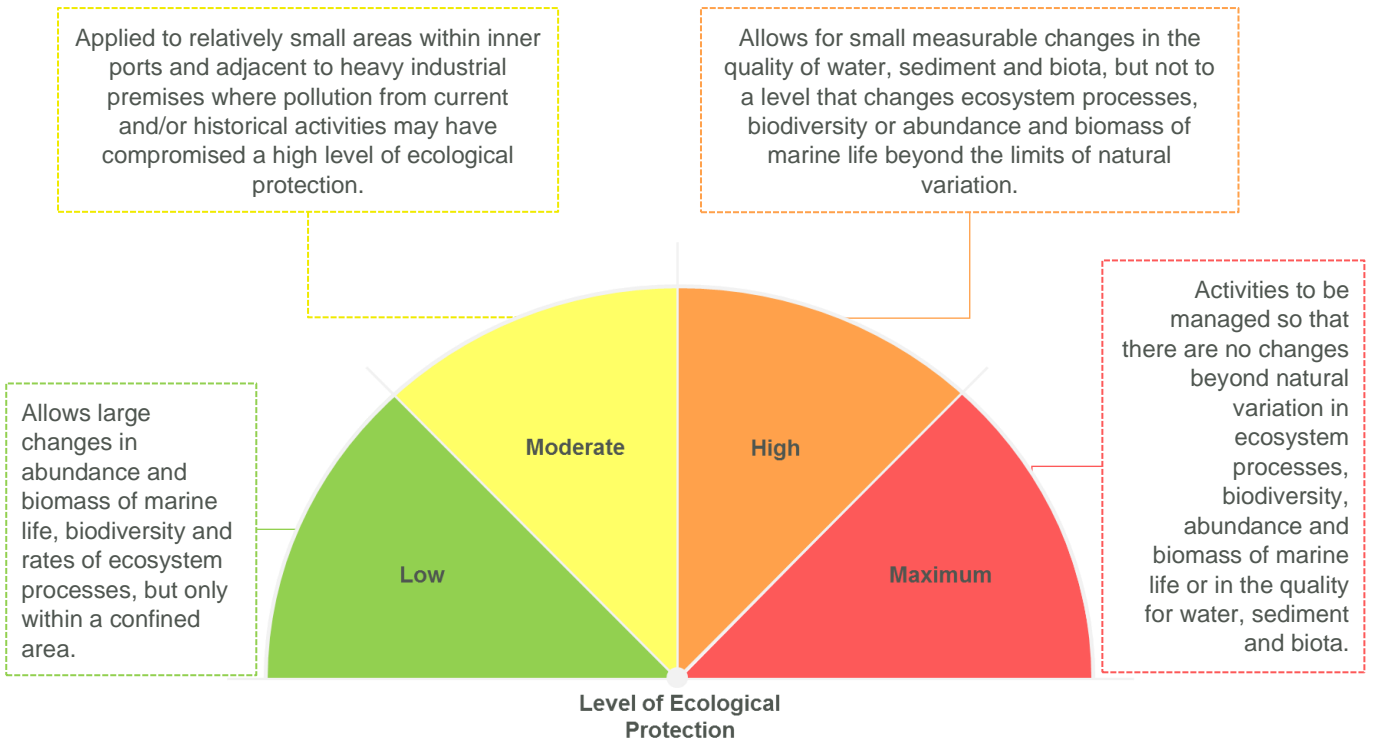


**Figure 3 Environmental Values and Environmental Quality Objectives (EQO) for the marine waters of Western Australia**



### 1.5.1 'Maintenance of Ecosystem Integrity' EQO

The intent of this EQO is to maintain a healthy and diverse ecosystem. There are four levels of ecological protection, with each applied depending on the designated level required: low, moderate, high or maximum (Figure 4).



**Figure 4** Level of Ecological Protection

A notional low ecological protection area (LEPA) has been established around the Ocean Reef outfalls and occupies the area within a 100 m radius of the diffusers (Figure 5). The LEPA size will be formalised as part of the AWRP approvals process. Waters outside the LEPA are maintained to a high level of ecological protection (HEPA; Figure 5).

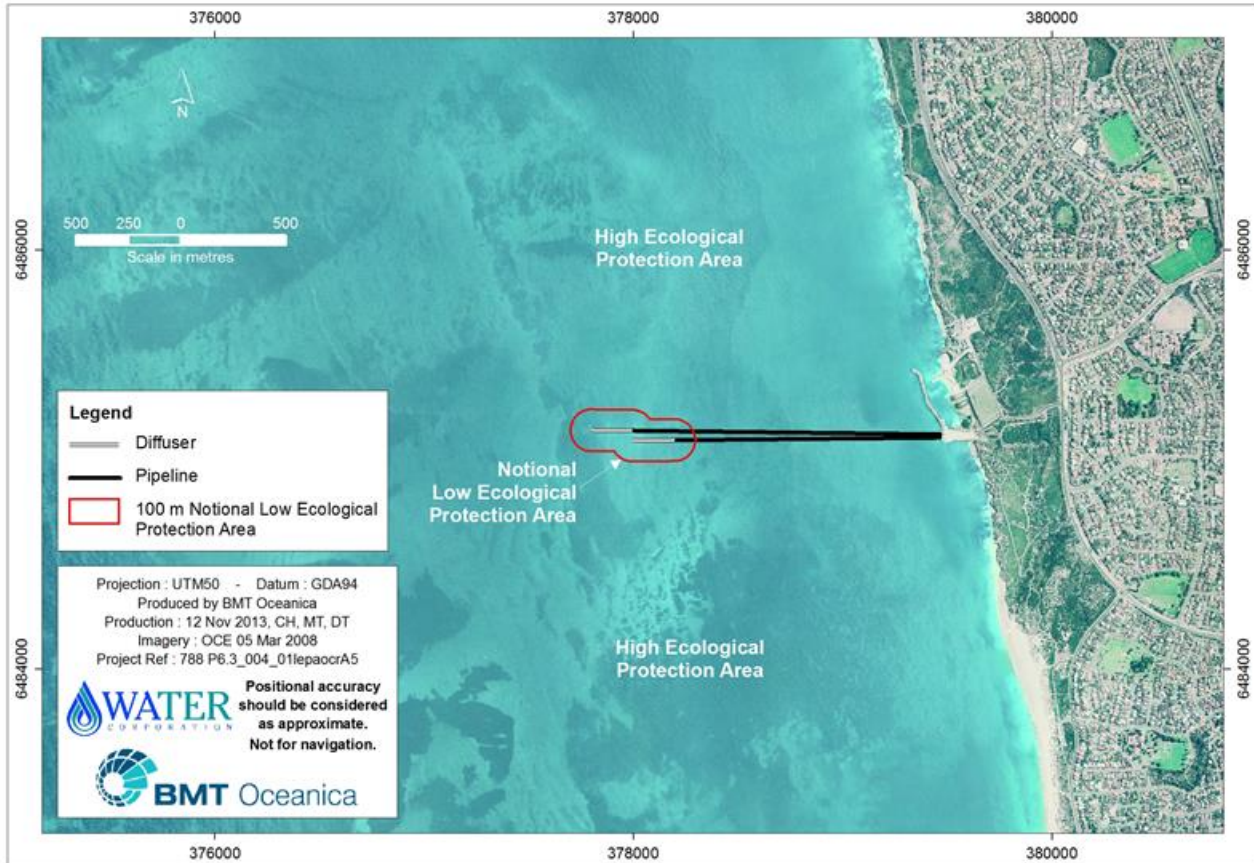


Figure 5 Ocean Reef ocean outlets notional ecological protection areas

### 1.5.2 'Maintenance of Seafood Safe for Human Consumption' EQO

The intent of this EQO is to maintain seafood safe for human consumption (a social value) outside a small area surrounding the ocean outlets where EQO 2 may not be achieved and seafood may be unsafe to eat. An informal zone has been developed for the Ocean Reef outlets encompassing the management area for seafood safe for human consumption based on microbiological observations from historical ocean monitoring data (Figure 6). The zone represents the area where microbiological organism concentrations are most likely to exceed the EPA's criteria for seafood safe for human consumption under worst-case conditions.

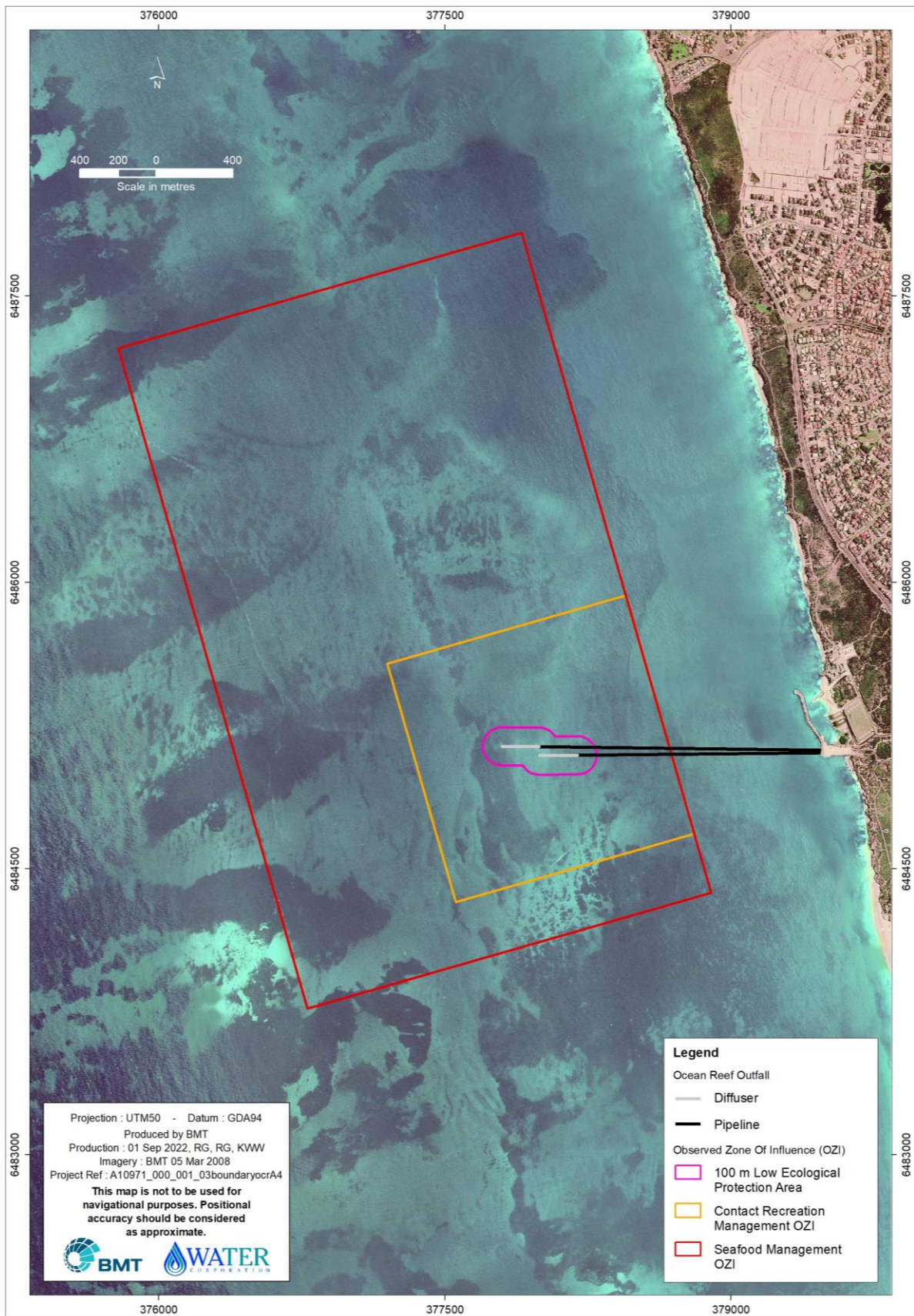


Figure 6 Ocean Reef ocean outlet protection area and management zones.



### **1.5.3 ‘Maintenance of Primary and Secondary Contact Recreation’ EQOs**

The primary and secondary contact EQOs support swimming and boating activities, respectively. The EQOs apply throughout Perth’s coastal waters except for areas immediately surrounding the ocean outlets, where water quality may not be suitable for swimming. An informal zone has been developed for the Ocean Reef outlets encompassing the management area for primary and secondary contact recreation (Figure 6).

### **1.5.4 ‘Maintenance of Aesthetic Value’ EQO**

The objective of this EQO is to ensure that the aesthetic value of Perth’s coastal waters is protected. To ensure this EQO is being met, monitoring routinely assesses the quality of the surface water appearance.



## 2 Toxicants in treated wastewater

### 2.1 Comprehensive treated wastewater characterisation (CTWWC)

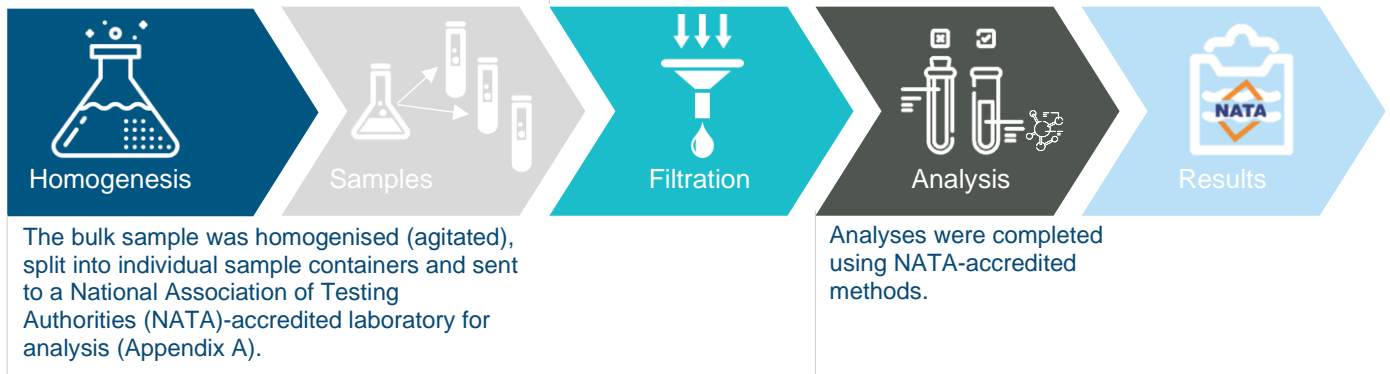
Treated wastewater (TWW; final effluent) from the Beenyup WRRF is analysed for potential contaminants of concern:

- nutrients (total nitrogen, ammonia, nitrate+nitrite, total phosphorus, orthophosphate)
- microbial contaminants (thermotolerant coliforms and *Enterococci* spp.)
- 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 discrete sample was obtained from the Beenyup WRRF site on 14 February 2023. The sample was collected after the point where the Beenyup TWW and AWRP reject streams join and it is representative of the final (combined) discharge to the ocean.

Samples for bioavailable metals were filtered through a 0.45 µm filter prior to analyses (EPA 2005).

The following sections detail the toxicant results in TWW from the Beenyup WRRF (Appendix B), with assessment made against relevant EQGs.



#### 2.1.1 Bioaccumulating toxicants

Concentrations of cadmium and mercury (i.e. bioaccumulating toxicants) in the TWW sample were below their respective LoRs (<0.1 µg/L for cadmium and <0.05 µg/L for mercury) and 80% species protection guidelines (36 and 1.4 µg/L, respectively) (ANZG 2018), meeting the EQG (Table 2).





**Table 2 Environmental Quality Guideline for bioaccumulating toxicants**

|            |                                                                                                                                           |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EQG</b> | Concentrations of bioaccumulating contaminants in the wastewater stream will not exceed the ANZG (2018) 80% species protection guidelines |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------|

Notes:

1. EQG = Environmental Quality Guideline
2. ANZG 2018.

### 2.1.2 Non-bioaccumulating toxicants

Modelling predicted an average initial dilution of 1:310 at Ocean Outlet A and 1:303 at Outlet B (Appendix C). The worst-case initial dilution of 1:303 was used as a conservative estimate of the dilution expected at the LEPA boundary. Contaminant concentrations after the initial dilution of 1:303 were below the ANZG (2018) 99% species protection guidelines (Table 4), and the EQG for non-bioaccumulating toxicants (Table 3) was met.

**Table 3 Environmental Quality Guideline for non-bioaccumulating toxicants**

|            |                                                                                                                                                                                                                                                                                                                                                                    |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EQG</b> | Wastewater contaminant concentrations, in conjunction with initial dilution modelling, will be evaluated to determine that the ANZG (2018) 99% species protection guideline trigger levels for toxicants are 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). |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Note:

1. EQG = Environmental Quality Guideline



**Table 4 Toxicants in the Beenyup TWW stream compared with relevant guideline trigger levels after initial dilution**

| Toxicant (ug/L)      | Beenyup TWW concentration (µg/L) | Concentration after initial dilution (µg/L) | Trigger (µg/L)               |
|----------------------|----------------------------------|---------------------------------------------|------------------------------|
| Ammonia-N            | 840                              | 2.77                                        | 500                          |
| Cadmium*             | <0.1                             | -                                           | 36                           |
| Chromium*            | <1                               | -                                           | 0.14 (Cr VI)<br>7.7 (Cr III) |
| Copper*              | 14                               | 0.046                                       | 0.3                          |
| Lead*                | <1                               | -                                           | 2.2                          |
| Mercury*             | <0.05                            | -                                           | 1.4                          |
| Nickel*              | 3.2                              | 0.01                                        | 7                            |
| Silver*              | <0.8                             | -                                           | 0.8                          |
| Zinc*                | 73                               | 0.24                                        | 7                            |
| Chloropyrifos        | <0.1                             | -                                           | 0.0005                       |
| Endrin               | <0.001                           | -                                           | 0.004                        |
| Endosulfan sulfate   | <0.001                           | -                                           | 0.005                        |
| Benzene              | <1                               | -                                           | 500                          |
| Naphthalene          | <0.01                            | -                                           | 50                           |
| Benzo(g,h,i)perylene | <0.01                            | -                                           | 50                           |

Notes:

1. Assessment against ANZG (2018) 99% species protection guideline values was undertaken only for those toxicants where trigger levels were available.
2. TWW = treated wastewater
3. Initial dilution = 1:303 (predicted average value at 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 ANZG (2018). 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. The bioaccumulating toxicants cadmium and mercury must meet the 80% species protection guidelines at the diffuser (i.e. prior to initial dilution), and therefore a diluted concentration was not calculated.
6. Analytical limits for chloropyrifos were not low enough to confirm exceedance of, or compliance with, the ANZG (2018) 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.
7. Trigger values are for endosulfan, not endosulfan sulfate; ANZG (2018).
8. \* = dissolved metals 0.45 µm filtered.

### 2.1.3 Total toxicity of the mixture (TTM)

The total toxicity of the mixture (TTM, an indicator of the potential for cumulative toxic effects on marine organisms) for the combined effect of ammonia, copper and zinc following initial dilution (0.49; Table 6) was less than the ANZG (2018) guideline value of 1.0 and the EQG for TTM (Table 5) was met.



**Table 5 Environmental Quality Guideline for the total toxicity of the mixture**

|            |                                                                                                                                                                       |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EQG</b> | The total toxicity of the mixture (TTM) for the additive effect of ammonia, copper and zinc, calculated as per ANZG (2018), will not exceed the trigger value of 1.0. |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Notes:

1. EQG = Environmental Quality Guideline; TTM = total toxicity of the mixture
2.  $TTM = \sum(C_i/EQG_i)$  where  $C_i$  is the concentration of the  $i$ 'th component in the mixture and the  $EQG_i$  is the guideline for that component
3. 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  $\mu$ m filter).

**Table 6 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 |        |      | Initial dilution of TWW with seawater | Total toxicity of the mixture (TTM) |
|--------------------------------------------------|--------|------|---------------------------------------|-------------------------------------|
| Ammonia                                          | Copper | Zinc |                                       |                                     |
| 1.5                                              | 0.08   | 0.15 | 1:303                                 | 0.49                                |

Notes:

1. Background concentrations for copper and zinc from McAlpine et al. (2005); Perth marine waters (99. 19; Table 12). Surface background concentration for ammonia calculated as median of reference site data from 2004–2019 (BMT, unpublished data).
2.  $TTM = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline$ .
3. Initial dilution at outlet A was 1:310, initial dilution at outlet B was 1:303. Initial dilution at outlet B was used in TTM calculation as conservative estimate (Appendix C).

## 2.2 Whole of effluent toxicity (WET) testing

WET testing is useful for assessing toxicity in the absence of guidelines, or where the effects may be cumulative. Fertilisation success in sea urchins (*Heliocidaris tuberculata*) exposed to salt adjusted dilutions (1.0, 1.6, 3.1, 6.3, 12.5, 25, 50 and 100%) of TWW was used to calculate a No Observed Effect Concentration (NOEC, the highest wastewater concentration where no significant effect is observed) (Appendix D).



In October 2022, January 2023 and April 2023, sea urchin fertilisation exposed to both the 50% and 100% TWW concentrations were significantly lower than the artificial seawater control (with all other concentrations not significantly different to the artificial seawater control; Figure 7; Appendix D). In July 2022 sea urchin fertilisation exposed to the 25%, 50% and 100% TWW concentrations were significantly lower than the artificial seawater control (with all other concentrations not significantly different to the artificial seawater control; Figure 7; Appendix D) For all sampling dates, the NOEC was greater than 1% TWW (Table 8) and the EQG for WET testing (Table 7) was met.



**Table 7 Environmental Quality Guideline for whole of effluent toxicity testing**

|            |                                                                                                                                                                                                                                                                                                                                                                  |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EQG</b> | The EQG will be exceeded if following the 1-hour sea urchin test:                                                                                                                                                                                                                                                                                                |
|            | $\frac{TDA}{DRNOEC} \leq 1.0$                                                                                                                                                                                                                                                                                                                                    |
|            | <p>where TDA = Typical Dilutions Achieved (constant based on 200-fold dilution)<br/> DRNOEC = number of dilutions required to achieve the no observed effects concentration (NOEC).</p> <p>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).</p> |

Note:

1. EQG = Environmental Quality Guideline.



Notes:

1. Error bars ± standard deviation.
2. TWW = treated wastewater.
3. Light grey bars represent concentrations of treated wastewater (TWW) 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.

**Figure 7 Comparison of whole effluent toxicity TWW dilution results to artificial seawater control**



**Table 8**      **Calculated parameters from whole of effluent toxicity tests**

| <b>Indicator</b>                      | <b>July 2022</b> | <b>October 2022</b> | <b>January 2023</b> | <b>April 2023</b> |
|---------------------------------------|------------------|---------------------|---------------------|-------------------|
| NOEC                                  | 12.5%            | 25%                 | 25%                 | 25%               |
| Dilutions required to meet the NOEC   | 8                | 4                   | 4                   | 4                 |
| Dilutions required/dilutions achieved | 0.04             | 0.02                | 0.02                | 0.02              |
| ≤1                                    | Yes              | Yes                 | Yes                 | Yes               |

Note:

1. NOEC = No observed effect concentration.



### 3 Water quality monitoring – receiving environment

Nutrients, phytoplankton biomass and physical and chemical stressors were monitored approximately fortnightly from the beginning of December 2022 to the end of March 2023 (coinciding with the summer non-river flow period) along a down-current gradient away from the diffusers (Table 9, Appendix E and Appendix F).

**Table 9 Water quality monitoring dates near the Ocean Reef ocean outlets between December 2022 and March 2023**

| Sample day | Date       |
|------------|------------|
| 1          | 09/12/2022 |
| 2          | 14/12/2022 |
| 3          | 09/01/2023 |
| 4          | 17/01/2023 |
| 5          | 14/02/2023 |
| 6          | 20/02/2023 |
| 7          | 09/03/2023 |
| 8          | 28/03/2023 |

Wind direction, strength, current direction grid and cloud cover on the day of sampling were recorded (Table 10).

**Table 10 Weather and current direction grid during water quality monitoring near the Ocean Reef ocean outlets**

| Date       | Wind direction  | Wind strength (knots) | Cloud cover (%) | Current grid |
|------------|-----------------|-----------------------|-----------------|--------------|
| 09/12/2022 | SW              | 12-16                 | 20-80           | NE           |
| 14/12/2022 | E, SE           | 10-14                 | 5-30            | SW           |
| 09/01/2023 | S, SE, SSE, SSW | 5-17                  | 0               | N            |
| 17/01/2023 | SE, SSE, ESE    | 10-17                 | 0               | NW           |
| 14/02/2023 | SW              | 14-16                 | 70-90           | NE           |
| 20/02/2023 | SE, SSE, ESE    | 5-7                   | 0               | NW           |
| 09/03/2023 | SW, SSW         | 5-7                   | 10-15           | E            |
| 28/03/2023 | E               | 12-16                 | 0               | W            |

Notes:

1. N = north, S = south, W = west, E = east, SW = south-west, SE = south-east, NW = north-west, NE = north-east, SSE = south-south-east, ENE = east-north-east, ESE = east-south-east, NNE = north-north-east
2. Winds are designated by the direction they come from while currents are designated by the direction they flow to.



### 3.1 Nutrient enrichment

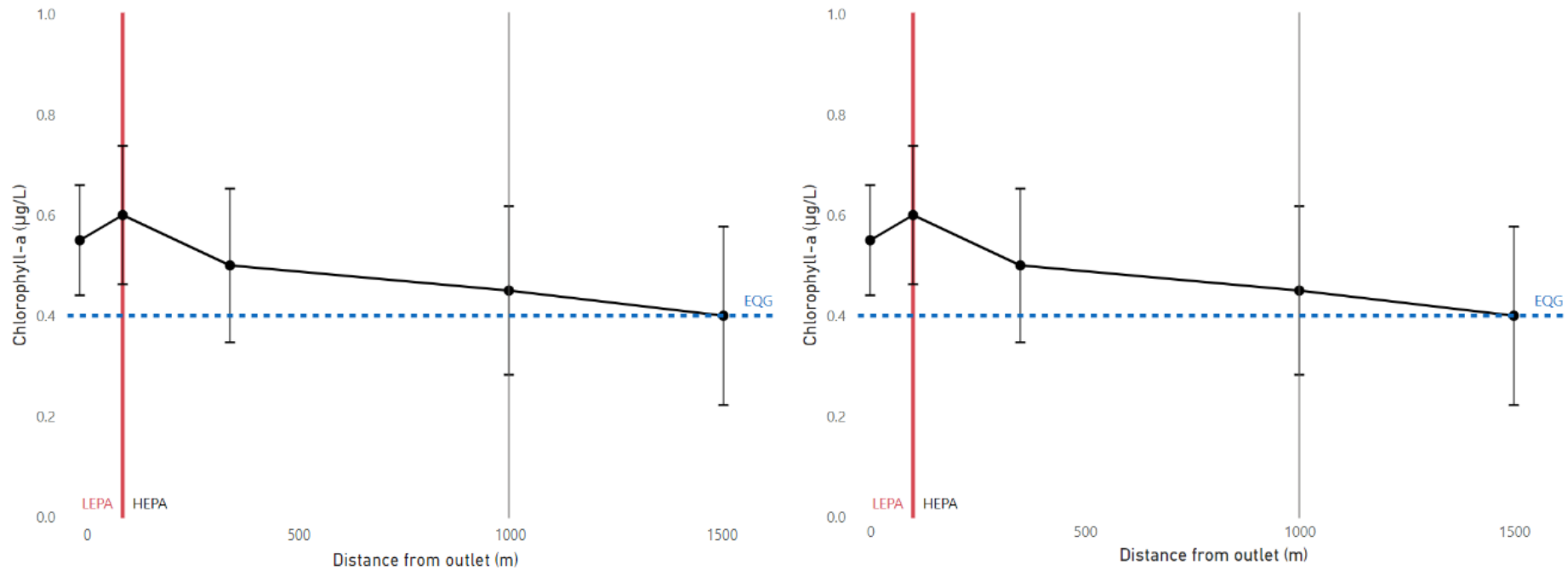
The median chlorophyll-a concentration in the Ocean Reef HEPA (100 m plus) was 0.55 µg/L and was greater than the 80<sup>th</sup> percentile of historical reference site data (0.4 µg/L; Figure 8), which exceeded the EQG (Table 11). The EQS for chlorophyll-a states that the EQG must not be exceeded in two consecutive years. Median chlorophyll-a concentration in the Ocean Reef HEPA (100 m plus) during 2021–22 was above the 80<sup>th</sup> percentile of historical reference site data (0.4 µg/L; Figure 8) and the EQG was exceeded in a second consecutive year therefore the EQS was not met (Table 11).

**Table 11 Environmental Quality Criteria for nutrients**

|            |                                                                                                                                                                                        |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EQG</b> | The median chlorophyll-a concentration in the HEPA (100 m plus) during the non-river flow period is not to exceed the 80 <sup>th</sup> percentile of historical reference site data.   |
|            | The median light attenuation coefficient in the HEPA (100 m plus) during the non-river flow period is not to exceed the 80 <sup>th</sup> percentile of historical reference site data. |
| <b>EQS</b> | EQGs are not to be exceeded in a second consecutive year.                                                                                                                              |

Note:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard



Notes:

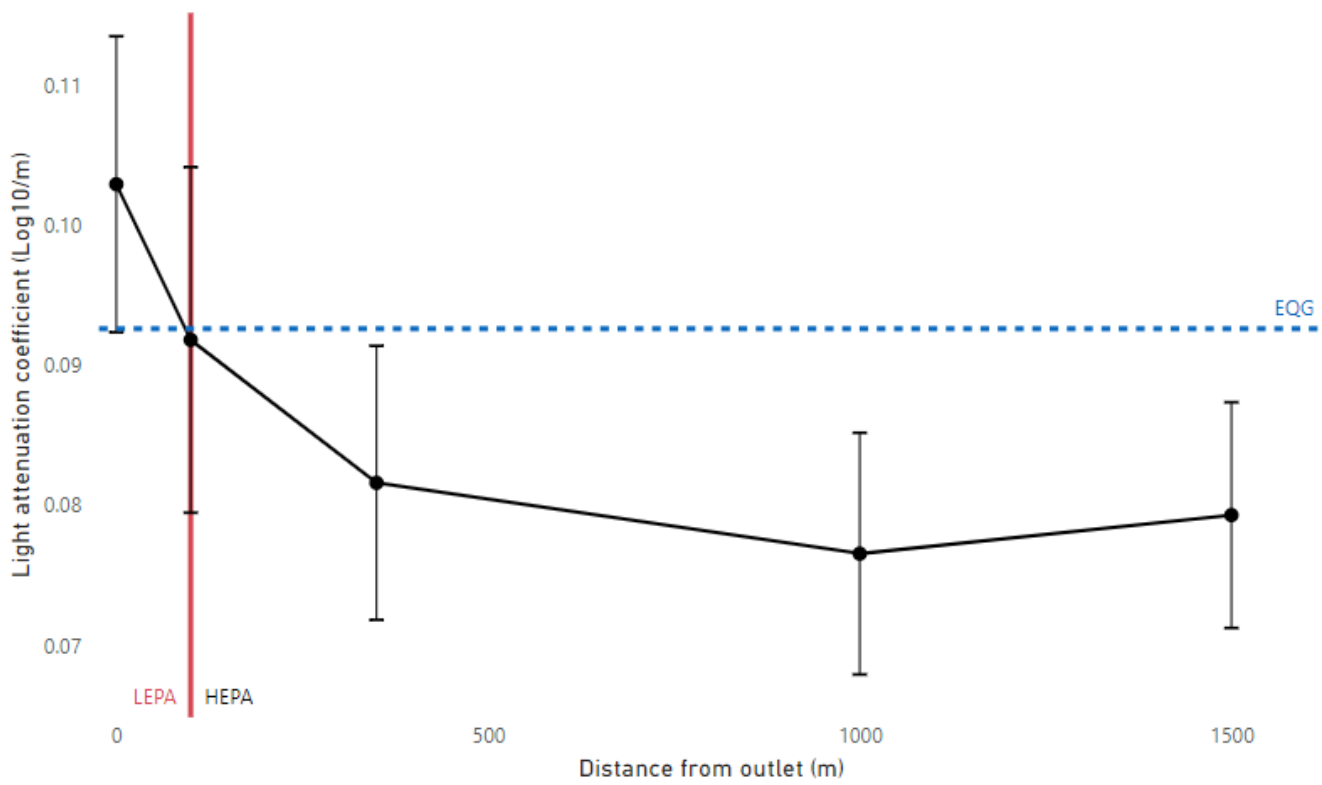
1. Error bars represent  $\pm 95\%$  confidence intervals.
2. Environmental Quality Guideline (EQG) is the 80<sup>th</sup> percentile of historical reference site data (0.4 µg/L chlorophyll-a).
3. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
4. Data for each distance were pooled across eight sampling days (n = 8) over December 2022–March 2023 (Appendix G).

**Figure 8** Median chlorophyll-a concentrations obtained at fixed monitoring sites above and down-current of the Ocean Reef outlets during the summer monitoring period. Left graph shows results from the 2022–23 monitoring period while the right graph shows results from the 2021–22 monitoring period.





The median light attenuation in the Ocean Reef HEPA (100 m plus) was 0.0877 Log<sub>10</sub>/m and lower than the 80<sup>th</sup> percentile of reference sites data (0.093 Log<sub>10</sub>/m), meeting the EQG (Figure 9).



Notes:

1. Error bars represent  $\pm 95\%$  confidence intervals.
2. Dark blue dashed line = Environmental Quality Guideline (EQG) is the 80<sup>th</sup> percentile of historical reference site data (0.093 Log<sub>10</sub>/m).
3. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
4. Data for each distance were pooled across eight sampling occasions (n = 8) over December 2022–March 2023.

**Figure 9** Median light attenuation coefficient obtained at fixed monitoring sites above and down-current of the Ocean Reef outlets during the summer monitoring period

### 3.2 Phytoplankton biomass

Median phytoplankton biomass measured as chlorophyll-a exceeded three times the median chlorophyll-a concentration of historical reference sites (0.6 µg/L; Figure 10) on three occasions (0.9 µg/L on 14 December 2022, 0.75 µg/L on 14 February 2023 and 0.65 µg/L on 9 March 2023) exceeding EQG1 (Table 12) and triggering assessment against EQS1. Median phytoplankton biomass measured as chlorophyll-a exceeded three times median chlorophyll-a concentration of historical reference sites, on more than one occasion in two consecutive years (exceeding three times in 2021–22 as well as the three times in 2022-23) therefore not meeting EQS1.



**Table 12 Environmental Quality Criteria for phytoplankton in receiving waters**

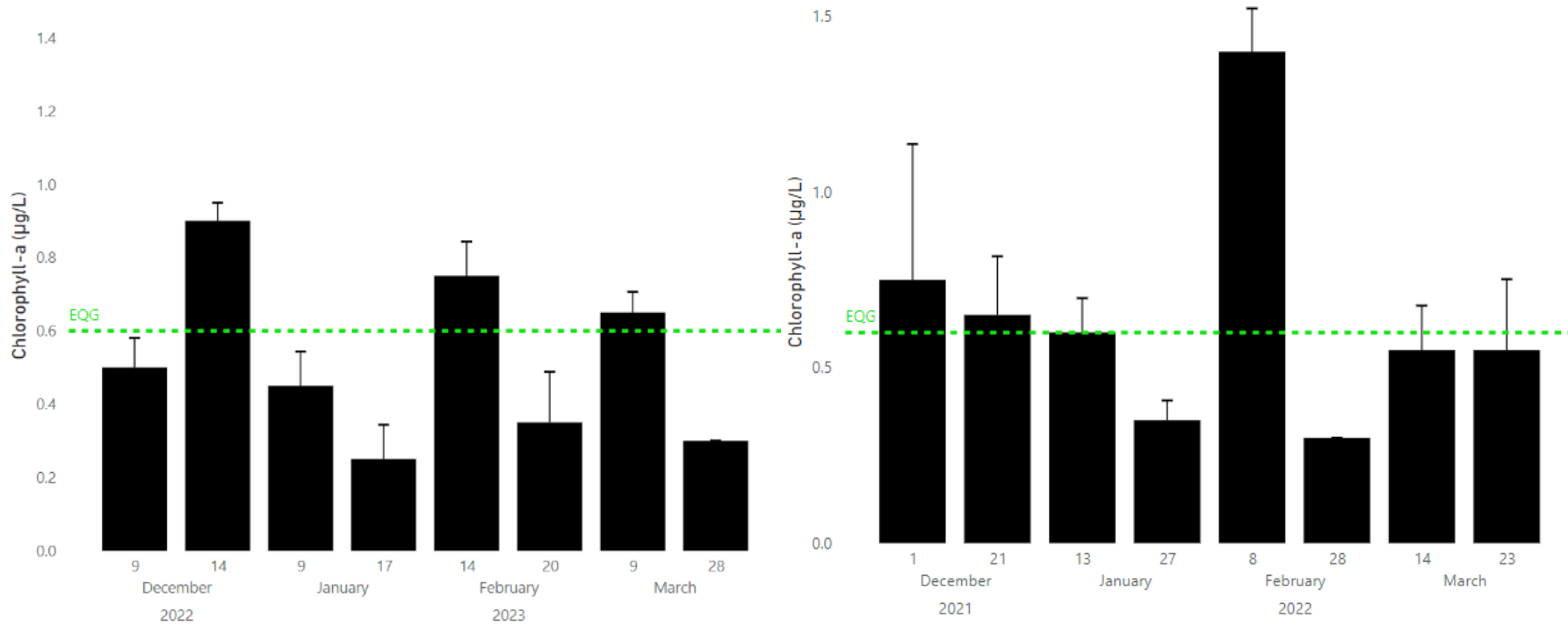
|             |                                                                                                                                                                                                                                                       |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EQG1</b> | Median phytoplankton biomass, measured as chlorophyll-a does not exceed three times the median chlorophyll-a concentration of historical reference sites, on any occasion during the non-river flow period.                                           |
| <b>EQG2</b> | Phytoplankton biomass measured as chlorophyll-a at any site does not exceed three times the median chlorophyll-a concentration of historical reference sites, on 25% or more occasions during the non-river flow period.                              |
| <b>EQS1</b> | Median phytoplankton biomass measured as chlorophyll-a does not exceed three times median chlorophyll-a concentration of historical reference sites, on more than one occasion during non-river flow period and in two consecutive years.             |
| <b>EQS2</b> | Phytoplankton biomass measures as chlorophyll-a at any site does not exceed three times the median chlorophyll-a concentration of historical reference sites, on 25% or more occasions during the non river-flow period and in two consecutive years. |

Notes:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard

Phytoplankton biomass, measured as chlorophyll-a, exceeded three times the median chlorophyll-a concentration of historical reference sites (0.6 µg/L) on three (37.5%) occasions during the non-river flow period exceeding EQG2 (Table 12) and triggering assessment against EQS2. Median phytoplankton biomass measured as chlorophyll-a exceeded three times the median chlorophyll-a concentration of historical reference sites on six occasions (37.5%) across the 2021–22 (three exceedances) and 2022–23 (three exceedances) non-river flow period, therefore EQS2 was not met.

An approved management plan is not yet in place for the Ocean Reef outlets and there is no requirement for Water Corporation to formally report any of the EQG or EQS exceedances. Nevertheless, Water Corporation may wish to consider an investigation into discharge composition and background variability over time to determine the potential for ongoing exceedances.



Notes:

1. Error bars represent  $\pm 95\%$  confidence intervals.
2. Environmental Quality Guideline (EQG) is three 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 outlets within the notional low ecological protection area (LEPA).
4. Data were pooled across four sites within the high ecological protection area (HEPA).

**Figure 10** Median phytoplankton biomass during the summer monitoring period, pooling data from fixed sites  $\geq 100$  m down-current of the Ocean Reef ocean outlets; left) 2022–23 monitoring period, right) 2021–22 monitoring period.



### 3.3 Physical-chemical stressors

#### 3.3.1 Dissolved oxygen (DO)

Bottom (0–0.5 m) dissolved oxygen saturation at HEPA sites (100, 350, 1000 and 1500 m) was >90% at all sites and times throughout the summer survey period except for a six week period between 17/01/2023 to 20/02/2023 at 1500 m (Figure 11), and the EQG for organic enrichment (Table 13) was not met thus triggering assessment against the EQS. Bottom (0–0.5 m) dissolved oxygen saturation at HEPA sites (100, 350, 1000 and 1500 m) was >60% at all sites and times throughout the summer survey period (Figure 11), and the EQS for organic enrichment (Table 13) was met.

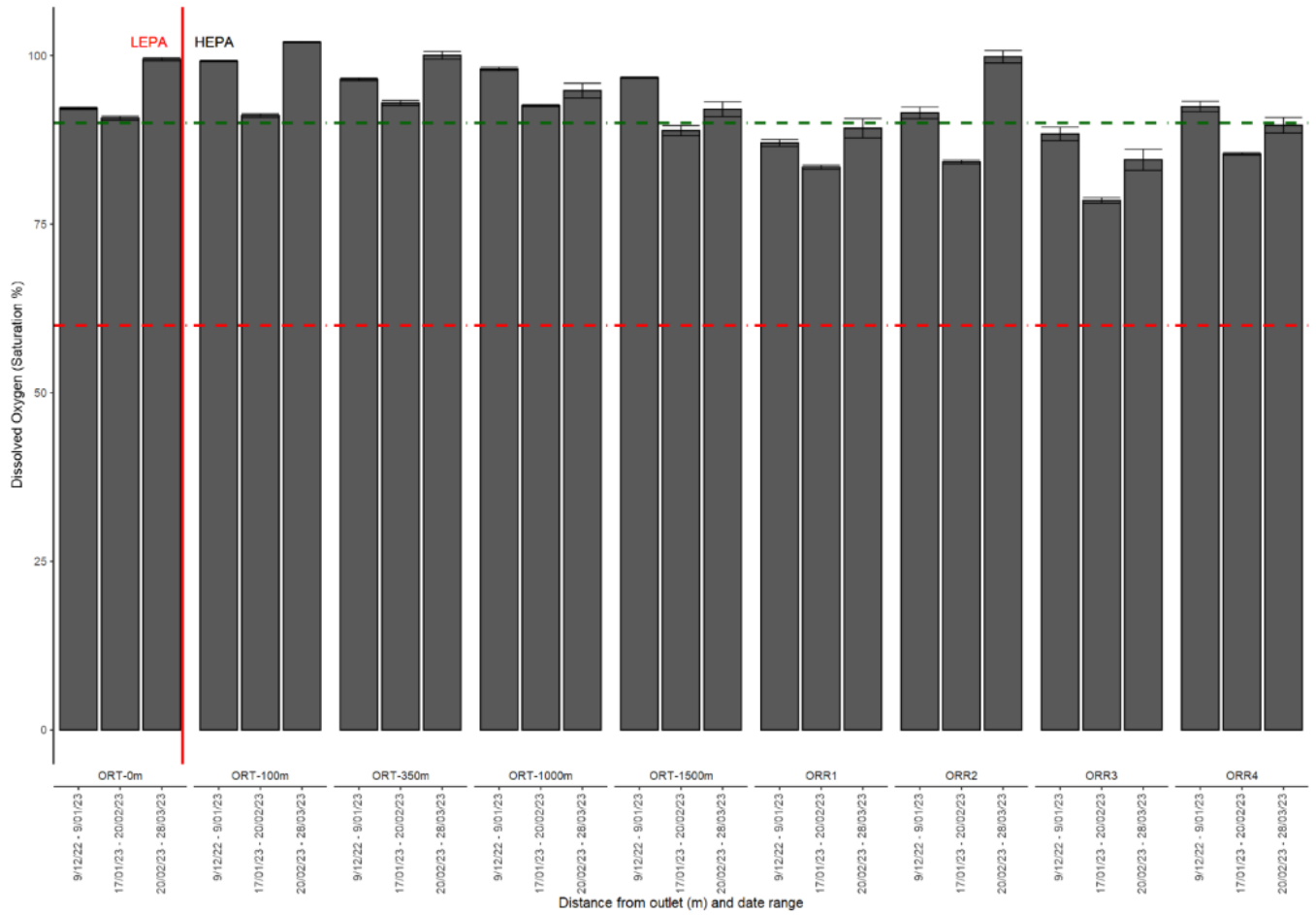
It should be noted that bottom dissolved oxygen concentrations were also <90% at the reference sites during the six week period the EQG was triggered, suggesting low dissolved oxygen concentrations were a regional phenomenon and not attributable to the outlet.

**Table 13 Environmental Quality Guideline for dissolved oxygen**

|            |                                                                                                                                                                                                                           |
|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EQG</b> | Median dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) in the HEPA must be greater than 90% saturation at any site for a defined period of not more than 6 weeks during the non-river flow period. |
| <b>EQS</b> | Median dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) in the HEPA must be greater than 60% saturation at any site for a defined period of not more than 6 weeks during the non-river flow period. |

Note:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard



Notes:

1. Error bars  $\pm 95\%$  confidence intervals
2. Dissolved oxygen (DO) measured 0–0.5 m above the seabed
3. Green dashed line = Environmental Quality Guideline (EQG) = 90% DO Saturation
4. Red dashed line = Environmental Quality Standard (EQS) = 60% DO saturation.
5. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
6. Reference site data (ORR1–ORR4) are compared against EQG for contextual purposes only.

**Figure 11 Median dissolved oxygen for defined periods of  $\leq 6$  weeks during the summer monitoring period**



### 3.3.2 Salinity

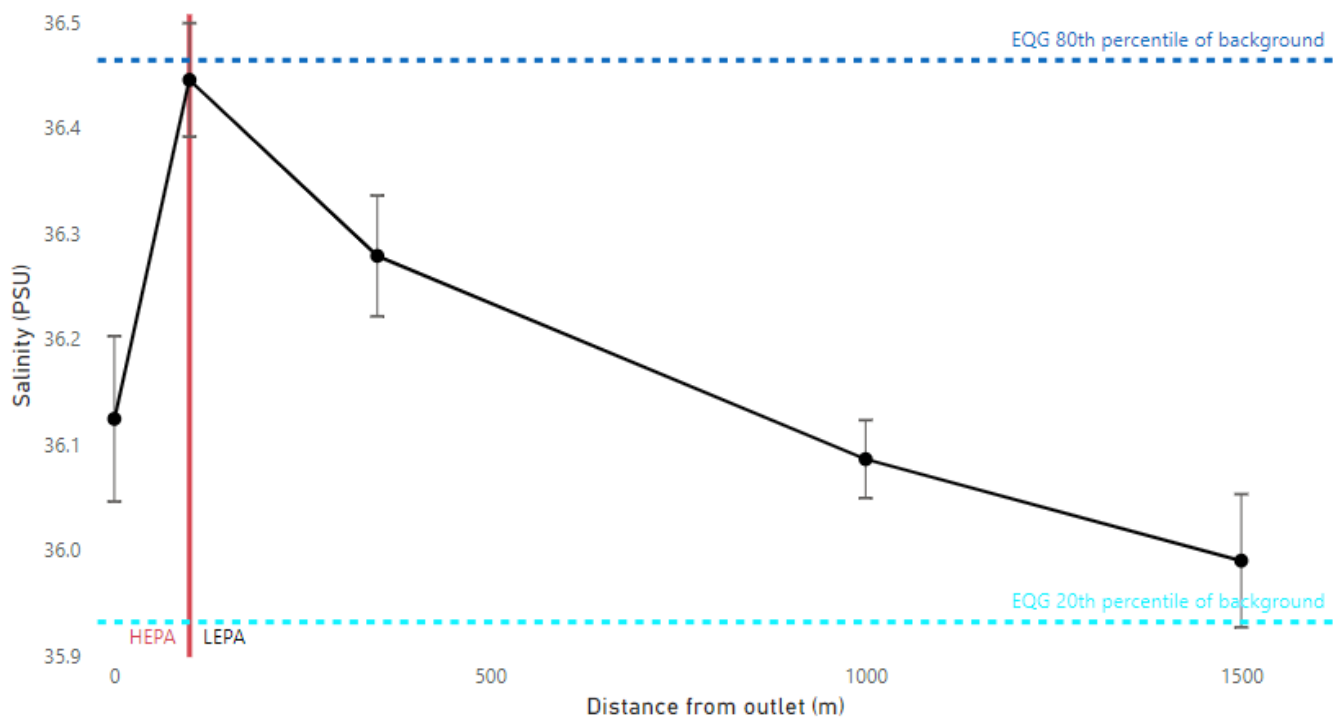
Median salinity was between the 20<sup>th</sup> and 80<sup>th</sup> percentile of the natural salinity range within the notional HEPA (at 100, 350, 1000 and 1500 m from the outlet), meeting the EQG (Table 14 and Figure 12).

**Table 14 Environmental Quality Guideline for salinity**

|            |                                                                                                                                                                                                                     |
|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EQG</b> | Median salinity (0.5 m below the water surface) at an individual site over any period is not to deviate beyond the 20 <sup>th</sup> and 80 <sup>th</sup> percentile of natural salinity range over the same period. |
| <b>EQS</b> | No deaths of marine organisms resulting from anthropogenically sourced salinity stress.                                                                                                                             |

Note:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard



Notes:

1. Error bars represent  $\pm 95\%$  confidence intervals
2. Salinity measured 0–0.5 m below the sea surface.
3. Dark blue line = 80<sup>th</sup> percentile of historical reference sites; light blue dashed line = 20<sup>th</sup> percentile of historical reference sites
4. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
5. Data for each distance were pooled across eight sampling occasions (n=8) over December 2022–March 2023.

**Figure 12 Median salinity compared to the 20<sup>th</sup> and 80<sup>th</sup> percentile of reference site data during the summer monitoring period**



## 4 Microbiological contaminants and algal biotoxins

### 4.1 Thermotolerant coliforms

TTC were sampled eight times over the 2022–2023 summer period (yielding a total of 40 samples). NHMRC (2008) guidelines and EPA (2005) require a minimum of 100 samples for accurate assessment of the EQC. Data from multiple years can be pooled where there are <100 samples provided local pollution conditions have not changed (NHRMC 2008). Assuming conditions have not changed, data collected over three summers (summer 2020–23 were pooled to yield 120 samples).

The median and 90<sup>th</sup> percentile TTC concentrations derived from the 3 years of pooled samples were both equal to the limit of detection (<10 CFU/100 mL; Table 16, Appendix H) and less than the 14 and 21 CFU/100 mL criteria, respectively meeting the EQG (Table 15).

**Table 15 Environmental Quality Guideline for thermotolerant coliforms**

|            |                                                                                                                                                                                                                    |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EQG</b> | Median TTC concentrations at sites at the boundary of the Observed Zone of Influence (OZI) are not to exceed 14 CFU/100 mL and the 90 <sup>th</sup> percentile of TTC concentrations must not exceed 21 CFU/100 mL |
|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Notes:

1. EQG = Environmental Quality Guideline
2. OZI = Observed Zone of Influence, refers to the Seafood Management Zone; TTC = thermotolerant coliforms.
3. TTC concentrations are measured using the membrane filtration method.
4. Marine Biotoxin Monitoring and Management Plan 2016: Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH 2016).

**Table 16 Median and 90<sup>th</sup> percentile of thermotolerant coliform concentrations at the fixed monitoring sites for the Ocean Reef outlets for 2020–2023 and comparison to the EQC**

| Sampling period                                             | Median         | 90 <sup>th</sup> percentile | Compliance (EQG)                                                                      |
|-------------------------------------------------------------|----------------|-----------------------------|---------------------------------------------------------------------------------------|
| Dec 2020–Mar 2021<br>Dec 2021–Mar 2022<br>Dec 2022–Mar 2023 | <10 CFU/100 mL | <10 CFU/100 mL              |  |

Notes:

1. Green symbols (■) indicate the Environmental Quality Criteria (EQC) were met
2. represent an exceedance of the Environmental Quality Guideline (EQG) and Environmental Quality Standard (EQS), respectively.
3. Thermotolerant coliform results below the analytical detection limit (<10 CFU/100 mL) were halved (=5 CFU/100 mL) to calculate the median and 90<sup>th</sup> percentile.
4. Environmental Quality Criteria are based on EPA (2017).



## 4.2 Toxic phytoplankton species

The EQG for toxic phytoplankton species states that concentrations of potentially toxic algae are not to exceed the WASQAP trigger concentrations in any samples (DoH, DPIRD and Industry, 2020). Table 17 lists the phytoplankton species known to produce toxins that may be concentrated in shellfish and their WASQAP (DoH, DPIRD and Industry, 2020) guideline trigger concentrations (alert level to initiate flesh testing).

**Table 17 Environmental Quality Guideline for toxic phytoplankton species**

| EQG | Cell counts of potentially toxic algae species at sites at the boundary of the OZI are not to exceed the WASQAP <sup>1</sup> trigger concentrations for any of the following:                                                                                                                                                                                                                                                                                                               |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|     | <ul style="list-style-type: none"> <li>• <i>Alexandrium</i><sup>2</sup> spp. (200 cells/L)</li> <li>• <i>Dinophysis</i> spp. (1,000 cells/L)</li> <li>• <i>Gymnodinium catenatum</i> (1,000<sup>3</sup> cells/L)</li> <li>• <i>Karenia brevis</i> (1,000 cells/L)</li> <li>• <i>Karenia/Karlodinium/Gymnodinium</i> group<sup>4</sup> (250,000 cells/L)</li> <li>• <i>Prorocentrum lima</i> (500 cells/L)</li> <li>• <i>Pseudo-nitzschia</i> group<sup>5</sup> (500,000 cells/L)</li> </ul> |

Note:

1. EQG = Environmental Quality Guideline
2. Marine Biotxin Monitoring and Management Plan 2020 version 2: Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH, DPIRD and Industry, 2020).
3. *Alexandrium* species may be difficult to identify when numbers are low, and they are being treated as potentially toxic.
4. Trigger management action for mussels and other shellfish is 2,000 cells/L.
5. The *Karenia/Karlodinium/Gymnodinium* group includes *Karenia bidigitata*, *Karenia brevisulcata*, *Karenia mikimotoi*, *Karenia papilionacea*, *Karenia selliformis*, *Karlodinium micrum* and *Gymnodinium impudicum*.
6. Species within the *Pseudo-nitzschia* groups are difficult to identify, and they are being treated as potentially toxic.
7. OZI = Observed Zone of Influence, refers to the Seafood Management Zone.
8. If the EQG is exceeded, assessment will proceed against the EQS for sentinel mussel tissues.

There were no instances where toxic phytoplankton species were present at densities greater than the WASQAP (DoH, DPIRD and Industry, 2020) guideline values (Table 18; Appendix I).





**Table 18** Estimated cell densities of phytoplankton species known to produce toxins

| Date       | Site <sup>1</sup> | Species                                     | Estimated density (cells/L) | WASQAP Guideline <sup>2</sup> (cells/L) | Compliance |
|------------|-------------------|---------------------------------------------|-----------------------------|-----------------------------------------|------------|
| 09/12/2022 | ORR3              | No Toxic Species                            | NA                          | NA                                      |            |
|            | OR5               |                                             |                             |                                         |            |
|            | OR18              |                                             |                             |                                         |            |
| 14/12/2022 | ORR3              | <i>Gymnodinium impudicum</i>                | 320                         | 250,000                                 |            |
|            |                   | <i>Gymnodinium</i> spp                      | 560                         | 250,000                                 |            |
|            |                   | <i>Karenia papilionaceae</i>                | 80                          | 250,000                                 |            |
|            | OR13              | <i>Gymnodinium</i> spp                      | 240                         | 250,000                                 |            |
|            | OR29              | <i>Gymnodinium</i> spp                      | 320                         | 250,000                                 |            |
| 09/01/2023 | ORR3              | <i>Pseudo-nitzschia delicatissima</i> group | 1,440                       | 500,000                                 |            |
|            |                   | <i>Pseudo-nitzschia seriata</i> group       | 240                         | 500,000                                 |            |
|            | OR7               | <i>Pseudo-nitzschia delicatissima</i> group | 25,360                      | 500,000                                 |            |
|            |                   | <i>Pseudo-nitzschia seriata</i> group       | 1,040                       | 500,000                                 |            |
|            | OR21              | <i>Pseudo-nitzschia delicatissima</i> group | 8,960                       | 500,000                                 |            |
|            |                   | <i>Pseudo-nitzschia seriata</i> group       | 880                         | 500,000                                 |            |
| 17/01/2023 | ORR2              | No Toxic Species                            | NA                          | NA                                      |            |
|            | OR9               | <i>Pseudo-nitzschia delicatissima</i> group | 640                         | 500,000                                 |            |
|            |                   | <i>Gymnodinium</i> spp                      | 240                         | 250,000                                 |            |
|            | OR26              | No Toxic Species                            | NA                          | NA                                      |            |
| 14/02/2023 | ORR1              | <i>Gymnodinium</i> spp                      | 80                          | 250,000                                 |            |
|            |                   | <i>Pseudo-nitzschia delicatissima</i> group | 1,840                       | 500,000                                 |            |
|            | OR7               | <i>Pseudo-nitzschia delicatissima</i> group | 26,800                      | 500,000                                 |            |
|            |                   | <i>Pseudo-nitzschia seriata</i> group       | 160                         | 500,000                                 |            |
|            | OR18              | <i>Pseudo-nitzschia delicatissima</i> group | 10,400                      | 500,000                                 |            |
|            |                   | <i>Gymnodinium</i> spp                      | 160                         | 250,000                                 |            |
| 20/02/2023 | ORR4              | <i>Pseudo-nitzschia delicatissima</i> group | 1,680                       | 500,000                                 |            |
|            |                   | <i>Gymnodinium</i> spp                      | 80                          | 250,000                                 |            |
|            | OR9               | <i>Pseudo-nitzschia delicatissima</i> group | 19,360                      | 500,000                                 |            |
|            |                   | <i>Pseudo-nitzschia seriata</i> group       | 400                         | 500,000                                 |            |
|            |                   | <i>Gymnodinium</i> spp                      | 80                          | 250,000                                 |            |
|            | OR26              | <i>Pseudo-nitzschia delicatissima</i> group | 2,560                       | 500,000                                 |            |
|            |                   | <i>Pseudo-nitzschia seriata</i> group       | 80                          | 500,000                                 |            |
|            |                   | <i>Gymnodinium</i> spp                      | 160                         | 250,000                                 |            |
| 09/03/2023 | ORR1              | <i>Pseudo-nitzschia delicatissima</i> group | 160                         | 500,000                                 |            |
|            | OR3               | <i>Pseudo-nitzschia delicatissima</i> group | 400                         | 500,000                                 |            |
|            |                   | <i>Pseudo-nitzschia seriata</i> group       | 80                          | 500,000                                 |            |
|            | OR32              | <i>Pseudo-nitzschia delicatissima</i> group | 720                         | 500,000                                 |            |
|            |                   | <i>Gymnodinium</i> spp                      | 240                         | 250,000                                 |            |
| 28/03/2023 | ORR2              | <i>Pseudo-nitzschia delicatissima</i> group | 240                         | 500,000                                 |            |
|            | OR12              | <i>Pseudo-nitzschia delicatissima</i> group | 640                         | 500,000                                 |            |
|            |                   | <i>Pseudo-nitzschia seriata</i> group       | 160                         | 500,000                                 |            |



| Date | Site <sup>1</sup> | Species                                     | Estimated density (cells/L) | WASQAP Guideline <sup>2</sup> (cells/L) | Compliance |
|------|-------------------|---------------------------------------------|-----------------------------|-----------------------------------------|------------|
|      | OR28              | <i>Pseudo-nitzschia delicatissima</i> group | 640                         | 500,000                                 |            |
|      |                   | <i>Pseudo-nitzschia seriata</i> group       | 80                          | 500,000                                 |            |
|      |                   | <i>Gymnodinium</i> spp                      | 160                         | 250,000                                 |            |

Notes:

1. Samples were analysed for one monitoring site and one reference site per sampling occasion. Reference results are not applicable (na) to compliance.
2. Marine Biotxin Monitoring and Management Plan 2020 version 2: Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH, DPIRD and Industry, 2020).
3. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met.



### 4.3 Faecal pathogens (*Enterococci* spp.)

Samples were collected eight times over the 2022–2023 summer monitoring period (yielding a total of 40 samples) for faecal pathogens analyses (measured as *Enterococci* spp.). NHMRC (2008) guideline and EPA (2005) require a minimum of 100 samples over the monitoring period for accurate assessment of the EQC. Data from multiple years can be pooled where there are less than 100 samples provided local pollution conditions have not changed (NHMRC 2008). Assuming conditions have not changed data from the past three summers (2020–2023) were pooled to yield 120 samples. The EQG for primary and secondary contact recreation are outlined in Table 19.

Over the past three summers, the 95<sup>th</sup> percentile of *Enterococci* spp. concentrations at the boundary of the observed zone of influence (contact recreation management zone) for the Ocean Reef ocean outlets was equal to the limit of detection (<10 MPN/100 mL; Table 20), and both the primary (<200 MPN/100 mL) and secondary (<2000 MPN/100mL) contact recreation EQG for faecal pathogens (Table 19) in the water were met.

**Table 19 Environmental Quality Guidelines for contact recreation**

|                              |            |                                                                                                                         |
|------------------------------|------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>Primary<sup>1</sup></b>   | <b>EQG</b> | The 95 <sup>th</sup> percentile bacterial content of marine waters should not exceed 200 <i>Enterococci</i> MPN/100 mL  |
| <b>Secondary<sup>2</sup></b> | <b>EQG</b> | The 95 <sup>th</sup> percentile bacterial content of marine waters should not exceed 2000 <i>Enterococci</i> MPN/100 mL |

Notes:

1. EQG = Environmental Quality Guideline
2. Primary contact recreation = activities where humans are in direct contact with the water (e.g. swimming, snorkelling and diving).
3. Secondary contact recreation = activities where humans are in secondary contact with the water (e.g. boating and fishing).
4. EQG = Environmental Quality Guideline.

**Table 20 The 95<sup>th</sup> percentile of *Enterococci* spp. concentrations at the boundary of the observed zone of influence for the Ocean Reef ocean outlets**

| Sampling period   | 95 <sup>th</sup> percentile | Compliance                                                                           |                                                                                       |
|-------------------|-----------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
|                   |                             | Primary contact                                                                      | Secondary contact                                                                     |
| Dec 2020–Mar 2021 | <10 MPN/100 mL              |  |  |
| Dec 2021–Mar 2022 |                             |                                                                                      |                                                                                       |
| Dec 2022–Mar 2023 |                             |                                                                                      |                                                                                       |

Notes:

1. MPN = most probable number of *Enterococci* spp.
2. *Enterococci* spp. concentrations below the analytical detection limit (<10 *Enterococci* spp. MN/100 mL) were halved (=5 MPN/100 mL) to calculate the 95<sup>th</sup> percentile.
3. Green symbols (■) indicate the Environmental Quality Criteria (EQC) were met
4. represent an exceedance of the Environmental Quality Guideline (EQG) and Environmental Quality Standard (EQS), respectively.
5. Environmental Quality Criteria (EQC) based on EPA (2017) water quality guidelines for recreation waters.



#### 4.4 Phytoplankton cell concentrations

The concentrations of phytoplankton cells are determined based on the Environmental Quality Criteria (EQC) for toxic algae in marine recreational water. Table 21 presents the specific EQC values for toxic algae in marine recreational water as outlined in EPA (2017) and the approach with respect to watch list species described by the DoH in 2022.

**Table 21 Environmental Quality Guideline for phytoplankton cell count**


|            |                                                                                                                                                                                       |
|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>EQG</b> | The phytoplankton cell count from a single site should not exceed 10 000 cells/mL; or detect the Department of Health watch list species or exceed their trigger levels (Appendix J). |
| <b>EQS</b> | The phytoplankton cell count from a single site should not exceed 50 000 cells/mL; or detect the Department of Health watch list species or exceed their action levels (Appendix J).  |

Notes:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard

During the 2022–2023 monitoring period, the densities of phytoplankton at the individual monitoring sites remained below 10,000 cells/mL (Table 22). The Environmental Quality Guideline (EQG) for phytoplankton concentrations was therefore met.

**Table 22 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                                                                            |
|------------|------|--------------------------|---------------------------------------------------------------------------------------|
| 9/12/2022  | OR5  | 98                       |  |
| 14/12/2022 | OR13 | 691                      |                                                                                       |
| 09/01/2023 | OR7  | 378                      |                                                                                       |
| 23/01/2023 | OR9  | 17                       |                                                                                       |
| 14/02/2023 | OR7  | 1,082                    |                                                                                       |
| 20/02/2023 | OR9  | 52                       |                                                                                       |
| 09/03/2023 | OR3  | 11                       |                                                                                       |
| 28/03/2023 | OR12 | 44                       |                                                                                       |

Note:

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



## 5 Aesthetics

Aesthetic quality was assessed fortnightly via a questionnaire completed by field personnel on eight occasions during the non-river flow period (Table 23). On each occasion, the questionnaire was completed at one location on the post upgrade boundary down-current of the diffuser. Water clarity around the outlet (mean LAC at 350 m from the diffuser, pooled from all days) was compared against water clarity at a greater distance from the outlet (mean LAC at 1500 m from the diffuser from all days pooled) to assess whether aesthetic differences exist. Water Corporation also maintains complaints register for the Ocean PLOOM program.

**Table 23 Environmental Quality Criteria for Recreation and Aesthetics**

| Indicator                | Environmental Quality Criteria                                                                                                                          |                                                                                                                                                                     |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                          | EQG                                                                                                                                                     | EQS                                                                                                                                                                 |
| Nuisance organisms       | Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae and sewage fungus should not be present in excessive amounts                 | There should be no overall decrease in the aesthetic water quality values of Cockburn Sound using direct measures of the community's perception of aesthetic value. |
| Faunal deaths            | There should be no reported incidents of large-scale deaths of marine organisms relating from unnatural causes.                                         |                                                                                                                                                                     |
| Water clarity            | The natural visual clarity of the water should not be reduced by more than 20%                                                                          |                                                                                                                                                                     |
| Colour                   | The natural hue of the water should not be changed by more than ten points on the Munsell scale.                                                        |                                                                                                                                                                     |
| Surface films            | Oil and petrochemicals should not be noticeable as a visible film on the water or detectable by odour.                                                  |                                                                                                                                                                     |
| Surface debris           | Water surfaces should be free of floating debris, dust and other objectionable matter, including substances that cause foaming.                         |                                                                                                                                                                     |
| Odour                    | There should be no objectionable odour.                                                                                                                 |                                                                                                                                                                     |
| Fish tainting substances | Concentrations of contaminants will not exceed the aesthetics guidelines for fish tainting substances at the Shellfish Harvesting Safety Zone boundary. | There should be no detectable tainting of edible fish harvested outside the Shellfish Harvesting Safety Zone boundary.                                              |

Notes:

1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard

The field surveys found algae/plant material visible on the surface on 62.5% of occasions (Table 24). No dead marine organisms were visible on any occasion (Table 24). There was noticeable colour variation on 25% of occasions (Table 24). There were no films or oil on the surface on any sampling occasion. There was no floating debris visible on the surface on any sampling occasion (Table 24). There was no noticeable odour associated with the water on any of the sampling occasions (Table 24). There was no



overall decrease in the aesthetic water quality values of Cockburn Sound using direct measures of the community's perception of aesthetic value.

Mean LAC at 350 m from the ocean outlet ( $0.082 \text{ Log}_{10}/\text{m}$ ) was slightly higher than at 1500 m distance from the outlet ( $0.079 \text{ Log}_{10}/\text{m}$ ) suggesting that light was more quickly attenuated at 350 m than 1500 m (Table 25). Overall water clarity was decreased by ~4% and therefore the EQG that the natural visual clarity of the water should not be reduced by more than 20% was met.



**Table 24 Aesthetic observations and measurements near the Ocean Reef ocean outlet from December 2022 to March 2023**

| Date       | Site | Algae/plant material? | Dead marine organisms? | Secchi depth (m) | Colour variation? | Oil or other films? | Floating debris? | Odour? |
|------------|------|-----------------------|------------------------|------------------|-------------------|---------------------|------------------|--------|
| 9/12/2022  | OR5  | Yes, macroalgal wrack | No                     | 4.8              | Yes, milky        | No                  | No               | No     |
| 14/12/2022 | OR13 | Yes, seagrass flower  | No                     | 5.7              | No                | No                  | No               | No     |
| 9/01/2023  | OR5  | Yes, macroalgae       | No                     | 9.2              | Yes, green        | No                  | No               | No     |
| 17/01/2023 | OR7  | Yes, seagrass         | No                     | 4.8              | No                | No                  | No               | No     |
| 14/02/2023 | OR5  | Yes, seagrass         | No                     | 3.5              | No                | No                  | No               | No     |
| 20/02/2023 | OR9  | No                    | No                     | 10               | No                | No                  | No               | No     |
| 9/03/2023  | OR5  | No                    | No                     | 6.9              | No                | No                  | No               | No     |
| 28/03/2023 | OR11 | No                    | No                     | 11.8             | No                | No                  | No               | No     |

**Table 25 Light attenuation coefficient at sites 350 m and 1500 m from the Ocean Reef ocean outlet from December 2022 to March 2023**

| Date        | Light attenuation coefficient (Log10/m) |                            |
|-------------|-----------------------------------------|----------------------------|
|             | 350 m (site ORT-350 m)                  | 1500 m (site ORT – 1500 m) |
| 9/12/2022   | 0.100                                   | 0.089                      |
| 14/12/2022  | 0.082                                   | 0.082                      |
| 9/01/2023   | 0.080                                   | 0.063                      |
| 17/01/2023  | 0.081                                   | 0.076                      |
| 14/02/2023  | 0.109                                   | 0.099                      |
| 20/02/2023  | 0.087                                   | 0.077                      |
| 9/03/2023   | 0.068                                   | 0.090                      |
| 28/03/2023  | 0.070                                   | 0.072                      |
| <b>Mean</b> | <b>0.082</b>                            | <b>0.079</b>               |



## 6 Shoreline monitoring

### 6.1 Thermotolerant coliforms

TTC were sampled at eight shoreline monitoring sites eight times over the 2022–2023 summer period (yielding a total of 64 samples). NHMRC (2008) guidelines and EPA (2005) recommend that a minimum of 100 samples are required for accurate assessment of the EQG. Data from multiple years can be pooled where there are <100 samples provided local pollution conditions have not changed (NHMRC 2008). Assuming conditions have not changed, data collected over two summers (summer 2021–22 and 2022–23) were pooled to yield 128 samples.

The shoreline sites are not formally assessed against the EQC but the median and 90<sup>th</sup> percentile TTC concentrations derived from the 128 samples were at the limit of detection (<10 CFU/100 mL; Table 16, 0) and less than the 14 and 21 CFU/100 mL criteria, respectively meeting the EQG criteria (Table 15).

Median TTC concentrations were 5 CFU/100 mL (the proxy for concentrations below the LoR) at all sites down current of the diffuser (Figure 13).

**Table 26 Median and 90<sup>th</sup> percentile thermotolerant coliform concentrations at the shoreline monitoring sites for the Ocean Reef outlets for 2021–2023 and comparison to the EQG**

| Sampling period                        | Median (CFU/100 mL) | 90 <sup>th</sup> percentile | Compliance (EQG)                                                                      |
|----------------------------------------|---------------------|-----------------------------|---------------------------------------------------------------------------------------|
| Dec 2021–Mar 2022<br>Dec 2022–Mar 2023 | <10 CFU/100 mL      | <10 CFU/100 mL              |  |

Notes:

1. EQG = Environmental Quality Guideline
2. Green symbols (■) indicate the Environmental Quality Criteria (EQC) were met
3. Thermotolerant coliform results below the analytical detection limit (<10 CFU/100 mL) were halved (=5 CFU/100 mL) to calculate the median and 90<sup>th</sup> percentile.
4. Environmental Quality Criteria are based on EPA (2017).

### 6.2 Faecal pathogens (*Enterococci* spp.)

Samples were collected eight times at eight shoreline monitoring sites over the 2022–2023 summer monitoring period (yielding a total of 64 samples) for faecal pathogens analyses. NHMRC guideline and EPA (2005) recommend a minimum of 100 samples over the monitoring period are required for accurate assessment of the EQC. Data from multiple years can be pooled where there are less than 100 samples provided local pollution conditions have not changed (NHMRC 2008). Assuming conditions have not changed, data collected over two summers (summer 2021–22 and 2022–23) were pooled to yield 128 samples.

Shoreline sites are not formally assessed against the EQC but the 95<sup>th</sup> percentile of *Enterococci* spp. concentrations at the shoreline monitoring sites for the Ocean Reef ocean outlets was at the limit of detection (<10 MPN/100 mL, Table 27, Appendix H), and met both the primary and secondary (<200 and <2000 MPN/100mL, respectively) contact recreation EQGs (Table 19).

Median *Enterococci* spp. concentrations were 5 MPN/100 mL (the proxy for concentrations below the LoR) at all sites down current of the diffuser (Figure 13).





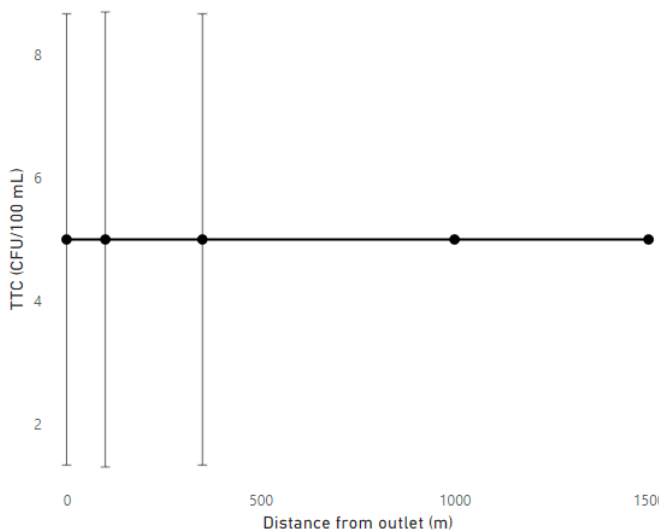
**Table 27** The 95<sup>th</sup> percentile of *Enterococci* spp. concentrations at the shoreline monitoring sites for the Ocean Reef ocean outlets for 2021–2023 and comparison to the EQG

| Sampling period                        | 95 <sup>th</sup> percentile | Compliance      |                   |
|----------------------------------------|-----------------------------|-----------------|-------------------|
|                                        |                             | Primary contact | Secondary contact |
| Dec 2021–Mar 2022<br>Dec 2022–Mar 2023 | 10 MPN/100 mL               | ■               | ■                 |

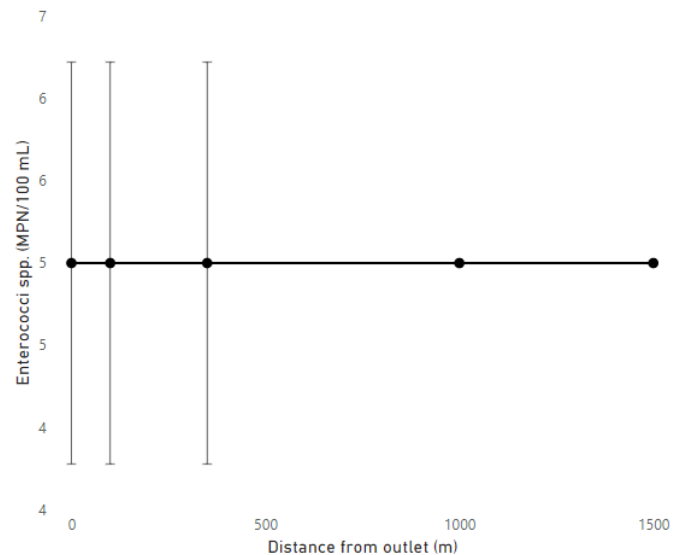
Notes:

1. MPN = most probable number of *Enterococci* spp.
2. *Enterococci* spp. concentrations below the analytical detection limit (<10 *Enterococci* spp. MN/100 mL) were halved (=5 MPN/100 mL) to calculate the 95<sup>th</sup> percentile.
3. Green symbols (■) indicate the Environmental Quality Criteria (EQC) were met
4. Environmental Quality Criteria (EQC) based on EPA (2017) water quality guidelines for recreation waters.

(A) Thermotolerant Coliforms



(B) *Enterococci* spp.



Notes:

1. Error bars represent  $\pm 95\%$  confidence intervals

**Figure 13** Median a) TTC and b) *Enterococci* spp. at 0, 100, 350, 1000, and 1500 m from the Ocean Reef outlet from December 2022 to March 2023



## References

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



## Appendices

The following Appendices are available from Water Corporation on request:



## Appendix A – Analytical laboratories



## Appendix B – Treated wastewater laboratory results



## Appendix C – Initial dilution model output



## Appendix D – Whole of effluent toxicity testing results



## Appendix E – Detailed methodologies





## Appendix F – Site Coordinates



## Appendix G – Nutrients results



## Appendix H – Microbiology results



## Appendix I – Phytoplankton results



## Appendix J – Department of Health watch list for potentially toxic algae