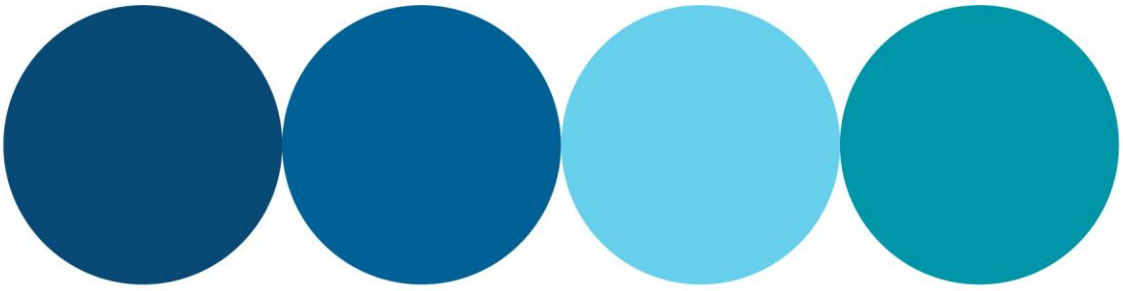
Perth Long Term Ocean Outlet Monitoring Program (PLOOM)

2022–2023 Annual Report

Subiaco Water Resource Recovery Facility



WATER CORPORATION

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Document history

Distribution

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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: 19/09/2023

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Date: 19/09/2023

Contents

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 Swanbourne 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). Under the EQMF, Water Corporation is required annually to demonstrate achievement against Environmental Quality Objectives (EQOs):

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

The 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
Monitor: EQG & EQS met (continue monitoring)	
Investigate: EQG not met (investigate against the EQS)	
Action: EQS not met (management response required)	

Note:

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

EQO 'Maintenance of Ecosystem Integrity'

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

Toxicants in treated wastewater: There are four EQGs relating to toxicants in the TWW, all of which are tested annually. EQG 1 and 2 relate to bioaccumulating and non-bioaccumulating toxicants, respectively. EQG 3 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 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 the ANZG (2018) 99% species protection guidelines at the LEPA boundary, 100 m from the diffuser. Initial dilution modelling for conditions on 7/02/2023 found that the Swanbourne outlets were achieving a worst-case average initial dilution of 1:52. 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 1.29, which is greater than the ANZG (2018) guideline value and exceeds the EQG. EQS 3 requires that the TTM at a single site or for a defined area, should not exceed 1, using the TTM formula and relevant environmental quality guidelines in the total toxicity of mixtures formula. TTM was calculated as 1.29 following initial dilution, however ammonia, copper and zinc were all below ANZG (2018) guideline for 99% species protection following initial dilution, therefore EQS 3 was met.

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 value across 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 were met, apart from EQG 1 for Phytoplankton blooms and EQG 2 for Physical chemistry (Table ES 2).

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 guideline (36 and 1.4 µg/L, respectively)	
	Non-bioaccumulating toxicants and initial dilution	EQG 2	Concentrations of copper after initial dilution (0.31 µg/L) exceeded the ANZG (2018) 99% species	

Environmental quality indicator		EQC	Comments	Compliance
			protection guideline trigger level (0.3 µg/L). Additional dilution between the point where the plume first reached the surface (i.e. after initial dilution 6 m) and the edge of the notional LEPA (i.e. 100 m from the outlet) will reduce the copper concentration to below the guideline trigger value and the EQG was almost certainly met at the boundary	
	Total toxicity of the mixture (TTM)	EQG 3	The TTM for the additive effect of ammonia, copper and zinc after initial dilution (1.29) exceeded the ANZG (2018) guideline value of 1.0	
		EQS 3	The TTM for the additive effect of ammonia, copper and zinc after initial dilution (1.29) exceeded the ANZG (2018) guideline value of 1.0, however individual concentrations of each toxicant after initial dilution did not exceed relevant environmental quality guidelines.	
	Whole of effluent toxicity testing	EQG 4	The lowest NOEC during the reporting period was 12.5%. Eight 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) (0.3 µg/L) was lower than the 80th percentile of historical reference site concentrations (0.5 µg/L).	
	Light attenuation coefficient (LAC)	EQG 2	Median LAC within the HEPA (0.066 Log_{10}/m) was lower than the 80th percentile of historical reference sites (0.094 Log_{10}/m).	

Environmental quality indicator		EQC	Comments	Compliance
Phytoplankton blooms	Phytoplankton biomass (measured as chlorophyll-a)	EQG 1	Median chlorophyll-a concentrations in the HEPA exceeded 3-times the median of reference sites .	
		EQS 1	Median phytoplankton biomass measured as chlorophyll-a did not exceed three times median chlorophyll-a concentration of historical reference sites, in two consecutive years.	
		EQG 2	Chlorophyll-a did exceed 3 times the median concentrations of reference sites on 12.5% of occasions.	
Physical chemistry	Organic enrichment	EQG 1	Dissolved oxygen saturation within the HEPA remained above 90% saturation at all times.	
	Salinity	EQG 2	Median salinity at the 350 and 1500m sites did deviate beyond the 20th and 80th percentile of natural salinity range over the same period.	
		EQS 2	There were no reported deaths of marine organisms from anthropogenically sourced salinity stress at Swanbourne over the summer monitoring period	

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 90th percentile of TTC concentrations must not exceed 21 CFU/100 mL.

For the present reporting period, the EQC for microbiological contaminants (as TTC) were assessed based on pooled data from three sampling seasons (2020-21, 2021-22 and 2022-23), with a sample size

(n=120) that allowed for appropriate comparison with the EQC (EPA 2005)[1]. Median TTC concentration was at the limit of detection (<10 CFU/100 mL), and therefore below the 14 CFU/100 mL trigger value. Over the three seasons, the 90th percentile was equal to the limit of detection (<10 CFU/100 mL), and less than the 21 CFU/100 mL criteria. As the median and 90th percentile concentrations were below their respective criteria, the EQG for microbiological contaminants (as TTC) 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 Industries 2020) concentrations. Densities of toxic phytoplankton were below relevant WASQP guidelines meeting the EQG for toxic phytoplankton species (Table ES 3).

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

Environmental quality indicator		Comments	Compliance
Microbial contaminants	Thermotolerant coliforms (TTC)	Median TTC concentrations derived from 120 samples collected over the 2020–2021, 2021–2022 and 2022–2023 sampling seasons was at the limit of detection (<10 CFU/100 mL) and less than 14 CFU/100 mL	■
		The 90th 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 Objective (EQO) were met
2. TTC results below the analytical detection limit (<10 CFU/mL) were halved (=5 CFU/mL) to calculate median value.

[1] *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.*

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 95th 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 95th percentile is not to exceed 2000 MPN/100 mL. The EQG for microbiological contaminants was assessed based on pooled data (n=120) from three sampling seasons (2020–2021, 2021–2022 and 2022–2023). The 95th percentile of *Enterococci* spp. concentrations equalled 10 MPN/100 mL, and met the EQG for both primary and secondary contact recreation (Table ES 4).

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

The EQG for algal biotoxins states:

- the median total phytoplankton cell concentration for the area of concern is not to exceed 10 000 cells/mL or
- Department of Health watch list species must not be detected in exceedance with their trigger levels

Phytoplankton densities at individual sites monitored 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 coliforms	*Enterococci* spp.	EQG (primary contact) EQG (secondary contact)	The 95th percentile of *Enterococci* spp. concentrations (10 MPN/100 mL) was lower than the 200 and 2 000 MPN/100 ml primary and secondary contact EQG, respectively	■
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 Guideline (EQG) were met

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'

Environmental Quality Indicator	EQC	Comments	Compliance[1]
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 ~15% (i.e. >20%).	■
Colour	EQG	There was a slight noticeable colour variation on 1 sampling occasion. 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.	■
Fish tainting substances	EQG	There were no recorded exceedances of fish tainting substances in the 2022-2023 monitoring period.	■

Note:

1. Green (■) symbols indicate the Environmental Quality Guideline (EQG) was met

1 Introduction

1.1 Document purpose

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

1.2 Wastewater treatment plant infrastructure and discharge

The Subiaco Water Resource Recovery Facility (WRRF) treats predominantly domestic wastewater from the central Perth area. The treated wastewater (TWW) comprises ~95% domestic wastewater and less than 5% industrial wastewater. The Subiaco WRRF discharges ~56 ML/day of secondary TWW to the ocean through a sub-marine ocean outlet (~11 m depth) offshore from Swanbourne Beach (Figure 1).

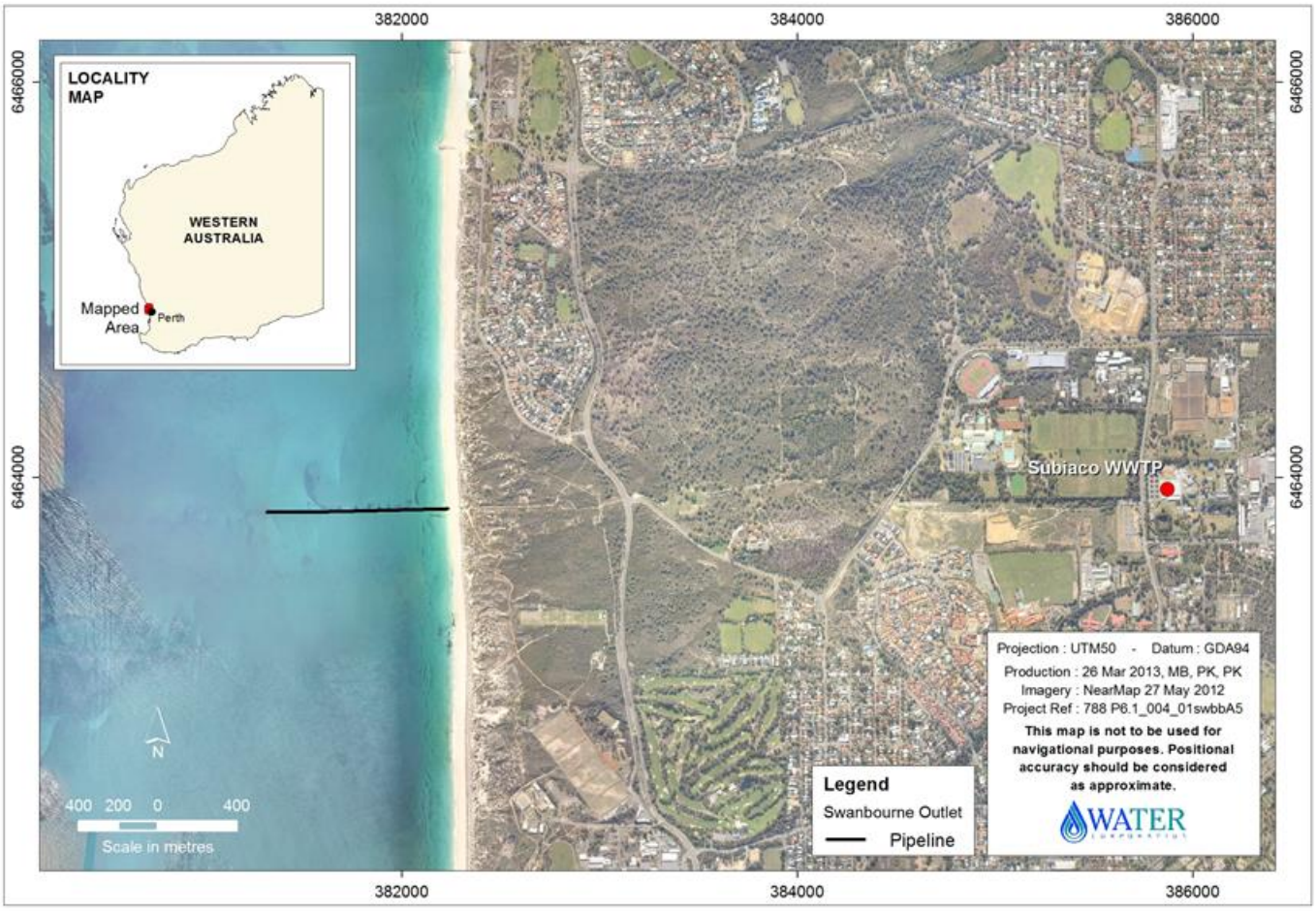
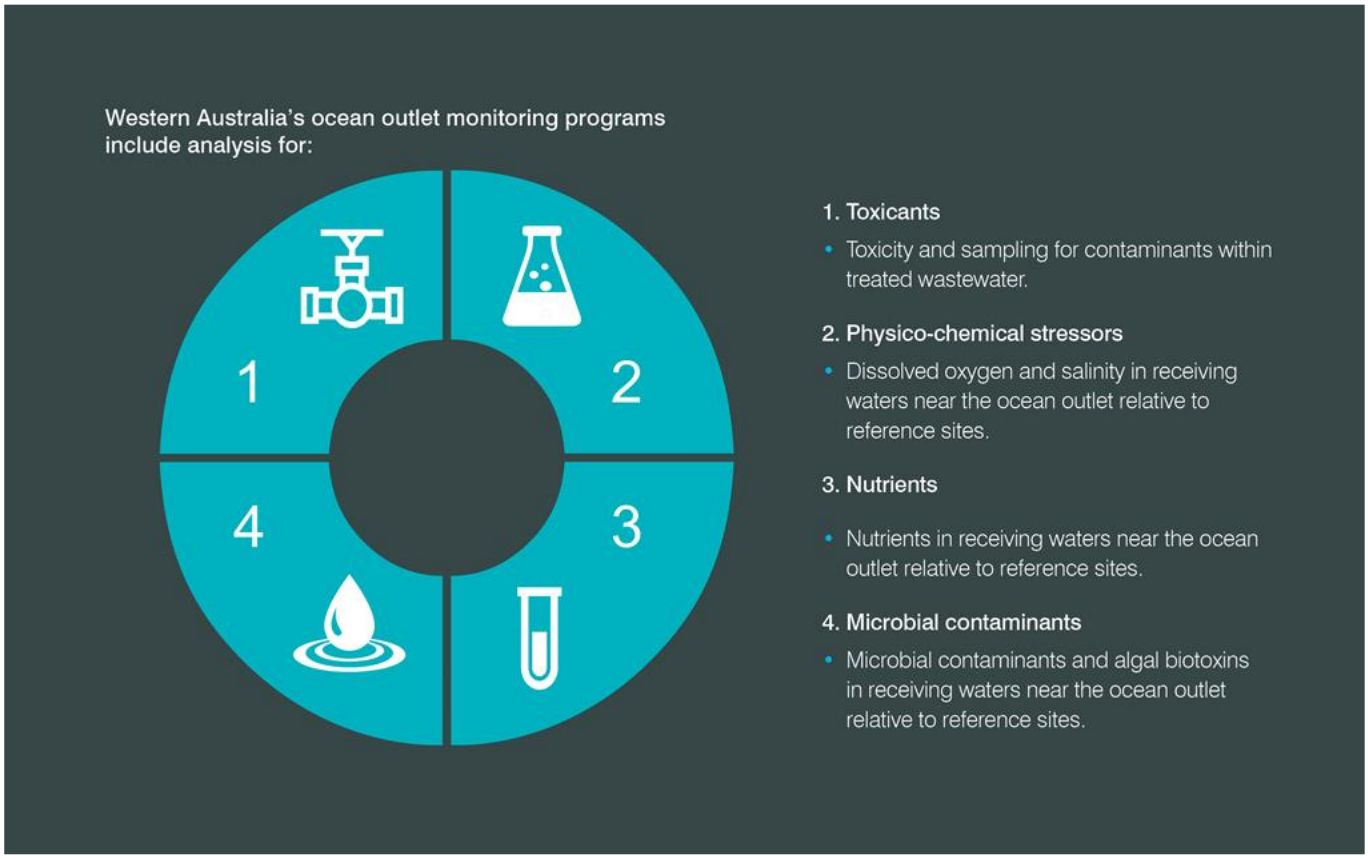


Figure 1 Location of the Subiaco water resource recovery facility (WRRF) and Swanbourne ocean outlet

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 EPA 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 outfall, relative to measurements at reference sites, 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 biologically the available nutrients ammonia, nitrite, nitrate and orthophosphate. At times, the addition of nutrients may 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 measured using in-water measures of chlorophyll-a (a proxy for phytoplankton biomass) and light attenuation (a measure for 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) criteria for primary and secondary contact, and the criteria for seafood for human consumption.

1.4 Environmental management approach

To maintain consistency with other metropolitan ocean outfall monitoring programs, the Swanbourne ocean outlet (Figure 2) is part of the Perth Long Term Ocean Outlet Monitoring (PLOOM) program.

Source: Google Earth

Figure 2 Aerial image of Swanbourne ocean outlet

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).

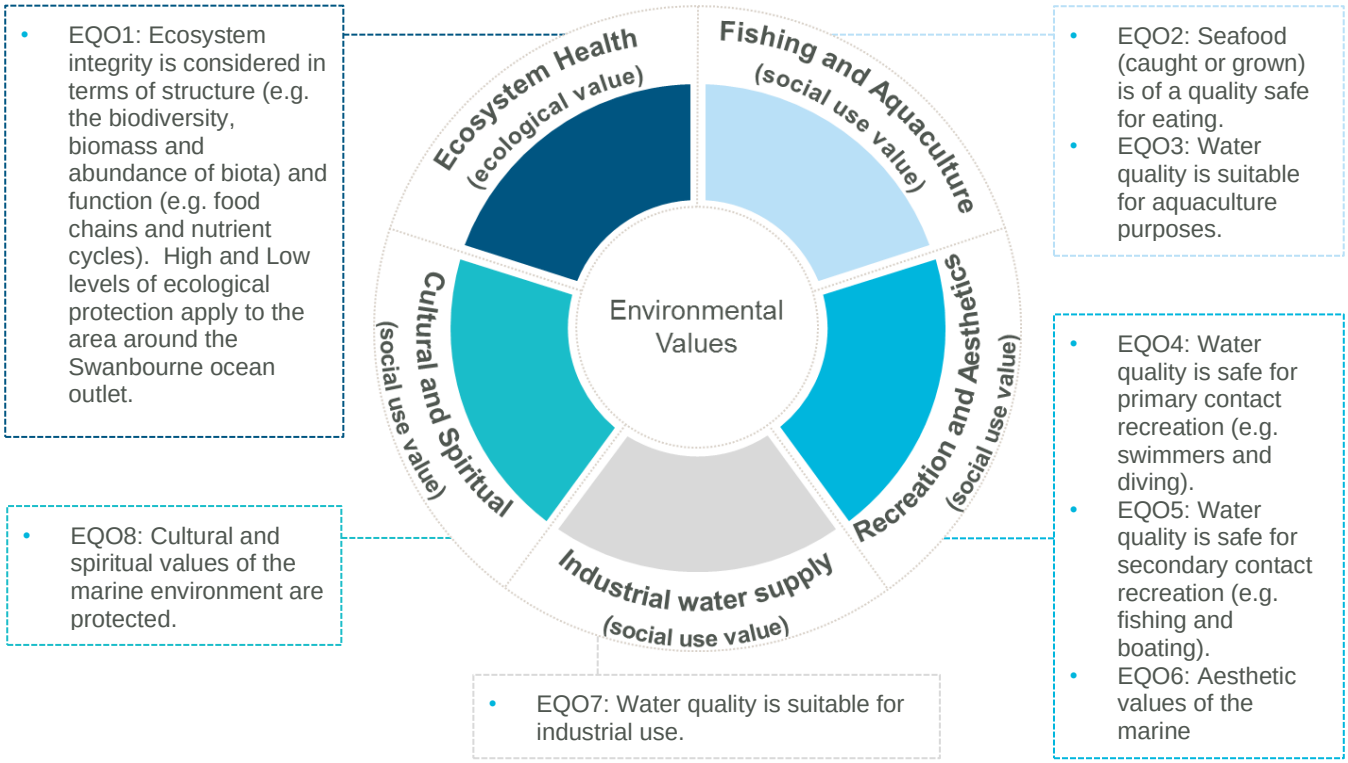
The EQMF is based on:

- 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 4)
- 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 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 the EQO is at risk of not being met and that a management response may be required.



Source: EPA (2016)

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

1.4.1 'Maintenance of Ecosystem Integrity' EQO

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

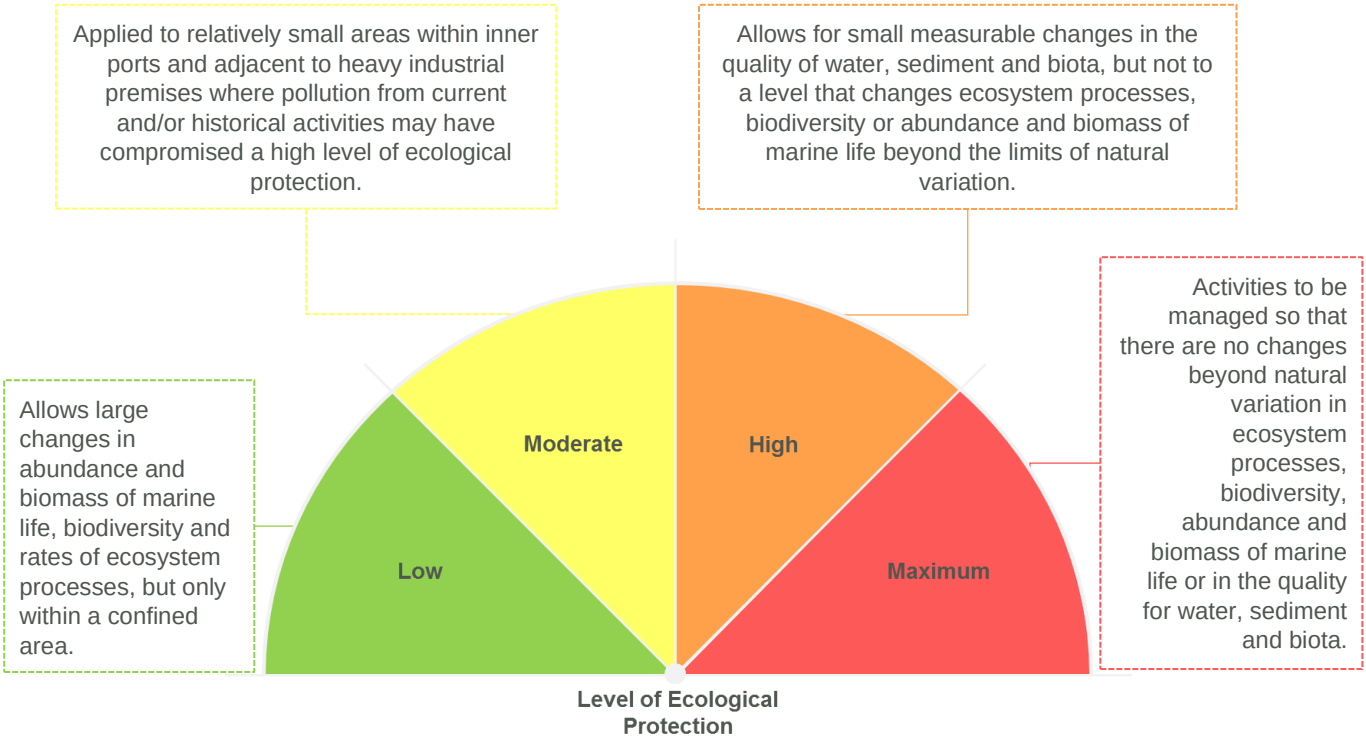


Figure 4 Level of Ecological Protection

In the absence of mandated management zones, a notional low ecological protection area (LEPA) has been established at the Swanbourne outfall, as per technical guidance (EPA 2016). The LEPA occupies the area within a 100 m radius of the diffuser (Figure 5). Waters outside the LEPA are maintained to a high level of ecological protection (HEPA; Figure 5).

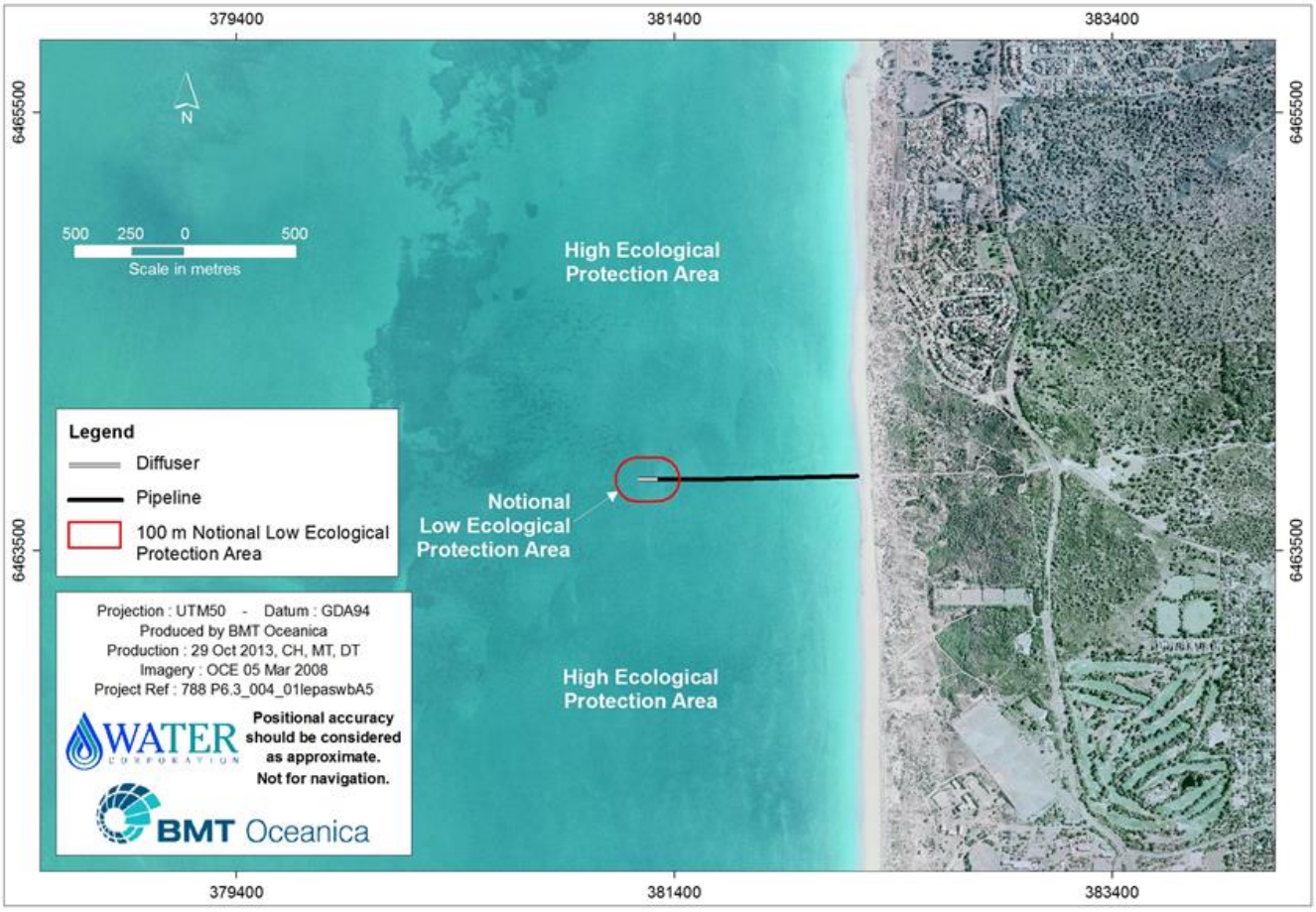


Figure 5 Swanbourne ocean outlet notional ecological protection boundaries

1.4.2 'Maintenance of Seafood Safe for Human Consumption' EQO

The intent of this EQO is to maintain seafood safe for human consumption (a social value) except for a small area surrounding the ocean outlet where seafood may be unsafe to eat. Formal management zones have not been established for the Swanbourne outlet. However, an informal zone has been established based on microbiological observations from historical monitoring (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.

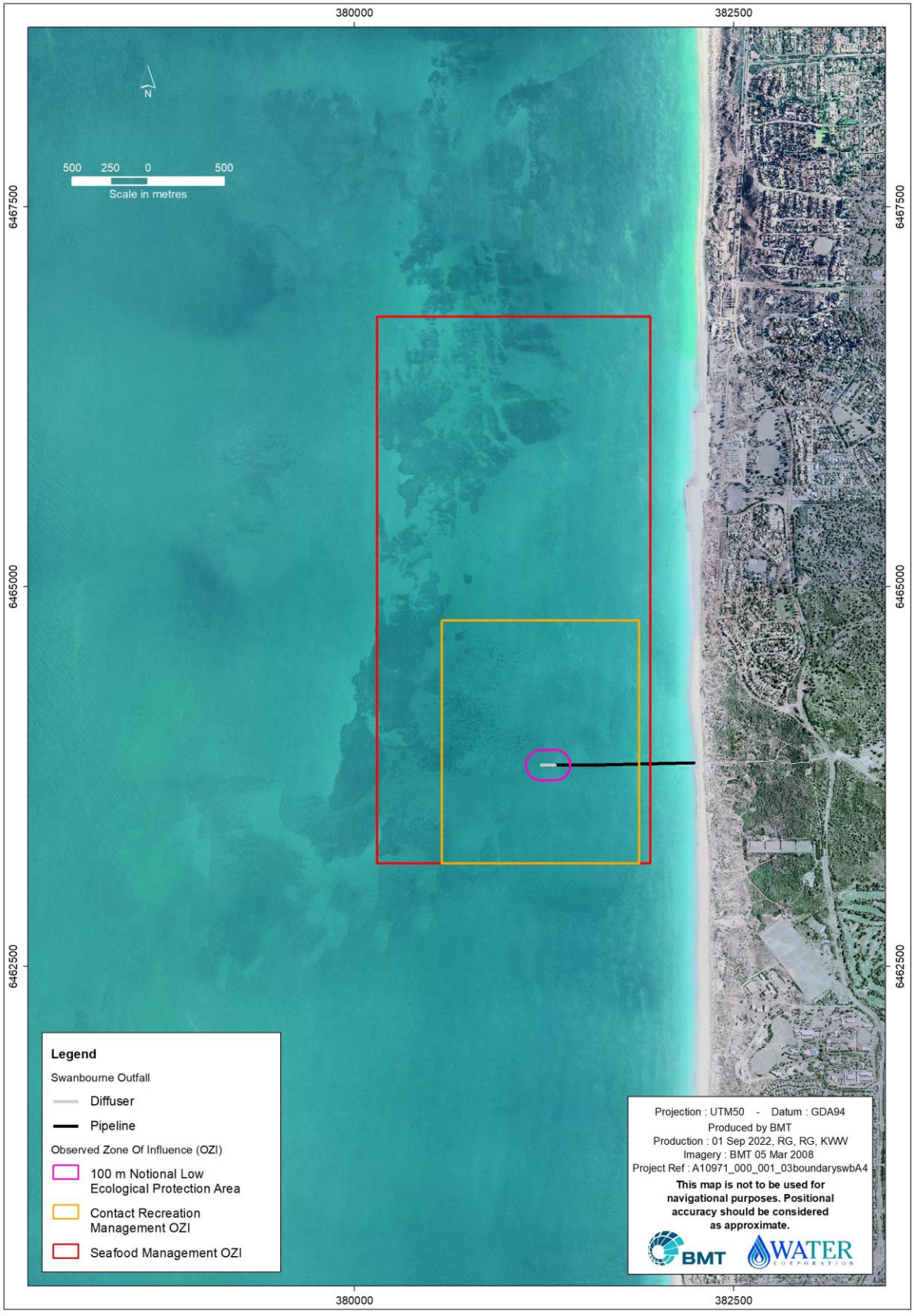


Figure 6 Swanbourne ocean outlet protection area and management zones.

1.4.3 '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 around the ocean outlets where water quality may not be suitable for swimming.

A formal area where primary contact recreation is not recommended has not been established for the Swanbourne outlet. However, an informal zone has been developed for the Swanbourne outlet encompassing the area containing elevated microbiological concentrations – this was derived from ten years of field data (Figure 6). As the EQO for maintenance of primary contact recreation uses a higher water quality standard than secondary contact recreation, it is assumed that if the primary contact criteria are met, then the secondary contact criteria are also met by default.

1.4.4 'Maintenance of Aesthetic Value' EQO

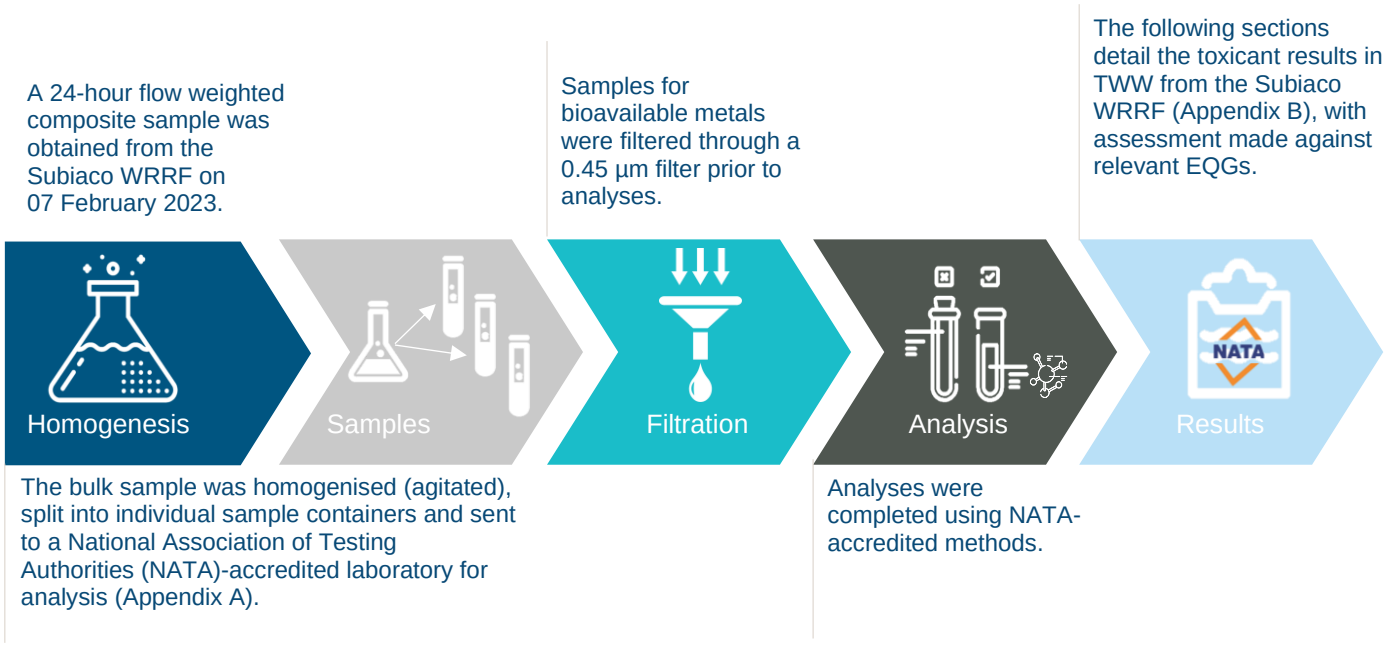
The objective of this EQO is to ensure that the aesthetic value of Perth's coastal waters is protected. To ensure this EQO is being met, monitoring routinely assesses the quality of the surface water appearance.

2 Toxicants in treated wastewater

2.1 Comprehensive treated wastewater characterisation

TWW (final effluent) from the Subiaco WRRF was analysed for a suite of potential contaminants of concern:

- nutrients (total nitrogen, ammonia, nitrate+nitrite, total phosphorus, orthophosphate)
- microbiological 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.



2.1.1 Bioaccumulating toxicants

Concentrations of cadmium and mercury (i.e. bioaccumulating toxicants) in the TWW sample were both below their analytical limit of reporting (<0.1 and <0.05 µg/L; Table 4) and their respective 80% species protection guidelines (36 and 1.4 µg/L, respectively) (ANZG 2018) meeting the EQG for bioaccumulating toxicants (Table 2).

Table 2 Environmental Quality Guideline for bioaccumulating toxicants

EQG	Concentrations of contaminants will not exceed the ANZG (2018) 80% species protection guideline trigger levels for bioaccumulating toxicants in wastewater stream

Note:

1. EQG = Environmental Quality Guideline

2.1.2 Non-bioaccumulating toxicants

Non-bioaccumulating toxicant concentrations were generally below the analytical limit of reporting except for ammonia, chromium, copper, nickel and zinc (Table 4). After initial dilution of 1:52 (a conservative estimate of the dilution expected at the LEPA boundary; Appendix C), concentrations of ammonia, chromium, nickel and zinc were below their ANZG (2018) 99% species protection guidelines. Concentrations of copper (0.31 µg/L) exceeded its respective guideline trigger value (0.3 µg/L) (Table 4), therefore, the EQG for non-bioaccumulating toxicants (Table 3) was potentially not met. However, additional dilution between the point where the plume first reached the surface (i.e. after initial dilution 6 m) and the edge of the notional LEPA (i.e. 100 m from the outlet) will reduce the copper concentration to below the guideline trigger value and the EQG was almost certainly met at the boundary.

Table 3 Environmental Quality Guideline for non-bioaccumulating toxicants

EQG	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 is 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 Swanbourne TWW stream compared with relevant guideline trigger levels after initial dilution

Toxicant	Swanbourne TWW concentration (µg/L)	Concentration after initial dilution (µg/L)	Trigger (µg/L)
Ammonia-N	2300	45.713	500
Cadmium*	<0.1	-	36
Chromium*	1.7	0.03	0.14 (Cr VI)
Copper*	12	0.31	0.3
Lead*	<1	-	2.2
Mercury*	<0.05	-	1.4
Nickel*	2.3	0.54	7
Silver*	<0.8	-	0.8
Zinc*	52	1.2	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 = 1:52 (predicted average value for Swanbourne outlet). 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, 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 (See Appendix D).
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 (1.29; Table 6), exceeded the ANZG (2018) guideline value of 1.0, and therefore, the EQG for TTM (Table 5) was not met triggering assessment against the EQS. After initial dilution, concentrations of ammonia, copper and zinc were below their individual ANZG (2018) 99% species protection guidelines (Table 4), therefore meeting the EQS.

Table 5 Environmental Quality Criteria for the total toxicity of the mixture

EQG	Where there are mixtures of toxicants, the TTM at a single site or for a defined area, should not exceed 1, using the TTM formula.
EQS	Where there are mixtures of toxicants, the TTM at a single site or for a defined area, should not exceed 1, using the TTM formula and relevant environmental quality guidelines in the total toxicity of mixtures formula.

Source EPA (2017)
Notes:

1. EQG = environmental quality guideline; TTM = total toxicity of the mixture
2. TTM = Σ(Ci/EQGi) where Ci is the concentration of the 'i'th component in the mixture and the EQGi is the guideline for that component.

Table 6 Total toxicity of treated wastewater (TWW) at the edge of the initial mixing zone associated with the Swanbourne ocean outlet

Toxicant	TWW concentration (µg/L)	Background concentration (µg/L)[1]	Guideline (µg/L)	Dilution	Concentration after dilution (µg/L)	contaminant /guideline	TTM[2]
Ammonia	2300	1.5	500	1:52	45.7	0.09	1.29
Copper	12	0.08	0.3		0.31	1.04	
Zinc	52	0.15	3.3		1.2	0.164	

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.

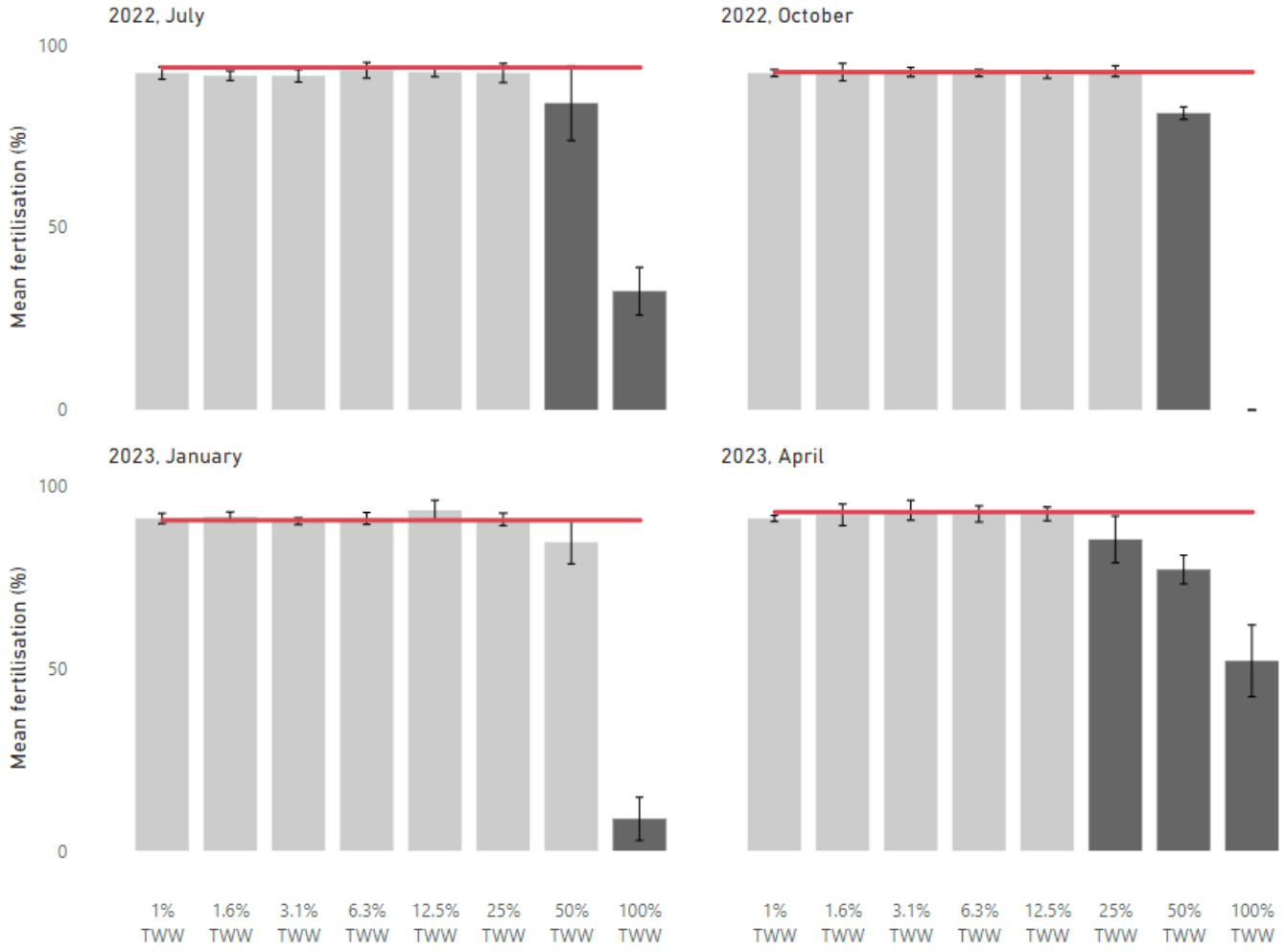
2.2 Whole of effluent toxicity (WET) testing

WET testing is useful for assessing toxicity in the absence of reliable guidelines, for toxicants that occur in low concentrations, or where the toxicity effects of contaminants are poorly understood. 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) (0).

In January 2023 sea urchin fertilisation in samples exposed to 100% TWW were significantly lower than the artificial seawater control. Fertilisation in all other dilutions were not significantly different to the control (Figure 7). In July 2022 and October 2022, sea urchin fertilisation in samples exposed to 50 and 100% TWW dilutions were significantly lower than the artificial seawater control (with all other dilutions not significantly different to the control; Figure 7). In April 2023, sea urchin fertilisation in samples exposed to 25, 50 and 100% TWW dilutions were significantly lower than the artificial seawater control (with all other dilutions not significantly different to the control; Figure 7). The NOEC was greater than 1% in TWW (i.e. ≤100-fold dilution) in all four samples (Table 8; 0), and the EQG for WET testing (Table 7) was met.

Table 7 Environmental Quality Guideline (EQG) for whole of effluent toxicity testing

EQG	The EQG will be exceeded if following the 1-hour sea urchin test: $\frac{TDA}{DRNOEC} \leq 1.0$ where TDA = Typical Dilutions Achieved (constant based on 200-fold dilution) DRNOEC = number of dilutions required to achieve the no observed effects concentration (NOEC). Breaching the above triggers investigations against the EQS, which would comprise the full suite of WET tests (minimum of five species from four trophic groups).



Notes:

1. Error bars represent ± 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 of effluent toxicity TWW dilution results to artificial seawater control

Table 8 Calculated parameters from whole of effluent toxicity tests

Indicator	July 2022	October 2022	January 2023	April 2023
NOEC	25%	25%	50%	12.5%
Dilutions required to meet the NOEC	4	4	2	8
Dilutions required/dilutions achieved	0.02	0.02	0.01	0.04
≤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 the summer non-river flow period) along a down-current gradient away from the diffuser (Table 9; Appendix E and Appendix F).

Table 9 Water quality monitoring dates near the Swanbourne ocean outlet between December 2022 and March 2023

Sample day	Date
1	09/12/2022
2	16/12/2022
3	04/01/2023
4	23/01/2023
5	07/02/2023
6	23/02/2023
7	10/03/2023
8	30/03/2023

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

Table 10 Weather and current grid during water quality monitoring near the Swanbourne ocean outlet

Date	Wind direction	Wind strength (knots)	Cloud cover (%)	Current grid
09/12/2022	SSW,S	5-12	30-90	N
16/12/2022	E,ESE	5-15	0	W
04/01/2023	E	15	0-5	NW
23/01/2023	W, SW, WSW	8-10	0	SE
07/02/2023	S	10-16	10-30	W
23/02/2023	S	16-18	50	SW
10/03/2023	SW, SSW	0-8	0	N
30/03/2023	E, ESE, ENE	8-12	80-95	NW

Notes:

1. N = north, S = south, W = west, E = east, SW = south-west, SE = south-east, NE = north-east; NW = north-west; SSE = south-south-east; ESE = east-south-east; ENE; - east-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

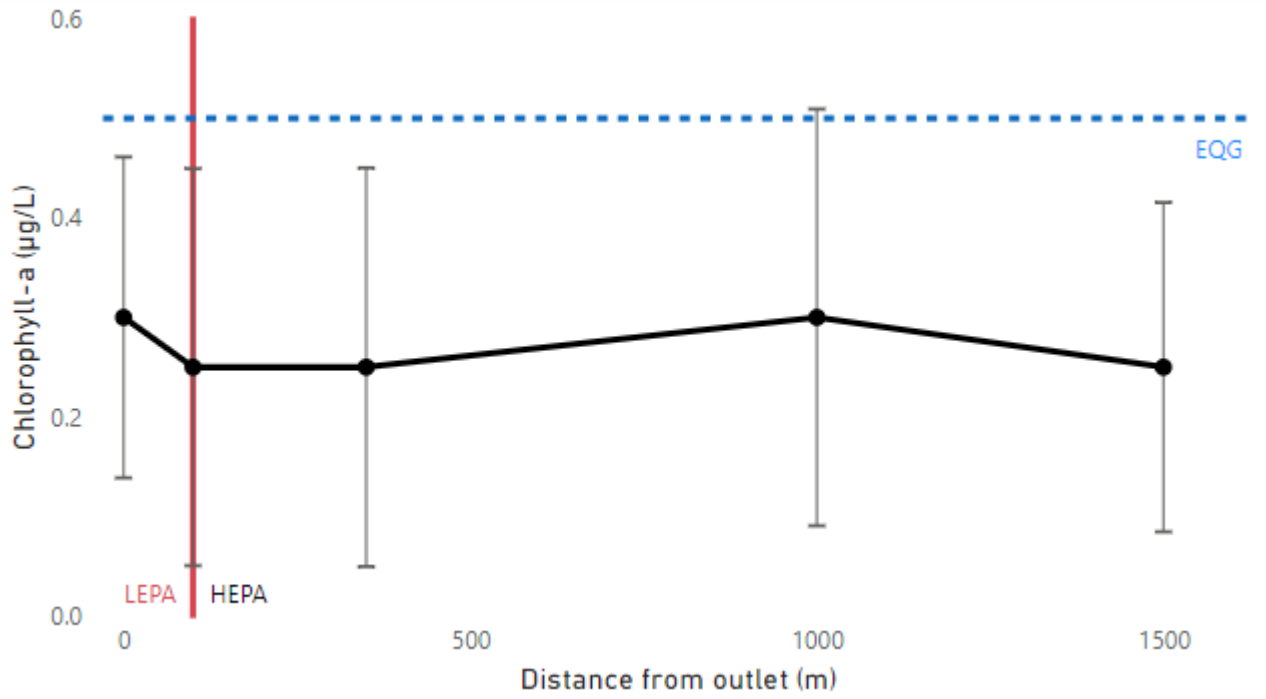
The median chlorophyll-a concentration in the Swanbourne HEPA (≥100 m) was 0.3 µg/L and below the 80th percentile of historical reference site data (0.5 µg/L; Figure 8), meeting the EQG (Table 11).

Table 11 Environmental Quality Guidelines for nutrients

EQG	The median chlorophyll-a concentration in the HEPA (100 m plus) during the non-river flow period is not to exceed the 80th 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 80th percentile of historical reference site data.

Note:

1. EQG = Environmental Quality Guideline

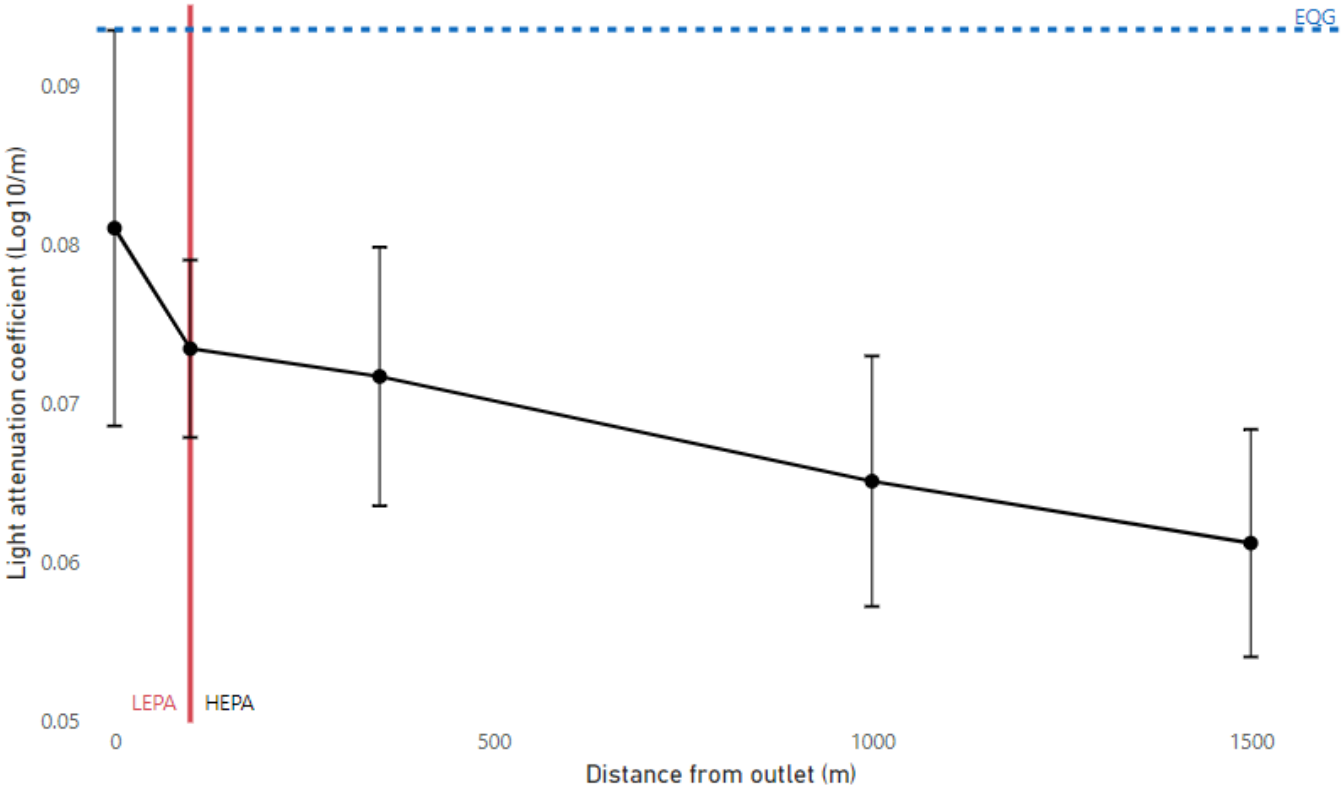


Notes:

1. Error bars represent ±95% confidence intervals.
2. Environmental Quality Guideline (EQG) is the 80th percentile of historical reference site data (0.5 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 over December 2022–March 2023; (Appendix G).

Figure 8 Median chlorophyll-a concentrations obtained at fixed monitoring sites above and down-current of the Swanbourne outlet during the summer monitoring period

The median light attenuation in the Swanbourne HEPA (100 m plus) was 0.066 Log_{10}/m and lower than the 80th percentile of historical reference site data (0.094 Log_{10}/m; Figure 9), meeting the EQG.



Notes:

1. Error bars represent ±95% confidence intervals
2. Environmental Quality Guideline (EQG) is the 80th percentile of historical reference site data (0.094 Log10/m)
3. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
4. Data for each distance were pooled across seven sampling days over December 2022–March 2023.

Figure 9 Median light attenuation coefficient obtained at fixed monitoring sites above and down-current of the Swanbourne outlet during the summer monitoring period

3.2 Phytoplankton biomass

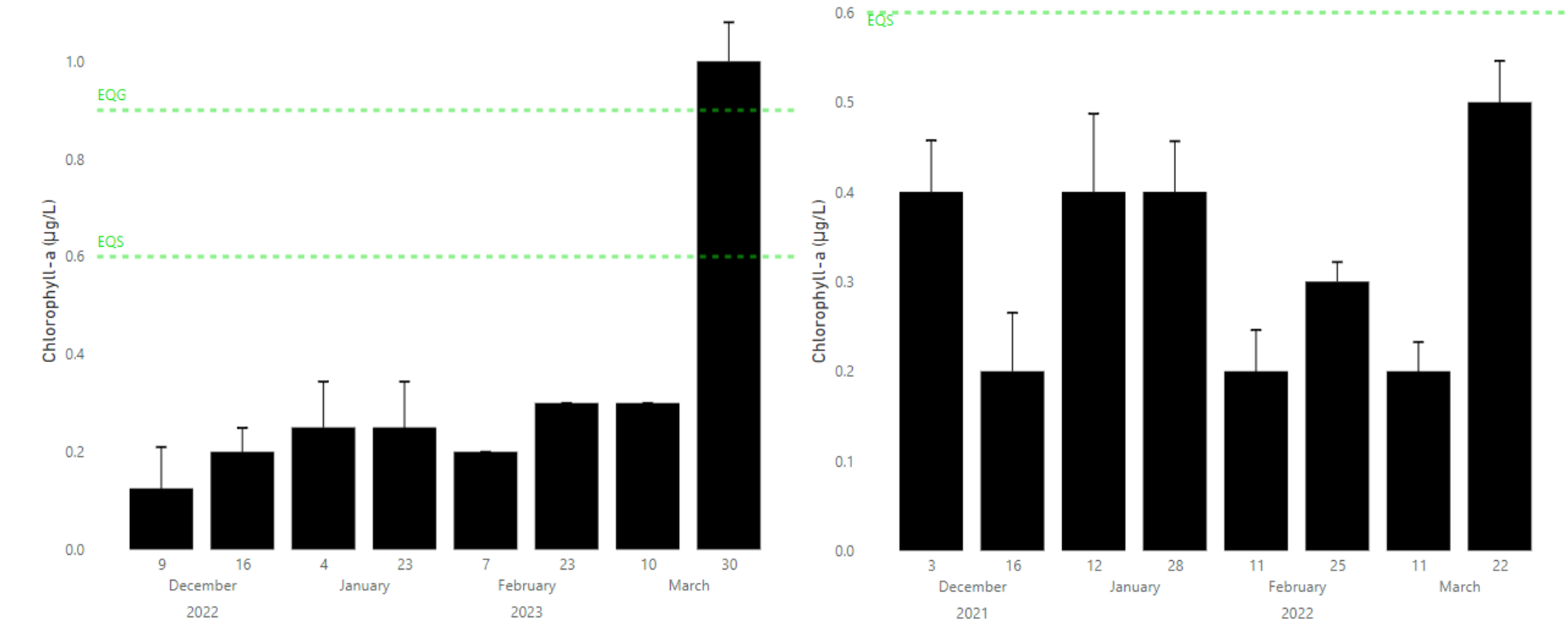
Median chlorophyll-a concentration within the HEPA exceeded three times the median of reference sites (0.9 µg/L; Figure 10) on one sampling occasion during the summer monitoring period (30/03/2023) and the EQG1 (Table 12) was not met, triggering EQS1. Phytoplankton biomass, measured as median chlorophyll-a at any site, only exceed three times the median of reference sites on one sampling occasion (12.5%) during the summer monitoring period meeting the requirements of EQG2 (<25% of occasions). Median phytoplankton biomass measured as chlorophyll-a did not exceed three times median chlorophyll-a concentration of historical reference sites, on more than one occasion in two consecutive years (no exceedances in 2021–22 and once in 2022-23) therefore meeting EQS1.

Table 12 Environmental Quality Guidelines for phytoplankton in receiving waters

EQG1	Median phytoplankton biomass, measured as chlorophyll-a is not to exceed 3 times the median chlorophyll-a concentration of reference sites, on any occasion during the non-river flow period.
EQG2	Phytoplankton biomass measured as chlorophyll-a at any site does not exceed 3 times the median chlorophyll-a concentration of reference sites, on 25% or more occasions during the non-river flow period.
EQS1	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.

Note:

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



Notes:

1. Error bars represent ±95% confidence intervals.
2. Environmental Quality Guideline (EQG) is three times the median chlorophyll-a concentration of reference site data.
3. Environmental Quality Standard (EQS) is three times the median chlorophyll-a concentration of historical reference site data.
4. 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).
5. 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 ≥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) DO saturation was >90% at all sites and times throughout the summer survey period (Figure 11) and the EQG for organic enrichment (Table 13) was met.

Table 13 Environmental Quality Guideline for dissolved oxygen

EQG	Median dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) 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.

Note:

1. EQG = Environmental Quality Guideline

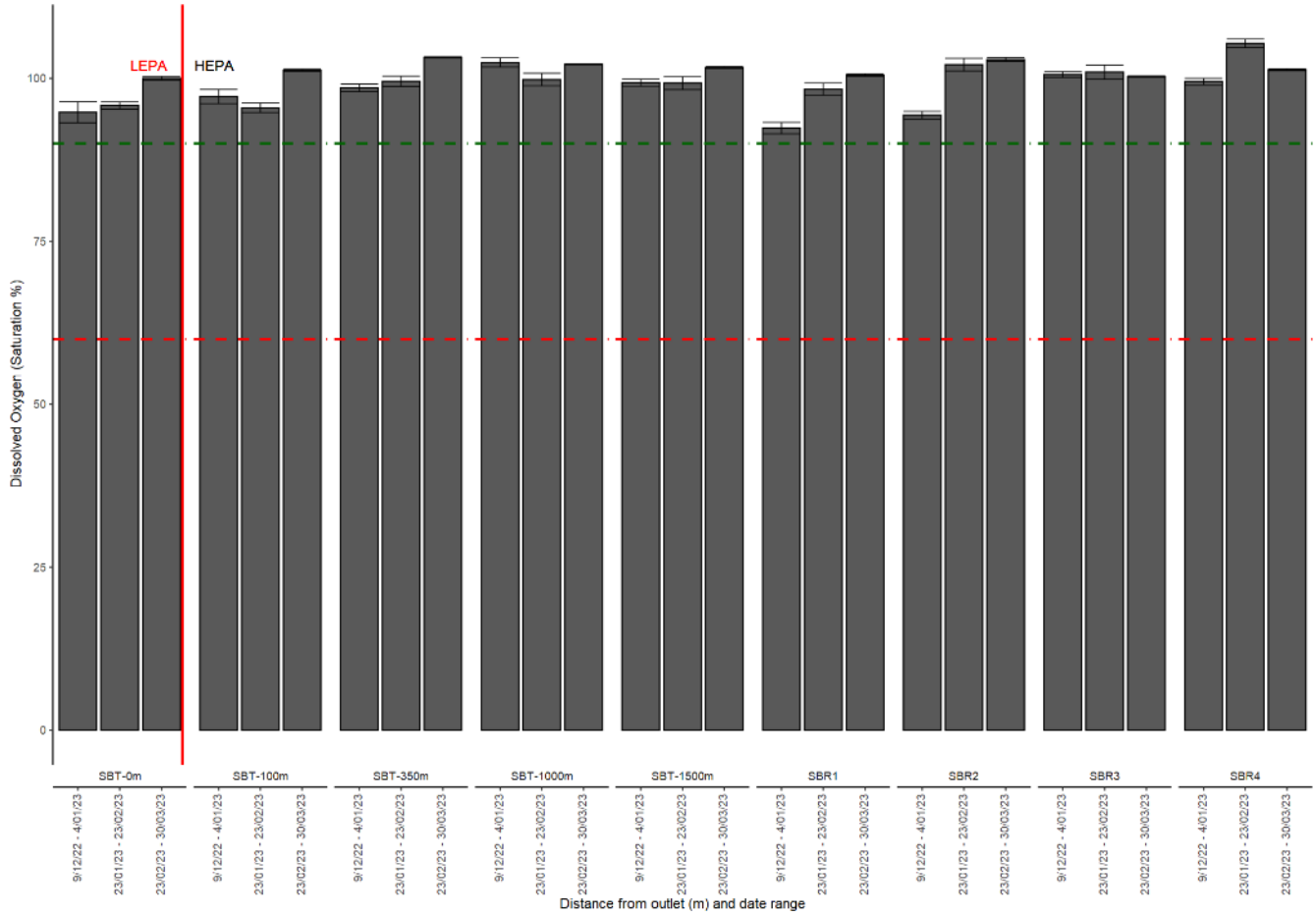


Figure 11 Median dissolved oxygen for defined period of ≤6 weeks during the summer monitoring period

3.3.2 Salinity

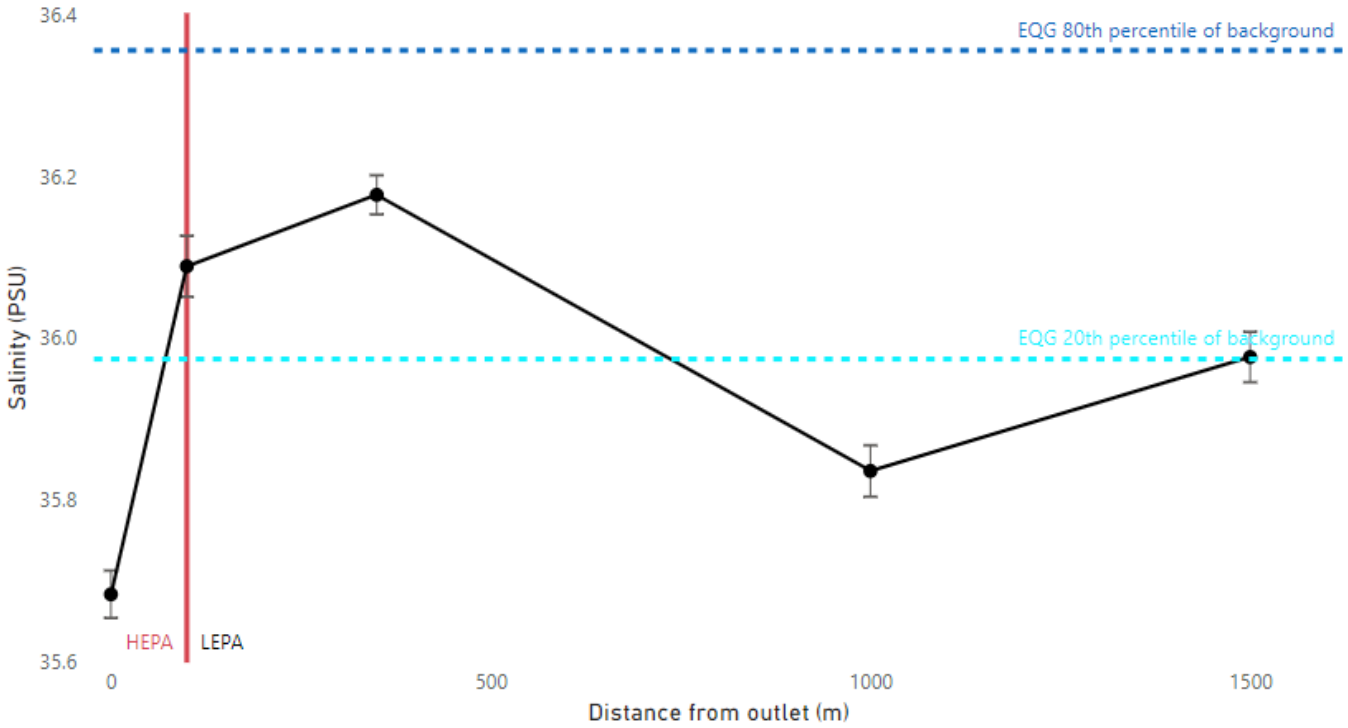
Median salinity was below the 20th percentile of the natural salinity range 1000 m, from the diffuser within the notional HEPA (Figure 12) over the summer monitoring period. The EQG was therefore not met, triggering the EQS (Table 14). There were no recorded deaths of marine organisms throughout the survey period, thus the EQS (Table 14) was met.

Table 14 Environmental Quality Criteria for salinity

EQG	Median salinity (0.5 m below the water surface) at an individual site over any period is not to deviate beyond the 20th and 80th percentile of natural salinity range over the same period.
EQS	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 ±95% confidence intervals.
2. Salinity measured 0–0.5 m below the sea surface.
3. Dark blue dashed line = 80th percentile background Environmental Quality Guideline
4. Light blue dashed line = 20th percentile background Environmental Quality Guideline
5. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
6. Data for each distance was pooled across seven sampling occasions over December 2022–March 2023.

Figure 12 Median salinity compared to the 20th and 80th 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 less than 100 samples provided local pollution conditions have not changed (NHMRC 2008). Assuming conditions have not changed, data collected over three summers (2020–2023) were pooled to yield 120 samples.

The median and 90th 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) and less than the 14 and 21 CFU/100 mL criteria, respectively, thus meeting the EQG (Table 15).

Table 15 Environmental Quality Guideline for thermotolerant coliforms

EQG	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 90th percentile of TTC concentrations must not exceed 21 CFU/100 mL

Notes:

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

Table 16 Median and 90th percentile thermotolerant coliform concentrations at the fixed monitoring sites for the Swanbourne ocean outlet for 2019–2022 and comparison to the EQC

Sampling period	Median	90th Percentile	Compliance
Dec 2020–Mar 2021 Dec 2021–Mar 2022 Dec 2022–Mar 2023	<10 CFU/100 mL	<10 CFU/100 mL	■

Notes:

1. Green symbol (■) indicate the Environmental Quality Criteria (EQC) was met
2. Thermotolerant coliform results below the analytical detection limit (<10 CFU/100 mL) were halved (=5 CFU/100 mL) to calculate the median and 90th percentile (0).
3. 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[1] trigger concentrations for any of the following: • *Alexandrium*[2] spp. (200 cells/L) • *Dinophysis* spp. (1,000 cells/L) • *Gymnodinium catenatum* (1,000[3] cells/L) • *Karenia brevis* (1,000 cells/L) • *Karenia/Karlodinium/Gymnodinium* group[4] (250,000 cells/L) • *Prorocentrum lima* (500 cells/L) • ***Pseudo-nitzchia* group[5] (500,000 cells/L)**

Note:

1. Marine Biotoxin Monitoring and Management Plan 2016: Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH, DPIRD and Industry, 2020).
2. *Alexandrium* species may be difficult to identify when numbers are low, and they are being treated as potentially toxic.
3. Trigger management action for mussels (other shellfish is 2,000 cells/L).
4. The *Karenia/Karlodinium/Gymnodium* group includes *Karenia bidigitata*, *Karenia brevisulcata, Karenia mikimotoi, Karenia papilionacea, Karenia selliformis, Karlodinium micrum* and *Gymnodinium impudicum*.
5. Species within the *Pseudo-nitzschia* groups are difficult to identify, and they are being treated as potentially toxic.
6. OZI = Observed Zone of Influence, refers to the Seafood Management Zone.
7. 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[1]	Species	Estimated density (cells/L)	WASQAP Guideline[2]	Compliance
09/12/2022	SBR3	GK Complex (*Gymnodinium-Karenia* Complex)	160	250,000	
		Karlodinium armiger	80	250,000	
		Karlodinium veneficum	80	250,000	
	SB7	*Karlodinium armiger*	108	250,000	
	SB22	GK Complex (*Gymnodinium-Karenia* Complex)	432	250,000	
16/12/2022	SBR2	*Gymnodinium* spp	480	1,000	
		Karenia spp.	160	250,000	
	SB10	*Gymnodinium* spp.	400	250,000	
		Karlodinium armiger	80	250,000	
		Karlodinium veneficum	160	250,000	
	SB30	*Gymnodinium* spp.	560	250,000	
04/01/2023	SBR3	*Gymnodinium* spp.	560	250,000	
		Karenia papilionaceae	80	250,000	
		Karenia spp.	80	250,000	
		Karlodinium armiger	160	250,000	
		Karlodinium veneficum	80	250,000	
	SB10	*Pseudo-nitzschia* delicatissima group	2,320	500,000	
		Pseudo-nitzschia seriata group	80	500,000	
		Gymnodinium spp.	160	250,000	
	SB27	*Pseudo-nitzschia* delicatissima group	1,760	500,000	
		Pseudo-nitzschia seriata group	880	500,000	
23/01/2023	SBR3	*Pseduo-nitzschia* delicatissima group	800	500,000	
		Gymnodinium spp.	400	250,000	
	SB15	*Pseudo-nitzschia* delicatissima group	960	500,000	
		Pseudo-nitzschia seriata group	80	500,000	
		GK Complex (*Gymnodinium-Karenia* Complex)	8,160	250,000	

Date	Site[1]	Species	Estimated density (cells/L)	WASQAP Guideline[2]	Compliance
	SB31	*Pseudo-nitzschia* delicatissima group	1,280	500,000	
		Pseudo-nitzschia seriata group	320	500,000	
		GK Complex (*Gymnodinium-Karenia* Complex)	160	250,000	
		Gymnodinium spp.	80	250,000	
07/02/2023	SBR3	*Pseudo-nitzschia* delicatissima group	880	500,000	
		Pseudo-nitzschia seriata group	160	500,000	
		Gymnodinium spp.	240	250,000	
	SB12	*Pseudo-nitzschia* delicatissima group	80	500,000	
		Gymnodinium spp.	80	250,000	
	SB27	*Gymnodinium* spp.	480	250,000	
23/02/2023	SBR3	*Pseudo-nitzschia* delicatissima group	800	500,000	
		Gymnodinium spp.	640	250,000	
	SB14	*Pseudo-nitzschia* delicatissima group	320	500,000	
		Gymnodinium spp.	160	250,000	
	SB28	*Pseudo-nitzschia* delicatissima group	160	500,000	
		Gymnodinium spp.	480	250,000	
10/03/2023	SBR3	*Pseudo-nitzschia* delicatissima group	80	500,000	
		GK Complex (*Gymnodinium-Karenia* Group)	80	250,000	
		Gymnodinium spp.	160	250,000	
	SB9	*Pseudo-nitzschia* delicatissima group	160	500,000	
		GK Complex (*Gymnodinium-Karenia* Group)	80	250,000	
	SB25	*Gymnodinium* spp.	160	250,000	
		Karlodinium spp.	80	250,000	
30/03/2023	SBR4	*Pseudo-nitzschia* delicatissima group	320	500,000	
		Pseudo-nitzschia seriata group	160	500,000	
	SB10	*Pseudo-nitzschia* delicatissima group	640	500,000	

Date	Site[1]	Species	Estimated density (cells/L)	WASQAP Guideline[2]	Compliance
	SB28	*Pseudo-nitzschia* seriata group	320	500,000	
		Pseudo-nitzschia delicatissima group	960	500,000	
		Gymnodinium spp.	640	250,000	

Notes:

1. Samples were analysed for one monitoring site and one reference site per sampling occasion.
2. Marine Biotoxin Monitoring and Management Plan 2020: Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH, DPIRD and Industries 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. NHMRC (2008) guidelines 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.

Table 19 Environmental Quality Guidelines for contact recreation

Primary[1]	**EQG**	The 95th percentile bacterial content of marine waters should not exceed 200 *Enterococci* MPN/100 mL
Secondary[2]	**EQG**	The 95th percentile bacterial content of marine waters should not exceed 2000 *Enterococci* MPN/100 mL

Notes:

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

Over the past three summers, the 95th percentile of *Enterococci* spp. concentrations at the boundary of the observed zone of influence for the Swanbourne ocean outlet was 5.25 MPN/100 mL and both the primary (<200 MPN/100 mL) and secondary (<2000 MPN/100 mL) contact recreation EQG for faecal pathogens in water were met (Table 20).

Table 20 The 95th percentile of *Enterococci* spp. concentrations at the boundary of the observed zone of influence for the Swanbourne ocean outlet

Sampling period	95th percentile	Compliance	
		Primary contact	Secondary contact
Dec 2020–Mar 2021 Dec 2021–Mar 2022 Dec 2022–Mar 2023	10 MPN/100 mL	■	■

Notes:

4. Green symbols (■) indicate the Environmental Quality Guideline (EQG) and Environmental Quality Criteria (EQC) were met

4.4 Phytoplankton cell concentrations

The concentrations of phytoplankton cells are compared to 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

EQG	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 (0).
EQS	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 (0).

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

Table 22 Estimated phytoplankton total cell densities collected at one of the fixed monitoring sites for contact recreation down-current of the Swanbourne outlet

Date	Site	Total density (cells/mL)	Compliance
09/12/2022	SB7	117	
16/12/2022	SB10	402	
04/01/2023	SB10	344	
23/01/2023	SB15	41	■
07/02/2023	SB12	4	
23/02/2023	SB14	8	
10/03/2023	SB9	3	
30/03/2023	SB10	29	

Note:

1. Green symbols (■) indicate the Environmental Quality Guideline (EQG) were met

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.

The field surveys found algae/plant material visible on the surface on 37.5% 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 floating debris visible on the surface on 12.5% of sampling occasions (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 (0.072 Log_{10}/m) was slightly higher than at 1500 m distance from the outlet (0.061 Log_{10}/m) suggesting that light was more quickly attenuated at 350 m than 1500 m (Table 25). Overall water clarity was decreased by ~15% 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 Sepia Depression 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	SB6	No	No	6.5	Yes, green	No	No	No
16/12/2022	SB9	No	No	9	No	No	Yes, seagrass flower	No
4/01/2023	SB7	No	No	7.8	Yes, greenish tinge	No	No	No
23/01/2023	SB16	Yes, seagrass wrack	No	8.5	No	No	No	No
7/02/2023	SB12	Yes, seagrass wrack	No	10.5	No	No	No	No
23/02/2023	SB13	No	No	11	No	No	No	No
10/03/2023	SB5	Yes, seagrass	No	8.8	No	No	No	No
30/03/2023	SB11	No	No	10	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 SBT-350 m)	1500 m (site SBT – 1500 m)
9/12/2022	0.085	0.083
16/12/2022	0.074	0.064
4/01/2023	0.079	0.063
23/01/2023	0.050	0.056
7/02/2023	0.058	0.056
23/02/2023	0.070	0.059
10/03/2023	0.065	0.060
30/03/2023	0.080	0.079
Mean	**0.072**	**0.061**

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 (NHRMC 2008). Assuming conditions have not changed, data collected over two summers (summer 2021–22 and 2022–2023) were pooled to yield 128 samples.

The shoreline sites are not formally assessed against the EQC but the median and 90th percentile TTC concentrations derived from the 128 samples were at the LoR (Table 26) (<10 CFU/100 mL; Table 15, 0) and less than the 14 and 21 CFU/100 mL criteria, respectively meeting the EQG (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 90th percentile of thermotolerant coliform concentrations at the shoreline monitoring sites for the Swanbourne outlet for 2021–2023 and comparison to the EQG

Sampling period	Median	90th percentile	Compliance (EQG)
Dec 2021–Mar 2022 Dec 2022–Mar 2023	<10 CFU/100 mL	<10 CFU/100 mL	■

Notes:

1. Green symbols (■) indicate the Environmental Quality Guideline (EQG) were met
2. Thermotolerant coliform results below the analytical detection limit (<10 CFU/100 mL) were halved (=5 CFU/100 mL) to calculate the median and 90th percentile.
3. 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) recommends that 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 <100 samples provided local pollution conditions have not changed (NHRMC 2008). Assuming conditions have not changed, data collected over two summers (summer 2021–22 and 2022–2023) were pooled to yield 128 samples.

Shoreline sites are not formally assessed against the EQC but over the 2022–2023 summer monitoring period, the 95th percentile of *Enterococci* spp. concentrations at the shoreline monitoring sites for the Swanbourne ocean outlets was <10 MPN/100 mL (Table 27), and met both the primary and secondary (<200 and <2000 MPN/100mL, respectively) contact recreation EQGs (Figure 13).

Median *Enterococci* spp. concentrations at the diffuser (0 m) and 100 m down current of the diffuser were 20 MPN/100 mL. All other sites down current of the diffuser had median concentrations of 5 MPN/100 mL (the proxy for concentrations below the LoR) (Figure 13). The down gradient sampling is contextual information in support of the shoreline sampling. Therefore, median concentrations were

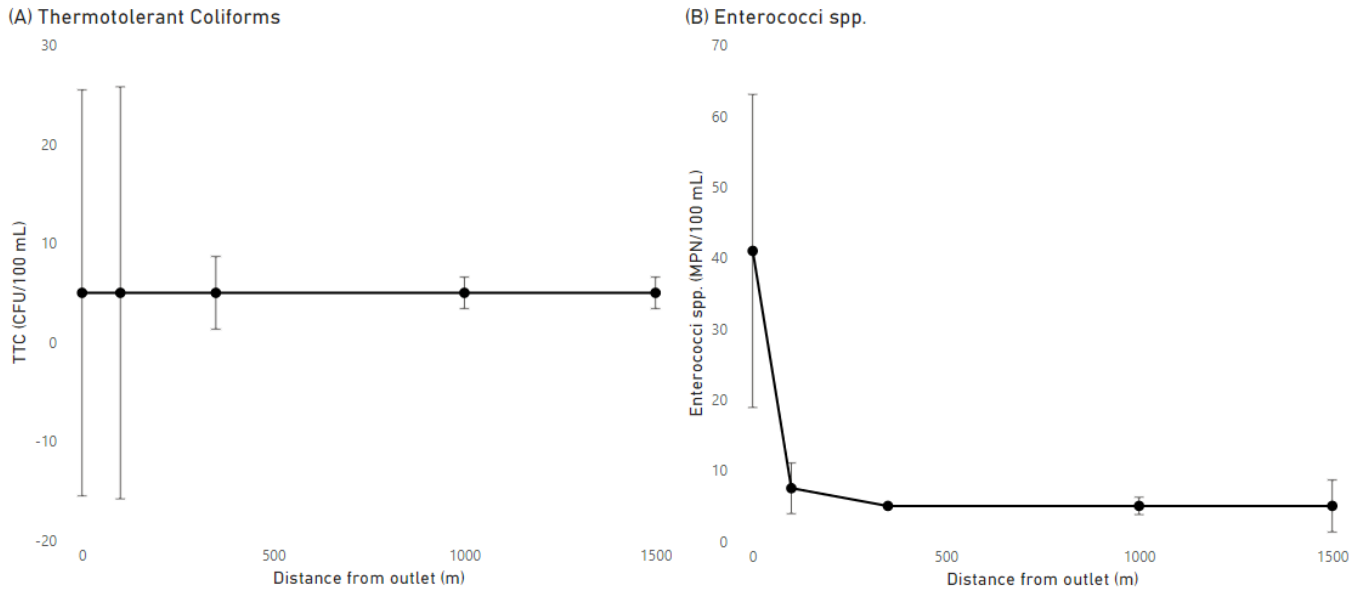
calculated to provided contextual data for an indicator of "typical" concentrations after dilution rather than the 95th percentile which is linked to compliance.

Table 27 The 95th percentile of *Enterococci* spp. concentrations at the shoreline monitoring sites for the Swanbourne ocean outlet for 2021–2023 and comparison to the EQG

Sampling period	95th percentile	Compliance	
		Primary contact	Secondary contact
Dec 2021–Mar 2022 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 95th percentile.
3. Green symbols (■) indicate the Environmental Quality Guideline (EQG) were met
4. Environmental Quality Criteria (EQC) based on EPA (2017) water quality guidelines for recreation waters.



Notes:

1. Error bars represent ±95% confidence intervals

Figure 13 Median a) thermotolerant coliform concentrations and b) *Enterococci* spp. at 0, 100, 350, 1000 and 1500 m from the Swanbourne outlet from December 2022 to March 2023

References

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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