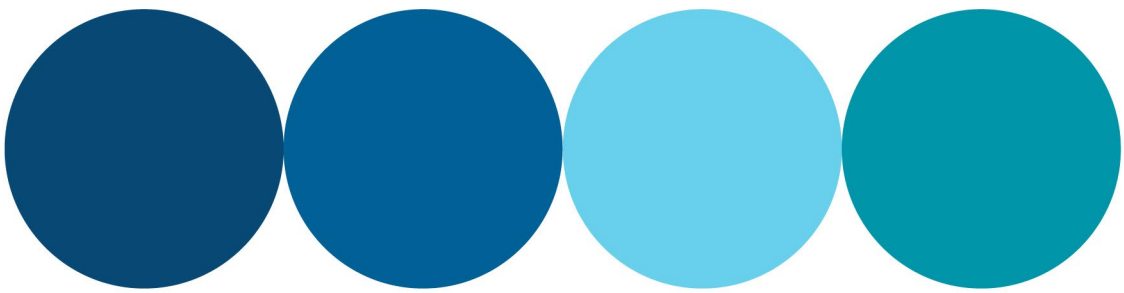
Perth Long Term Ocean Outlet Monitoring Program (PLOOM)

Subiaco Water Resource Recovery Facility

2023–2024 Annual Report



WATER CORPORATION

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

Status

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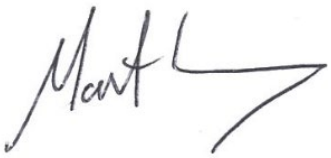


Author **Martin Lourey**
Date: **19/12/24**

Contents

Acronyms

Acronym	Extension
ANZG (2018)	Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand
CFU	Colony forming unit
CTWWC	Comprehensive Treated Wastewater Characterisation
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
EMMP	Environmental Monitoring and Management Plan
MMP	Monitoring and Management Plan
MPN	Most probable number
NATA	National Association of Testing Authorities
NOEC	No Observed Effect Concentration
OZI	Observed Zone of Influence
PLOOM	Perth Long-Term Ocean Outlet Monitoring
SHEZ	Shellfish Harvesting Exclusion Zone
TCM	Trial Compliance Monitoring
TTC	Thermotolerant coliforms
TTM	Total toxicity of the mixture
TWW	Treated wastewater
WASQAP	Western Australian Shellfish Quality Assurance Program
WET	Whole of effluent toxicity
WRRF	Water Resource Recovery Facility
WWTP	Wastewater Treatment Plant

What do the results in this report mean for our community?

Ocean discharge is practiced worldwide and is a safe, sustainable and cost effective way to dispose of wastewater. Treated wastewater from Perth's Water Resource Recovery Facilities (WRRF's) are discharged to the ocean via ocean outlets, and is diluted through a number of physical and chemical processes. It is lighter and lower in density, so it rises and mixes with seawater, diluting the wastewater. Ocean outlet activities are regulated by the Department of Water and Environmental Regulation. The purpose of this summary is to highlight the key results from the PLOOM reports for each of Perth's ocean outlets that are completed to meet the department's requirements.

Water Corporation discharges treated wastewater from the Subiaco WRRF to the ocean via the Swanbourne outlet pipelines. A small area around the outlet, measuring 100 metres in radius, is designated as a Low Ecological Protection Area (or LEPA). Within this area, the EPA allows for changes to marine water quality. Outside the LEPA, the EPA has designated the surrounding ocean to be a High Ecological Protection Area (HEPA) and expects there to be no detectable change in marine water quality.

Water Corporation undertakes investigations to test that water quality has returned to within the natural range expected in the HEPA and protect the environment and recreational users (swimmers, boaters and fishers). Water samples are collected within the LEPA, at the boundary of the LEPA and the HEPA, and at reference sites selected to be as similar as possible to the waters around the outlets. The Perth Long-term Ocean Outlet Monitoring (PLOOM) program comprises of these investigations, results from the monitoring are compared against nationally agreed criteria. There are two levels of criteria - a simple, conservative early warning trigger (Environmental Quality Guideline or EQG) and a more detailed, complicated assessment of potential impacts (Environmental Quality Standard or EQS).

This annual report documents the findings of the 2023-2024 Swanbourne ocean monitoring as part of the PLOOM program. The compliance results for 2023-2024 and for the previous five years (2018-2019, 2019-2020, 2020-2021, 2021-2022 and 2022-2023) are summarised in Report Card format are summarised in report card format. The report card contains colour-coded results with the individual colours representing the extent to which the Environmental Quality Criteria (EQC) were met.

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.

Summary of key indicators

Ecosystem integrity

Ecosystem Integrity aims to protect the ecosystem from potential impacts from the discharge and maintain the variety and quantity of marine life at a high level. The top indicators we look at that give us an understanding of this are as follows:

Indicator	Indicator purpose	Result	Commentary
Toxicants in treated wastewater (TWW)			
Bioaccumulating toxicants	Cadmium and mercury are toxicants that can build up in the tissues of marine organisms and contaminate seafood. The concentration of these toxicants are measured in undiluted TWW against national guidelines that are designed to protect marine life.		Concentrations of cadmium and mercury were below the national guideline values.
Non-bioaccumulating toxicants	Some contaminants commonly discharged with domestic wastewater (e.g. detergents, metals and oils) may find their way into treated wastewater and monitoring ensures they are not directly toxic or likely to accumulate in marine life. Wastewater was screened for toxic substances and the concentrations were below the early warning EQG.		Concentrations of toxicants were below the national guideline values.
Total toxicity of the mixture (TTM)	TTM measures the potential for a combined, or cumulative, effect of ammonia, copper, and zinc in the TWW after it has been diluted into the ocean. It is used as an additional interpretative tool for estimating the potential toxicity of TWW.		The total toxicity of the mixture was below the national guideline value.
Whole of effluent toxicity (WET) testing	WET testing is another tool to test the potential toxicity of the TWW to marine life. WET testing is particularly useful for toxicants that occur in very low concentrations, or for which there are no national guidelines on safe levels. Direct tests on organisms determine the actual toxicity of the wastewater demonstrate that the discharge is not harmful to the ocean environment.		The TWW plume is sufficiently diluted to achieve the No Ecological Effects Concentration at the management boundary.
Nutrient enrichment and phytoplankton blooms			
Chlorophyll-*a*	Phytoplankton are a naturally occurring part of the marine environment, but treated wastewater contains nutrients (ammonia, nitrite, nitrate and orthophosphate) that can stimulate phytoplankton growth. Chlorophyll-*a* (the		Chlorophyll-*a* concentration outside the direct vicinity of the Ocean Reef outlet exceeded the two of the three relevant early warning EQGs but met the EQSs. This is due to naturally

Indicator	Indicator purpose	Result	Commentary
	active constituent in phytoplankton) concentration is used as an indicator for phytoplankton abundance.		occurring increases over time. See below
Light attenuation coefficient	Increased phytoplankton can also block (attenuate) light from reaching the bottom (impacting seagrass and macroalgae).		Light attenuation outside the direct vicinity of the Ocean Reef outlet met the early warning EQG. Light transmission to the sea floor was not reduced.
Chlorophyll-*a*			
The higher-than-normal chlorophyll-*a* were due to naturally occurring increases over time. Concentrations around the outlet were similar to the reference sites indicating that the gradual increase over time is regional and not a result of the ocean discharge. This increase in the baseline has caused chlorophyll-*a* concentrations to exceed the EQGs. The EQGs should be updated to account for the high background to prevent confusion and focus on identifying actual impacts in the future. Water Corporation is in the process of investigating the apparent EQC exceedances with the aim of formulating and if necessary, implementing a formal response.			
Physical & chemical stressors			
Organic enrichment	Organic matter in treated wastewater is naturally decomposed by bacteria. Oxygen dissolved in water is used by the bacteria during the decomposition process. If the bacteria use more dissolved oxygen (DO) than they produce, the DO levels fall. Low DO levels can be harmful to marine life. We measure the dissolved oxygen concentration against the Environmental Protection Authority (EPA) guidelines		The amount of DO was high at all times and at all locations near the outlet. DO levels near the outlet were similar to those at the reference sites. There was a very low risk of DO levels falling below critical levels.
Salinity	Salinity refers to the 'saltiness' of water. Treated wastewater is fresh whereas the ocean is saline. When treated wastewater is discharged to the ocean, salinity will be reduced in an area around the outlet until the fresher water is fully mixed with the saline seawater. Low salinity water may cause stress to marine life.		Measurements of salinity near the outlet were similar to the salinity at appropriate reference sites. Stress to marine life from low salinity is unlikely.

Seafood safe for human consumption

Seafood safe for human consumption aims to ensure that caught or grown seafood remains safe for eating. The top indicators we look at that give us an understanding of this are as follows:

Indicator	Indicator purpose	Result	Commentary
Microbial contaminants			
Thermotolerant coliforms (TTC) near the outlets	The risk from bacteria to seafood safety is assessed using the indicator organism thermotolerant coliforms.		The relevant concentrations of thermotolerant coliforms near the outlet and adjacent the beaches were below the level where they can be detected by the laboratory. The risk to public health from bacteria via seafood in the vicinity of the outfalls was very low.
Shoreline TTC			
Algal biotoxins			
Toxic phytoplankton species	In some cases, phytoplankton can contain species than can taint seafood.		Densities of potentially toxic phytoplankton species were below levels that would pose a risk to seafood.

Primary and secondary contact recreation

Primary and secondary contact recreation aims aims to ensure that water quality is suitable for primary (e.g. swimming and diving) and secondary (e.g. fishing and boating) recreation contact activities. The top indicators we look at that give us an understanding of this are as follows:

Indicator	Indicator purpose	Result	Commentary
Faecal pathogens			
Enterococci spp. at the outlets	The risk from bacteria to recreation contact (swimming and boating) is assessed using the indicator organism *Enterococci* spp.		The relevant concentrations of *Enterococci* spp. near the outlets and adjacent beaches were below the level where they can be detected by the laboratory. The risk to public health from bacteria via recreation in the vicinity of the outfalls was very low.
Shoreline *Enterococci* spp.			
Algal biotoxins			
Phytoplankton cell concentration	In some cases, phytoplankton can reach concentrations that may harm swimmers (called blooms). The level that defines an algal bloom for recreational purposes is a phytoplankton cell count exceeding 10,000 cells/mL.		The chlorophyll-*a* based guidelines for phytoplankton are well below a level that would be visible as an algal bloom. The highest total phytoplankton cell concentration in the HEPA was 1,727 cells/mL. There were no

			phytoplankton blooms during the monitoring period

Aesthetics

Aesthetics aims to ensure that aesthetic values of the marine environment are protected. The top indicators we look at that give us an understanding of this are as follows:

Indicators	Indicator purpose	Result	Commentary
Aesthetic factors	Perth's coastal waters are aesthetically pleasing, and that aesthetic value needs to be protected. Nuisance organisms (macrophytes, scums, algal mats, blue-green algae and fungus), dead organisms, dirty water, oily films, debris, or objectionable odours have the potential to reduce the aesthetic appeal.		Aesthetic values of Perth coastal waters were maintained and protected.

For further results please refer to the full report below.

Executive Summary

This report documents the findings of the 2023–2024 Swanbourne marine water quality monitoring program, completed as part of the Perth Long Term Ocean Outlet Monitoring Program (PLOOM). The report outlines the findings of three environmental monitoring programs:

- Compliance Monitoring
- Whole of Effluent Toxicity testing
- Comprehensive Treated Wastewater Characterisation.

Results are reported in the context of the Environmental Quality Management Framework (EQMF) described in EPA (2017). Under the EQMF, Water Corporation annually demonstrates achievement against Environmental Quality Objectives (EQOs):

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

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 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:

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

Environmental Quality Objective '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 treated wastewater (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 Environmental Quality Guidelines (EQGs) for TWW toxicants:

- Concentrations of bioaccumulating toxicants (specifically, cadmium and mercury) must be below their respective ANZG (2018) 80% species protection guidelines prior to discharge and dilution with seawater. Concentrations of bioaccumulating toxicants were below their laboratory limits of reporting and the 80% species protection guidelines in all cases, thus meeting EQG1.
- Concentrations of non-bioaccumulating contaminants must not exceed their ANZG (2018) 99% species protection guideline at the Low Ecological Protection Area (hereafter LEPA) boundary, 100 m radius from the

diffuser. Concentrations of non-bioaccumulating toxicants were below their ANZG (2018) criteria scaled for initial dilution (1:140), a conservative indicator for dilution at the LEPA boundary, thus meeting EQG2.

- The total toxicity of the mixture (TTM) for the additive effect of ammonia, copper, and zinc in the diluted TWW plume must be less than the guideline of 1.0 (ANZG 2018). The TTM following initial dilution was 0.49, which is lower than the guideline and the EQG3 was met.
- The highest concentration of TWW at which there is no statistically significant observed effect on fertilisation of sea urchin gametes exposed to different concentrations of TWW (No Observed Effect Concentration [NOEC]) must be greater than 1.0% TWW concentration. The lowest NOEC from tests undertaken in October 2023, January 2024 and April 2024 was 25% and the EQG4 was met (Table ES 2).

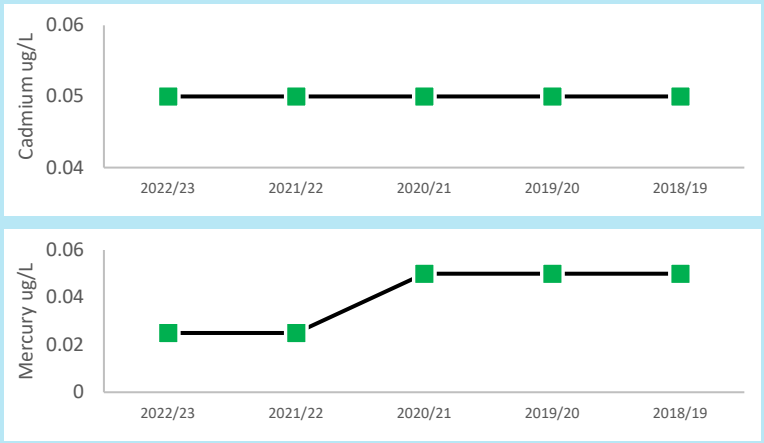
Water quality monitoring – receiving environment

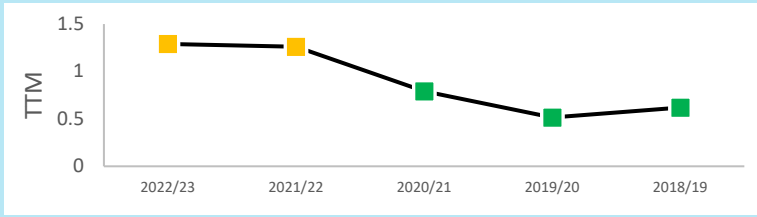
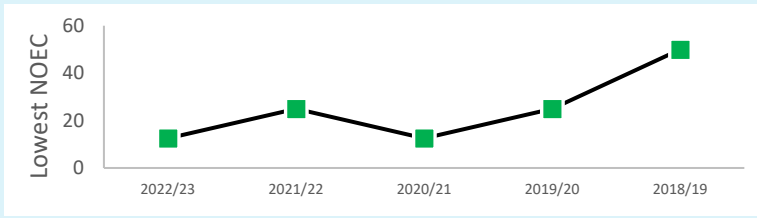
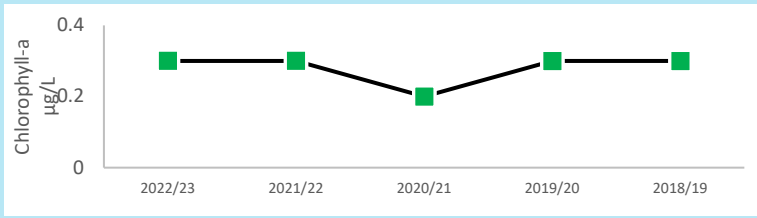
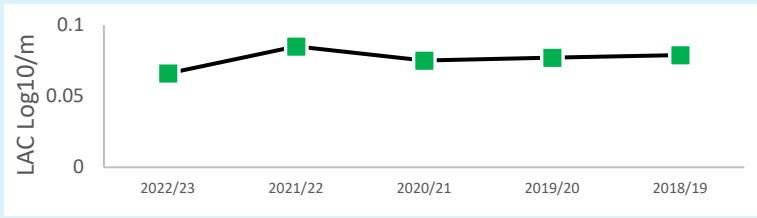
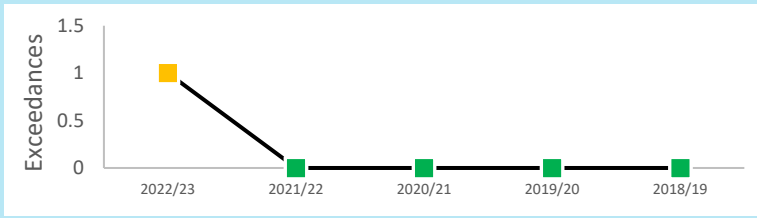
Ocean sampling was conducted fortnightly between December 2023 and March 2024 at fixed distance intervals down-current (determined using a drogue) of the TWW ocean outlet. There are six EQGs based on chlorophyll–a concentration (a measure of phytoplankton biomass), water temperature, salinity, dissolved oxygen and light attenuation coefficient:

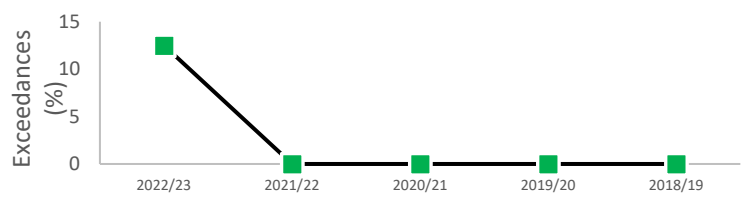
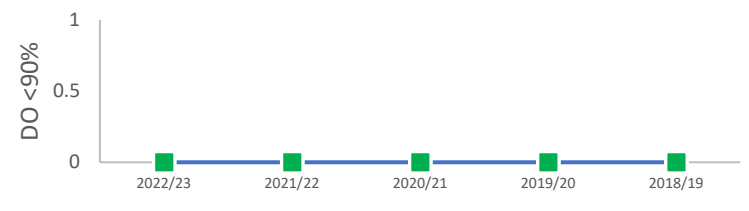
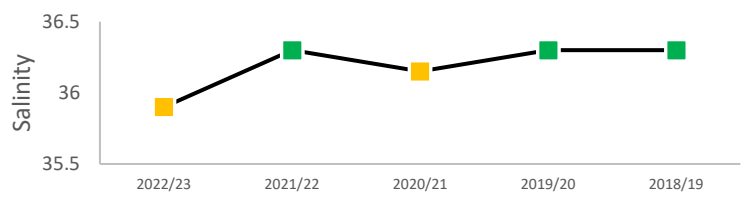
- The median chlorophyll–a concentration in the High Ecological Protection Area (HEPA; 100 m and greater from the diffuser) during the non-river flow period must not exceed the 80th percentile of historical reference site data. Median chlorophyll–a concentration within the HEPA (0.5 µg/L) was equal to the 80th percentile of historical reference site concentrations (0.5 µg/L) and the EQG was met.
- The median light attenuation coefficient (LAC) in the HEPA must not exceed the 80th percentile of historical reference site data. Median LAC within the HEPA (0.079 Log_{10}/m) was lower than the 80th percentile of historical reference sites (0.094 Log_{10}/m) and the EQG was met.
- Median phytoplankton biomass, measured as chlorophyll–a must not exceed three times the chlorophyll–a concentration of historical reference sites, on any occasion. Median chlorophyll–a concentrations exceeded three times the median of reference sites on one occasion during the summer monitoring period and the EQG was not met.
  - Median chlorophyll–a concentrations in the HEPA did not exceed 3-times the median of reference sites on more than one occasion in the 2023-2024 sampling season and EQS1 was met.
- Phytoplankton biomass measured as chlorophyll–a at any site must not exceed three times the median chlorophyll–a concentration of historical reference sites, on 25% or more occasions. Phytoplankton biomass measured as chlorophyll–a exceeded three times the median of reference sites at two sites on one sampling occasion (25%) during the summer monitoring period and the EQG was not met.
  - Phytoplankton biomass at any site did not exceed three times the median chlorophyll–a concentration of historical reference sites on 25% or more occasions in two consecutive years and the EQS was met
- Median dissolved oxygen in bottom waters (0–0.5 m above the seabed) in the HEPA must be greater than 90% saturation at any site for a defined period of not more than 6 weeks. Dissolved oxygen saturation within the HEPA was above 90% saturation at all times and the EQG was met.
- 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. Median salinity was between the 20th and 80th percentile of the natural salinity range at all sites within the HEPA and the EQG was met

The exceedances of the EQGs described above were due to a gradual increase in the background chlorophyll–a concentration (and associated increase in light attenuation). The EQGs were met if assessed against the criteria based on the corresponding sampling period – that is, the water quality at the LEPA boundary was within the range measured at the reference sites during the same sampling event. The current approach to assessing compliance with the EQC is to compare against historical data collection over 16 years.

Table ES 2 Summary report card for the Environmental Quality Objective 'Maintenanc… system Integrity'

Environmental quality indicator		EQC	Comments	Compliance	Previous 5 years (2018-2019 – 2022 – 2023)
Toxicants in treated wastewater (TWW)	Bioaccumulating toxicants	EQG1	Concentrations of cadmium and mercury in the undiluted TWW sample were below the ANZG (2018) 80% species protection guideline.		
	Non-bioaccumulating toxicants and initial dilution	EQG2	Contaminant concentrations were lower than the ANZG (2018) 99% species protection guidelines after initial dilution (a conservative indicator for dilution expected at the Low Ecological Protection Area boundary).		

Environmental quality indicator		EQC	Comments	Compliance	Previous 5 years (2018-2019 – 2022 – 2023)
	Total toxicity of the mixture (TTM)	EQG3	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	EQG4	The lowest No Observed Effect Concentration from tests undertaken in October 2023, January 2024 and April 2024 (25%) was >1%.		
Nutrient enrichment	Chlorophyll–a	EQG1	The median chlorophyll–a concentration in the High Ecological Protection Area (HEPA; ≥100 m) was 0.5 µg/L and below the 80th percentile of historical reference site data (0.5 µg/L).		
	Light attenuation coefficient (LAC)	EQG2	The median LAC in the HEPA (≥100 m) was 0.079 Log_{10}/m and was lower than the 80th percentile of historical reference site data (0.094 Log_{10}/m).		
Phytoplankton blooms	Phytoplankton biomass (measured as chlorophyll–a)	EQG1	Median chlorophyll–a concentration within the HEPA exceed three times the median of historical reference sites on one sampling occasion during the summer monitoring period.		

Environmental quality indicator		EQC	Comments	Compliance	Previous 5 years (2018-2019 – 2022 – 2023)
		EQS1	Median chlorophyll–a concentrations in the HEPA exceeded 3-times the median of reference sites on at least 1 occasion in two consecutive years.		
		EQG2	Phytoplankton biomass measured as chlorophyll–a exceeded three times the median of reference sites at two sites (100 m and 350 m) on two sampling occasions (25%).		
		EQS2	Phytoplankton biomass at any site did not exceed three times the median chlorophyll–a concentration of historical reference sites on 25% or more occasions in two consecutive years.		Not assessed
Physical chemical stressors	Organic enrichment	EQG1	Dissolved oxygen saturation within the HEPA was above 90% saturation at all times.		
	Salinity	EQG2	Median salinity was between the 20th and 80th percentile of the natural salinity range at all sites within the HEPA.		

Notes:

1. Environmental Quality Criteria (EQC): Green (■) symbols indicate the Environmental Quality Guideline (EQG) was met, amber (■) and red (■) symbols represent an exceedance of the EQG or Environmental Quality Standard (EQS), respectively.
2. LEPA = low ecological protection area.
3. HEPA = high ecological protection area.
4. LAC = light attenuation coefficient.
5. NOEC = no observed effect concentration; the highest concentration of TWW at which there is no statistically significant observed effect on gamete fertilisation.

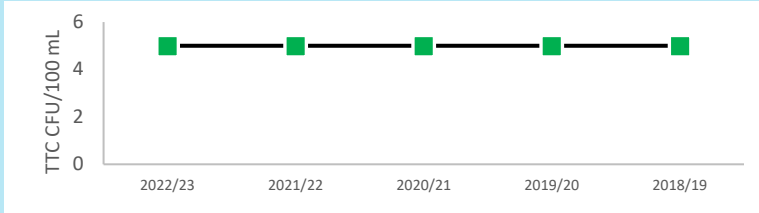
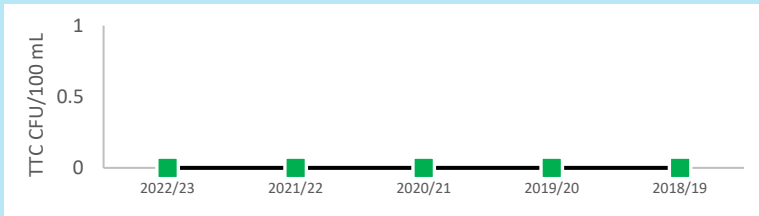
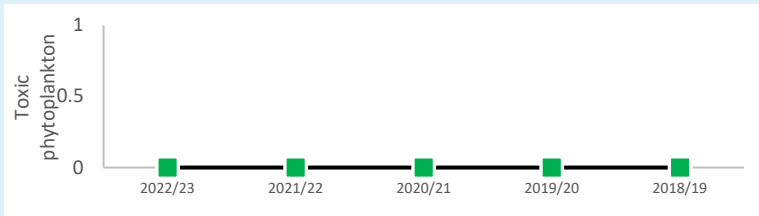
Environmental Quality Objective 'Maintenance of Seafood Safe for Human Consumption'

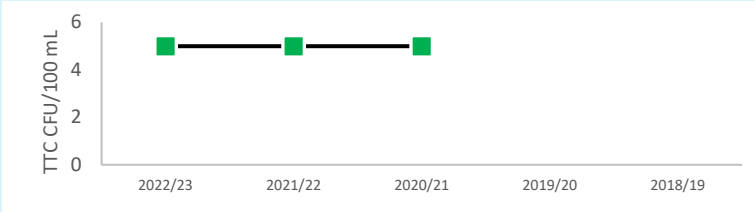
There are two EQC for the EQO 'Maintenance of the Seafood for Human Consumption': the first is based on in-water concentrations of thermotolerant coliforms (TTC), and the second is based on in-water concentrations of toxic phytoplankton species (to monitor for algal biotoxins):

- To meet the first EQG, median TTC concentrations at sites at the boundary of the Shellfish Observed Zone of Influence (OZI) are not to exceed 14 CFU/100 mL with no more than 10% of the samples exceeding 21 CFU/100 mL. The median TTC concentration pooled from three sampling seasons (2021–22, 2022–23 and 2023–24) required to achieve a suitable sample size (EPA 2005)[1] was at the limit of detection (<10 CFU/100 mL) and below 14 CFU/100 mL. There were 4 instances where TTC exceeded 21 CFU/100 mL, representing 3.3% of samples. The EQG for TTC was met (Table ES 3).
- To meet the second EQG, 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).

[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.*

Table ES 3 Summary report card for the Environmental Quality Objective 'Maintenanc… ood for Human Consumption

Environmental quality indicator		EQC	Comments	Compliance	
Microbial contaminants	Thermotolerant coliforms (TTC)	EQG: Median TCC concentrations at sites at the boundary of the OZI are not to exceed 14 CFU/100 mL.	Median TTC concentrations derived from120 samples collected over the 2021–2022, 2022–2023 and 2023–2024 sampling seasons was at the limit of reporting (<10 CFU/100 mL) and below the 14 CFU/100 mL criteria.		
		EQG2: >10% of TCC concentrations must not exceed 21 CFU/100 mL.	Only 4 samples (3.3%) exceeded the 21 CFU/100 mL criteria, which was below the trigger of 10%.		
Algal biotoxins	Toxic phytoplankton species	EQG: Cell counts of potentially toxic algae species at sites at the boundary of the OZI are not to exceed the WASQP guideline concentrations.	There were no recorded instances of toxic phytoplankton species exceeding the Western Australian Shellfish Quality Guidelines during the 2023–2024 monitoring period.		

Microbiological contaminants at the shoreline sites[6]	Thermotolerant coliforms (TTC)	EQG: Median TTC concentrations at sites along the shoreline are not to exceed 14 CFU/100 mL and the 90th percentile of TCC concentrations must not exceed 21 CFU/100 mL.	Median TTC concentrations derived from128 samples collected over the 2022-2023 and 2023-2024 sampling seasons was at the limit of reporting (<10 CFU/100 mL) and below the 14 CFU/100 mL criteria. The 90th percentile was equal to the limit of reporting (<10 CFU/100 mL), and less than the 21 CFU/100 mL criteria.	■	

Notes:

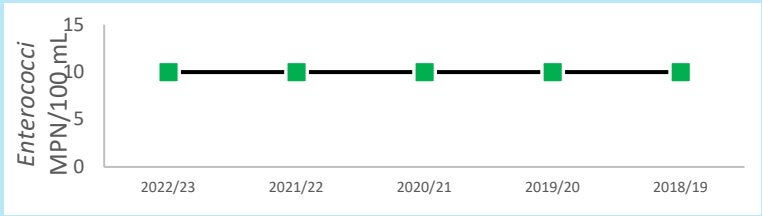
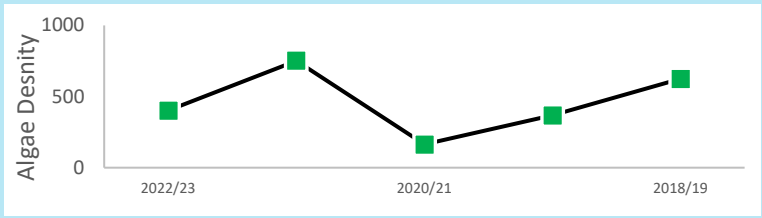
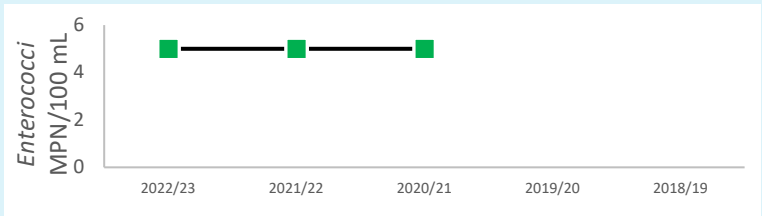
1. Environmental Quality Criteria (EQC): Green (■) symbols indicate the Environmental Quality Guideline (EQG) was met; amber (■) and red (■) symbols represent an EQG or Environmental Quality Standard (EQS), respectively.
2. TTC results below the limit of reporting (<10 CFU/mL) were halved (=5 CFU/mL) to calculate median value (ANZG 2018).
3. TTC = Thermotolerant coliforms, CFU = colony forming units.

Environmental Quality Objective '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 meet the first EQG, the 95th percentile of faecal pathogens (*Enterococci* spp.) concentrations outside the Recreation Contact OZI must not exceed 200 MPN/100 mL and 2000 MPN/100 mL for primary and secondary contact recreation, respectively. The 95th percentile of *Enterococci* spp. concentrations based on pooled data from three sampling seasons (2021–2022, 2022–2023 and 2023–2024) was 10 MPN/100 mL and both the primary and secondary contact recreation EQGs were met.
- To meet the second EQG, the phytoplankton cell count from a single site should not exceed 10,000 cells/mL. The highest cell count at any site was 2,429 cells/mL and the EQG was met.

Table ES 4 Summary report card for the Environmental Quality Objective 'Maintenance [illegible]mary and Secondary Contact Recreation'

Environmental Quality Indicator		EQC	Comments	Compliance	
Faecal pathogens	*Enterococci* spp.	EQG1 (primary contact; 200 MPN/100 mL)	The 95th percentile of *Enterococci* spp. of marine waters was 10 MPN/100 mL not exceeding 200 *Enterococci* MPN/100 mL.	■	
		EQG2 (secondary contact; 2000 MPN/100 mL)	The 95th percentile of *Enterococci* spp. of marine waters was 10 MPN/100 mL not exceeding 2000 *Enterococci* MPN/100 mL.	■	
Algal biotoxins	Phytoplankton (cell concentration)	EQG (10 000 cells/mL)	The highest cell count at any site was 2429 cells/mL not exceeding 10,000 cells/mL.	■	
Faecal pathogens along the shoreline[2]	*Enterococci* spp.	EQG 1 (primary contact; 200 MPN/100 mL)	The 95th percentile of *Enterococci* spp. concentrations (<10 MPN/100 mL) was lower than the 200 MPN/100 mL.	■	
		EQG 2 (secondary contact; 2000 MPN/100 mL)	The 95th percentile of *Enterococci* spp. concentrations (<10 MPN/100 mL) was lower than the 2000 MPN/100 mL.	■	

Note:

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

Environmental Quality Objective 'Maintenance of Aesthetic Values'

The EQO for the Environmental Value 'Recreation and Aesthetics' is to ensure that the aesthetics of Perth's coastal waters are maintained and that the aesthetic values are protected. There are a series of EQGs that ensure this EQO is met:

- Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae and sewage fungus should not be present in excessive amounts. Macrophytes were observed during sampling occasions but were not present in excessive amounts and the EQG1 was met (Table ES 5).
- There should be no reported incidents of large-scale deaths of marine organisms relating from unnatural causes. There were no instances of dead marine organism observed during sampling occasions and the EQG2 was met (Table ES 5).
- The natural visual clarity of the water should not be reduced by more than 20%. Measurements of light attenuation determined that the natural visual clarity of the water was reduced by ~13% (i.e. <20%) and the EQG3 was met (Table ES 5).
- The natural hue of the water should not be changed by more than ten points on the Munsell scale. There was noticeable colour variation on 3 sampling occasions but overall, not changed by ten points on the Munsell scale over the long-term and the EQG4 was met (Table ES 5).
- Oil and petrochemicals should not be noticeable as a visible film on the water or detectable by odour. No surface films or oil were recorded on any sampling occasion and the EQG5 was met (Table ES 5).
- Water surfaces should be free of floating debris, dust and other objectionable matter, including substances that cause foaming. No floating debris or matter was visible on the surface on any sampling occasion and the EQG6 was met (Table ES 5).
- There should be no objectionable odour. There was no noticeable odour on any of the sampling occasions and the EQG7 was met (Table ES 5).

Table ES 5 Summary report card for the Environmental Quality Objective 'Maintenance of Aesthetic Values'

Environmental Quality Indicator	EQC	Comments	Compliance[1]	Previous year (2022-2023)[2]
Nuisance organisms	EQG1	Macrophytes were observed but were not present in excessive amounts.	■	■
Faunal deaths	EQG2	There were no instances of dead marine organism observed.	■	■
Water clarity	EQG3	Measurements of light attenuation determined that the natural visual clarity of the water was reduced by <20% (~13%).	■	■
Colour	EQG4	There was noticeable colour variation on 3 sampling occasion but overall, not changed by ten points on the Munsell scale over the long-term.	■	■
Surface films	EQG5	No surface films or oil were recorded on any sampling event.	■	■
Surface debris	EQG6	No floating debris or matter was visible on the surface on any sampling occasion.	■	■
Odour	EQG7	There was no noticeable odour on any of the sampling occasions.	■	■

Note:

1. Environmental Quality Criteria (EQC): Green (■) symbols indicate the Environmental Quality Guideline (EQG) was met; amber (■) and red (■) symbols represent an exceedance of the EQG or Environmental Quality Standard (EQS), respectively.
2. Aesthetics surveys commenced at Swanbourne in 2022-2023.

1 Introduction

1.1 Document purpose

This annual report documents the findings of the 2023–2024 marine monitoring program 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).

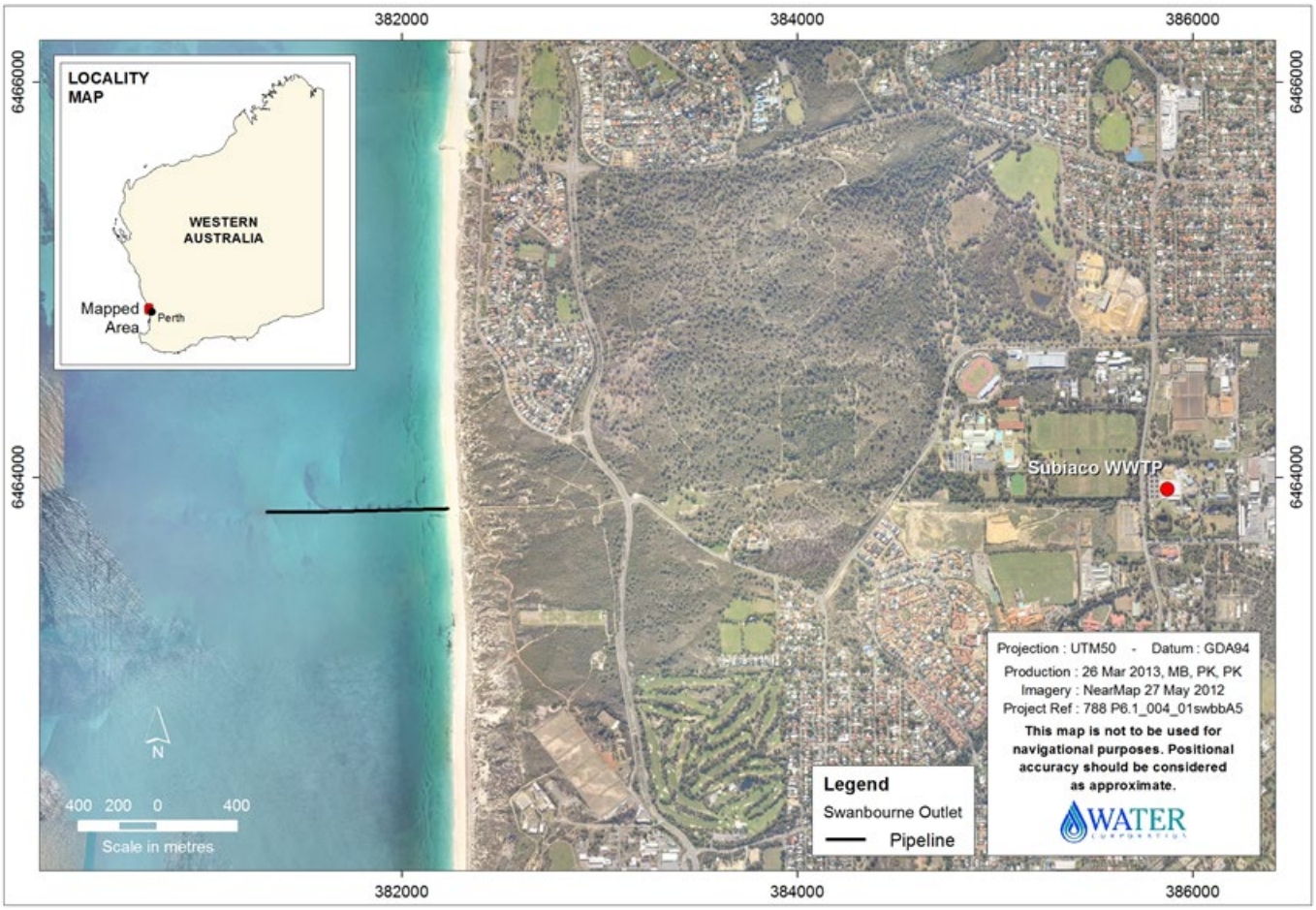


Figure 1 **Location of the Subiaco water resource recovery facility (WRRF) and Swanbourne ocean outlet**

1.3 Potential stressors in treated wastewater

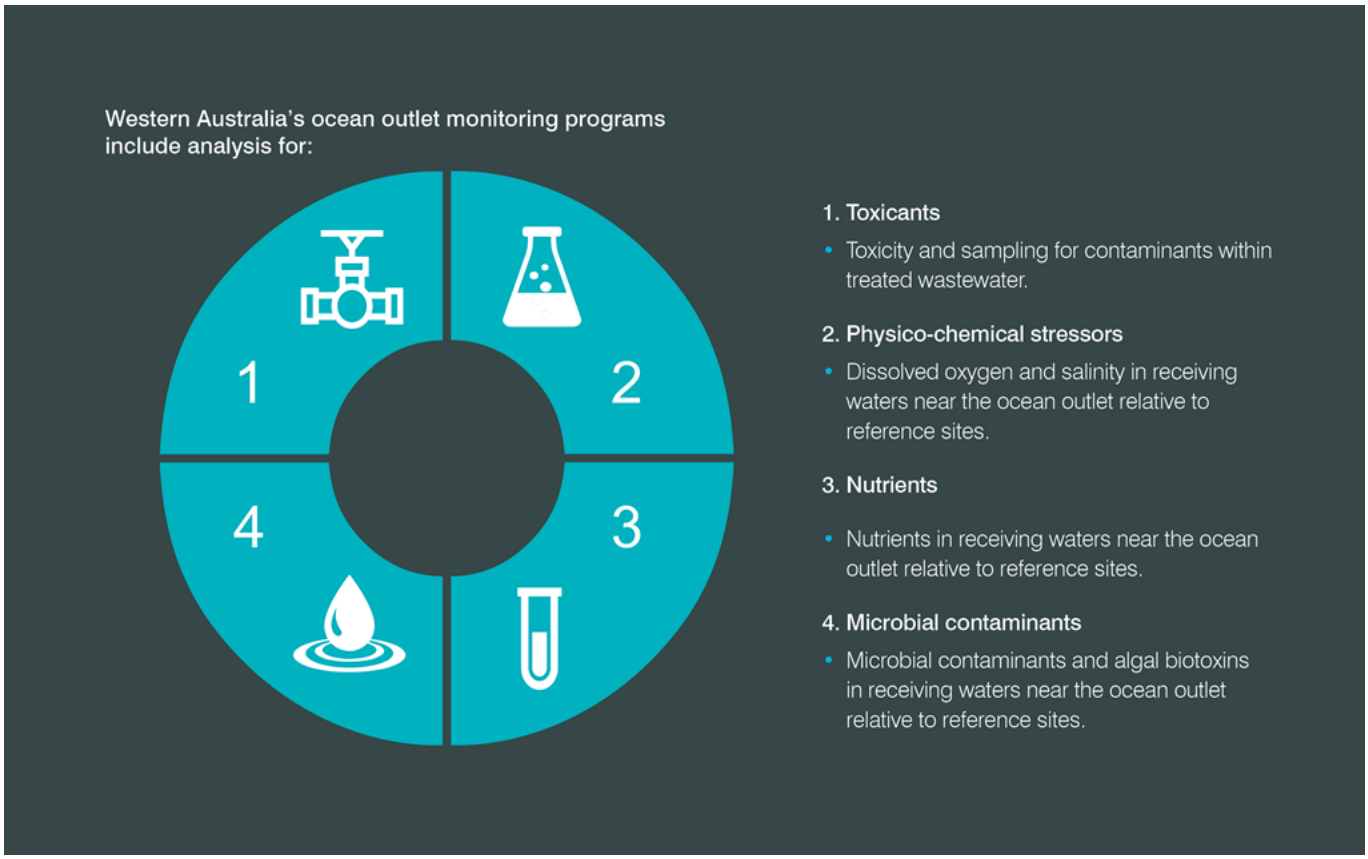


Figure 2 Potential stressors in treated wastewater

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, the 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 outlet, relative to measurements at reference sites, provide an indication of the risk posed by deoxygenation.

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

1.3.3 Nutrients

TWW contains elevated concentrations of biologically available nutrients such as 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 contaminated 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 outlet monitoring programs, the Swanbourne ocean outlet (Figure 3) is part of the Perth Long Term Ocean Outlet Monitoring (PLOOM) program.

Source: Google Earth

Figure 3 Aerial image of Swanbourne ocean outlet

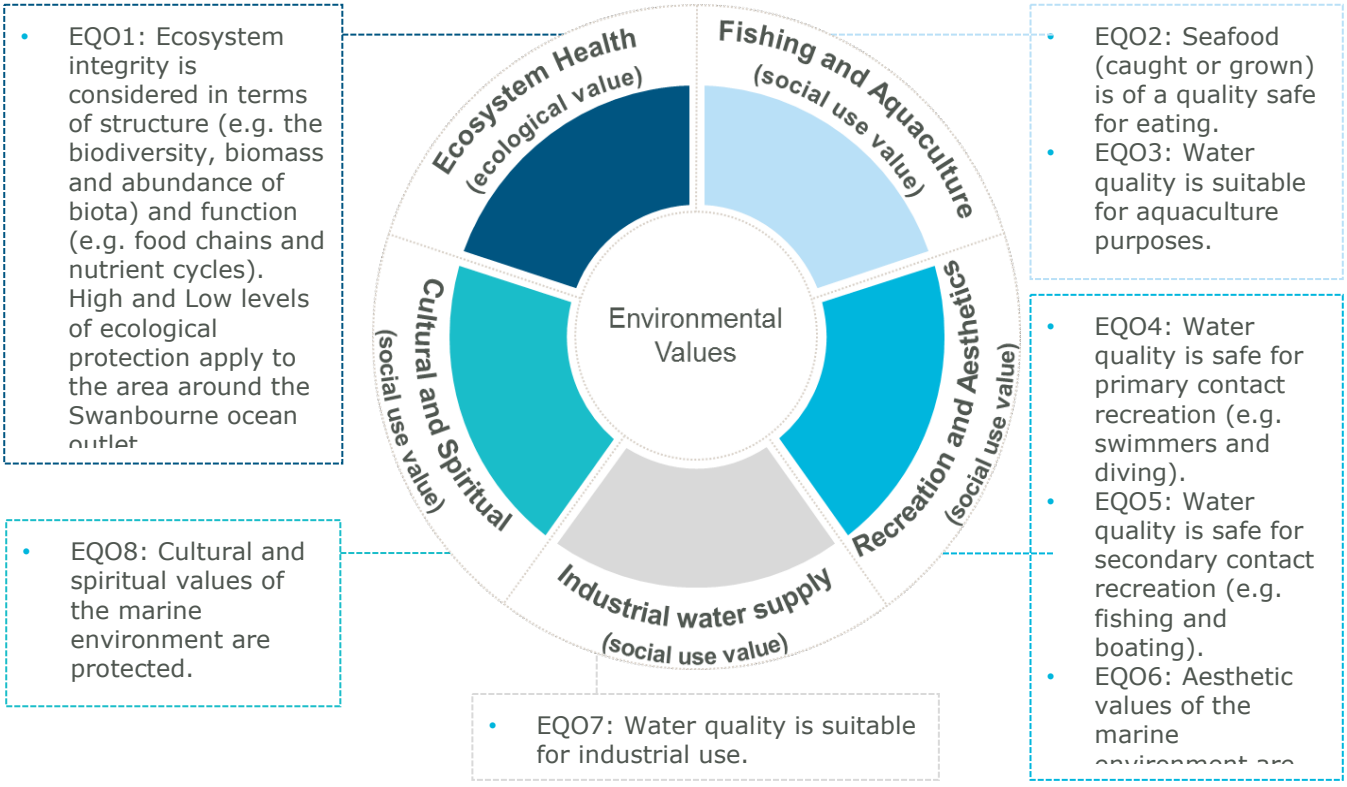
The PLOOM program is consistent with the approach advocated under the State Government's EQMF, which is applied to Western Australia's coastal waters (EPA 2016).

The EQMF is based on:

- Identifying Environmental Values (EVs) (Figure 4)
- 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 4 Environmental Values and Environmental Quality Objectives (EQO) for the marine waters of Western Australia

The compliance results for 2023-2024 are summarised in Report Card format (Table 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 1 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.

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 5).

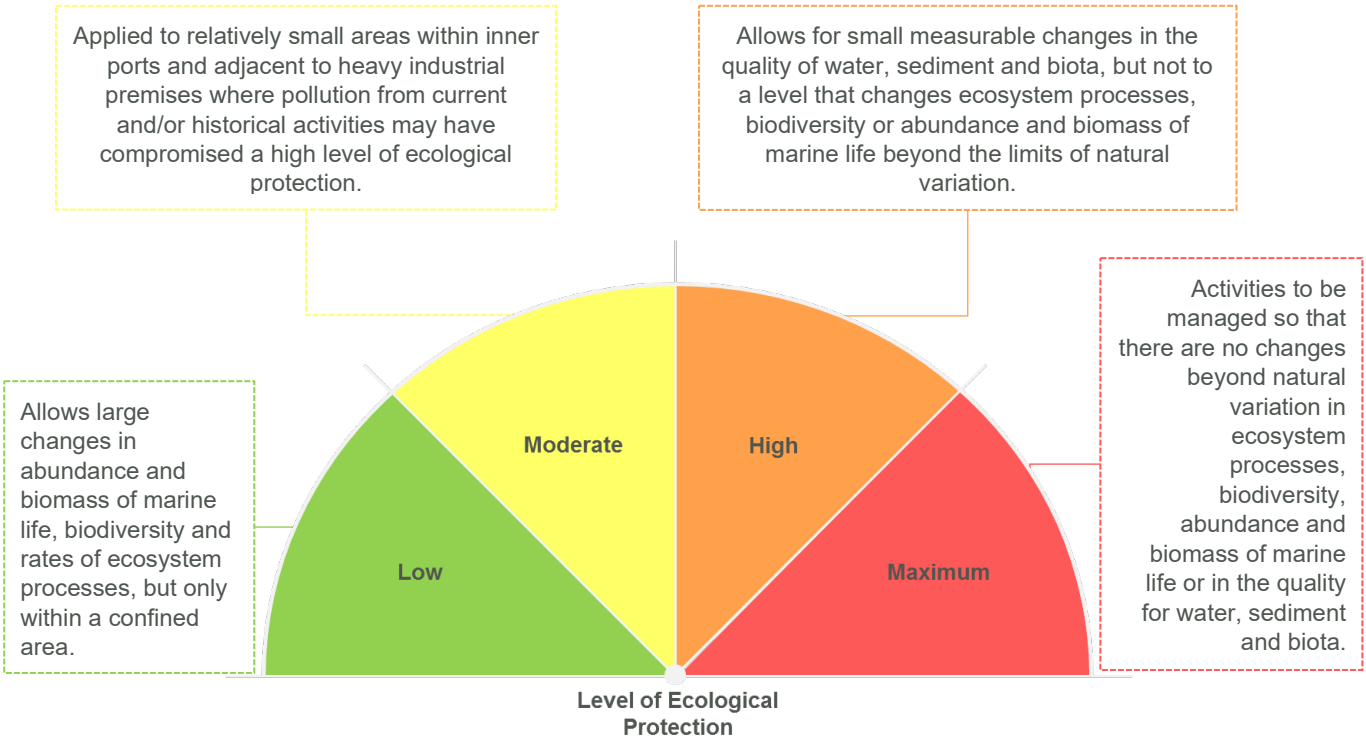


Figure 5 Level of Ecological Protection

In the absence of mandated management zones, a notional Low Ecological Protection Area (LEPA) has been established at the Swanbourne outlet, as per technical guidance (EPA 2016). The LEPA occupies the area within a 100 m radius of the diffuser (Figure 6). Waters outside the LEPA are designated a High Ecological Protection Area (HEPA; Figure 6).

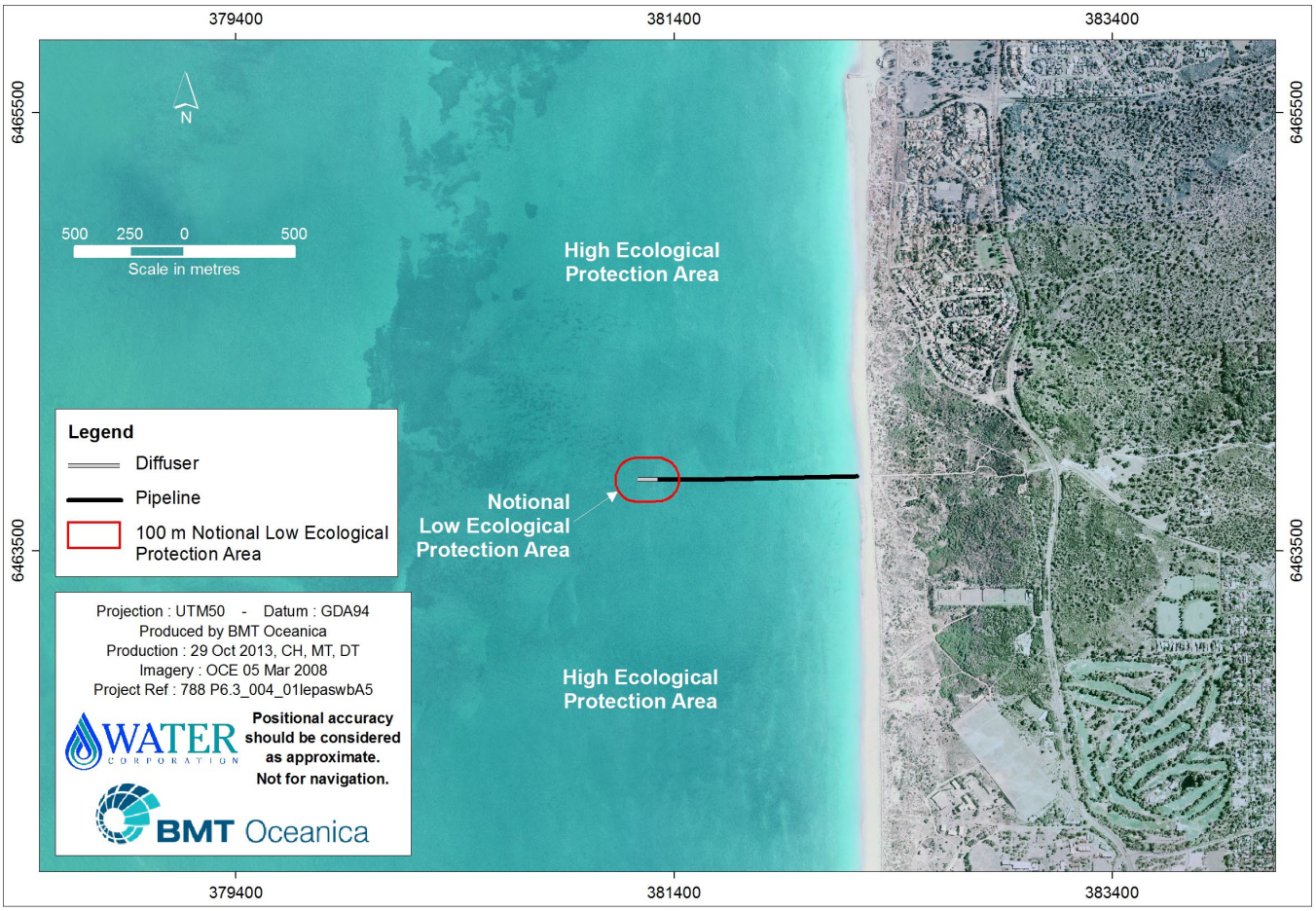


Figure 6 **Swanbourne Ocean Outlet notional Low Ecological Protection Areas**

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 7). 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.

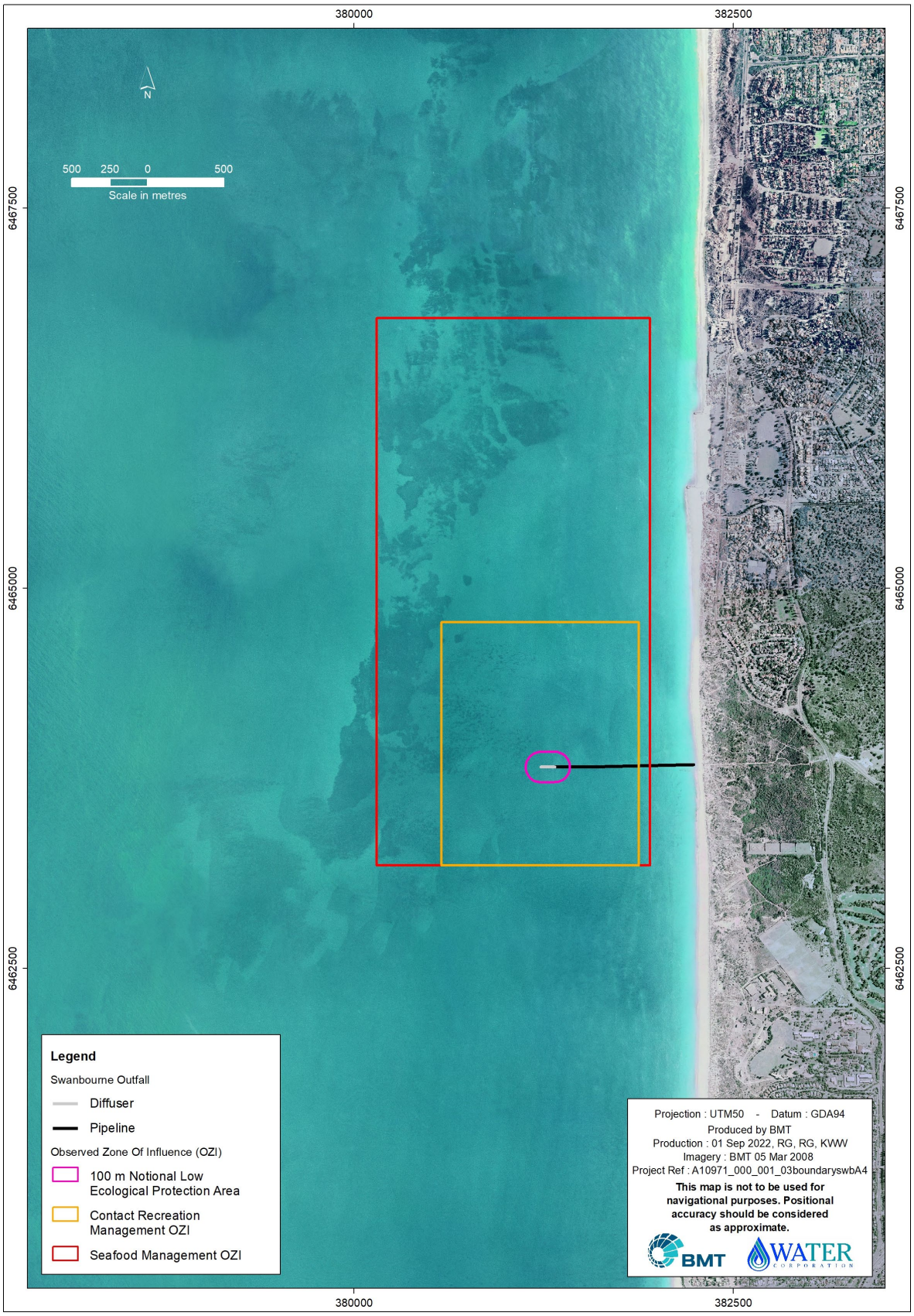


Figure 7 **Swanbourne Ocean Outlet Low Ecological Protection Area, Contact Recreation Observed Zone of Influence and Seafood Management Observed Zone of Influence**

1.4.3 Maintenance of Primary and Secondary Contact Recreation EQO

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 for primary contact recreation 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 7). 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 Swanbourne ocean outlet was analysed for a suite of parameters comprising the major contaminants of concern (Figure 8):

- nutrients (total nitrogen, ammonia, nitrate+nitrite (NOx), 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.

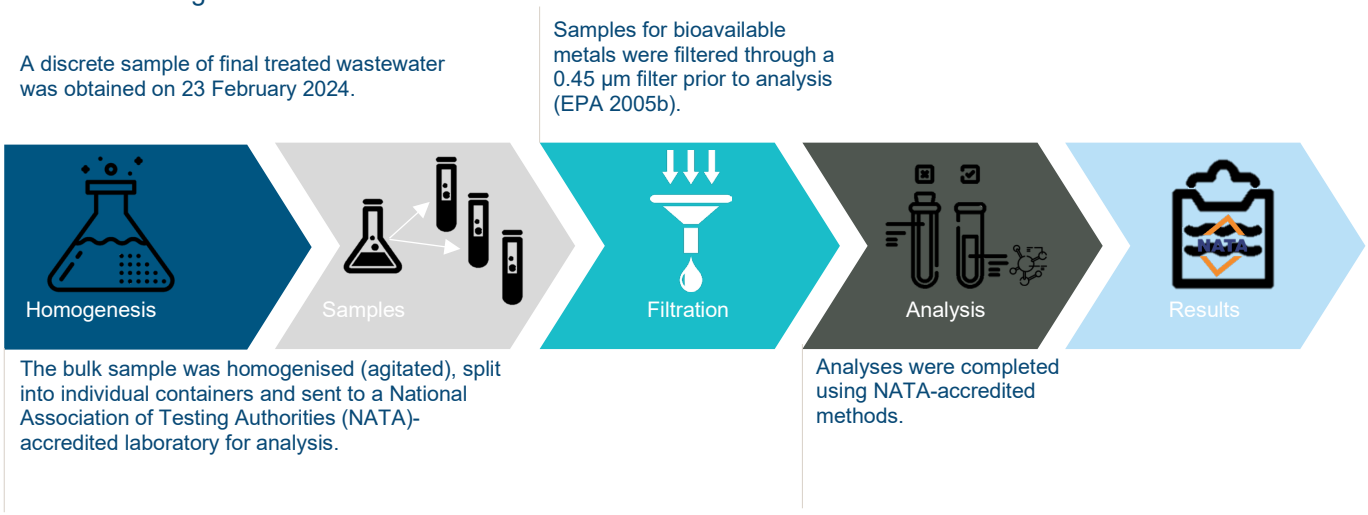


Figure 8 Wastewater sampling and analysis process

2.1.1 Bioaccumulating toxicants

Concentrations of cadmium and mercury (i.e. bioaccumulating toxicants) in the undiluted TWW sample were both below their analytical limit of reporting (LoR; 0.1 µg/L) and the EQG (Table 2) for EQG for cadmium and mercury as bioaccumulating toxicants (36 and 1.4 µg/L, respectively) was met (Table 3). Concentrations of bioaccumulating toxicants in the discharge have been consistent since 2007-2008 (Figure 9).

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:

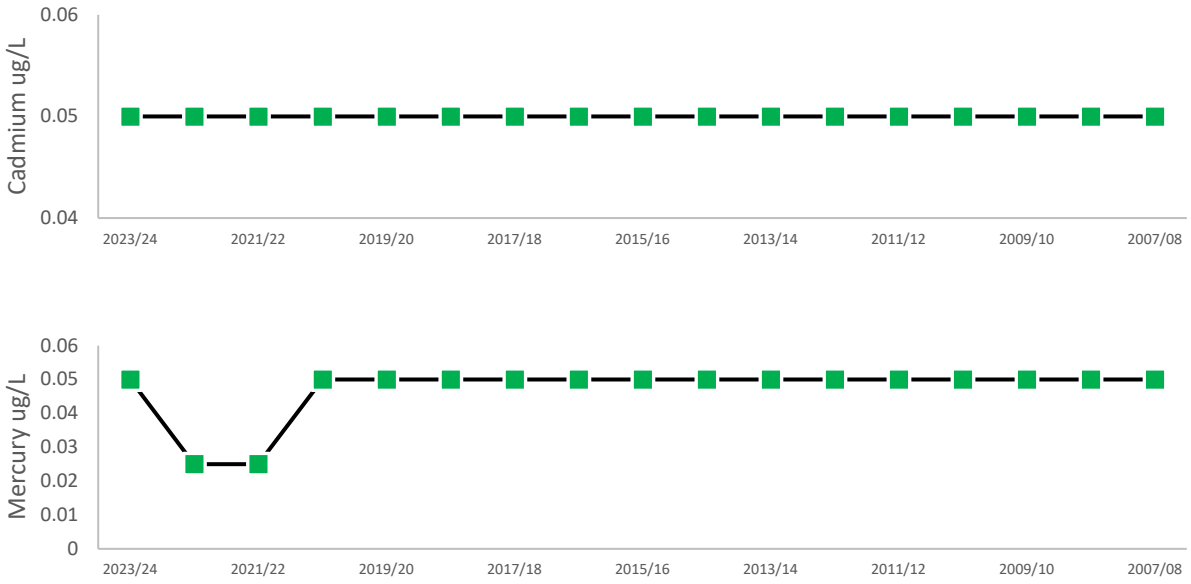
1. EQG = Environmental Quality Guideline, ANZG = Australian and New Zealand Environment Guidelines

Table 3 Bioaccumulating toxicants in the Swanbourne treated wastewater stream

Toxicant	Swanbourne TWW concentration (µg/L)	Trigger (µg/L)[1]
Cadmium*	<0.1	36
Mercury*	<0.1	1.4

Notes:

1. Assessment against ANZG (2018) guidelines. 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.
2. TWW = Treated wastewater



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

Figure 9 Historical compliance of concentrations of the bioaccumulating toxicants cadmium and mercury

2.1.2 Non-bioaccumulating toxicants

Contaminant concentrations scaled for dilution equivalent to that expected at the LEPA boundary (1:140; refer to Appendix C) were below the ANZG (2018) 99% species protection guidelines. Therefore, the EQG (Table 4) was met (Table 5). Initial dilution (Figure 10) has been sufficient to reduce the concentration of non-bioaccumulating toxicants to below their EQG concentrations with the exception of copper in 2009/10 (0.33 µg/L) and 2010/11 (0.31 µg/L) which exceeded the 99% species protection guideline (0.3 µg/L) (Figure 11).

Table 4 Environmental Quality Guideline for non-bioaccumulating toxicants

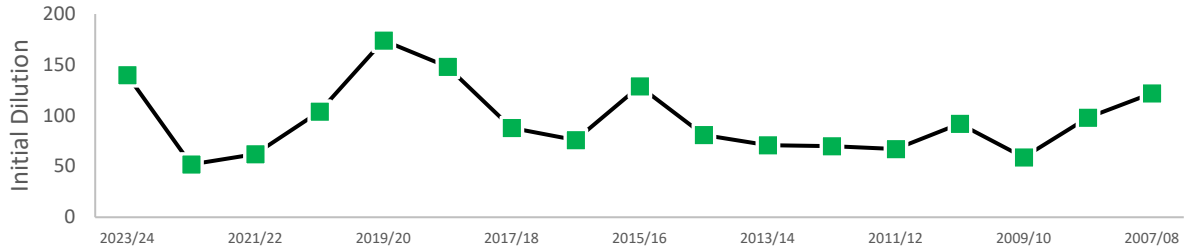
EQG	Wastewater contaminant concentrations, in conjunction with initial dilution modelling, will be evaluated to determine that the ANZG (2018) 99% species protection guideline trigger levels for toxicants is achieved at the boundary of the low ecological protection area (LEPA) (i.e. a high level of protection is met beyond a 100 m radius of the diffuser).

Table 5 Non bioaccumulating toxicants in the Swanbourne treated wastewater stream after initial dilution

Toxicant	Swanbourne TWW concentration (µg/L)	Concentration after initial dilution (µg/L)[3,4]	Trigger (µg/L)[1,5,7]
Ammonia-N	5500	41	500
Chromium*	<1	-	0.14 (Cr VI)
Copper*	4.6	0.11	0.3
Lead*	<1	-	2.2
Nickel*	1.1	-	7
Silver*	<0.8	-	0.8
Zinc*	22	0.31	7
Chlorpyrifos[6]	<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

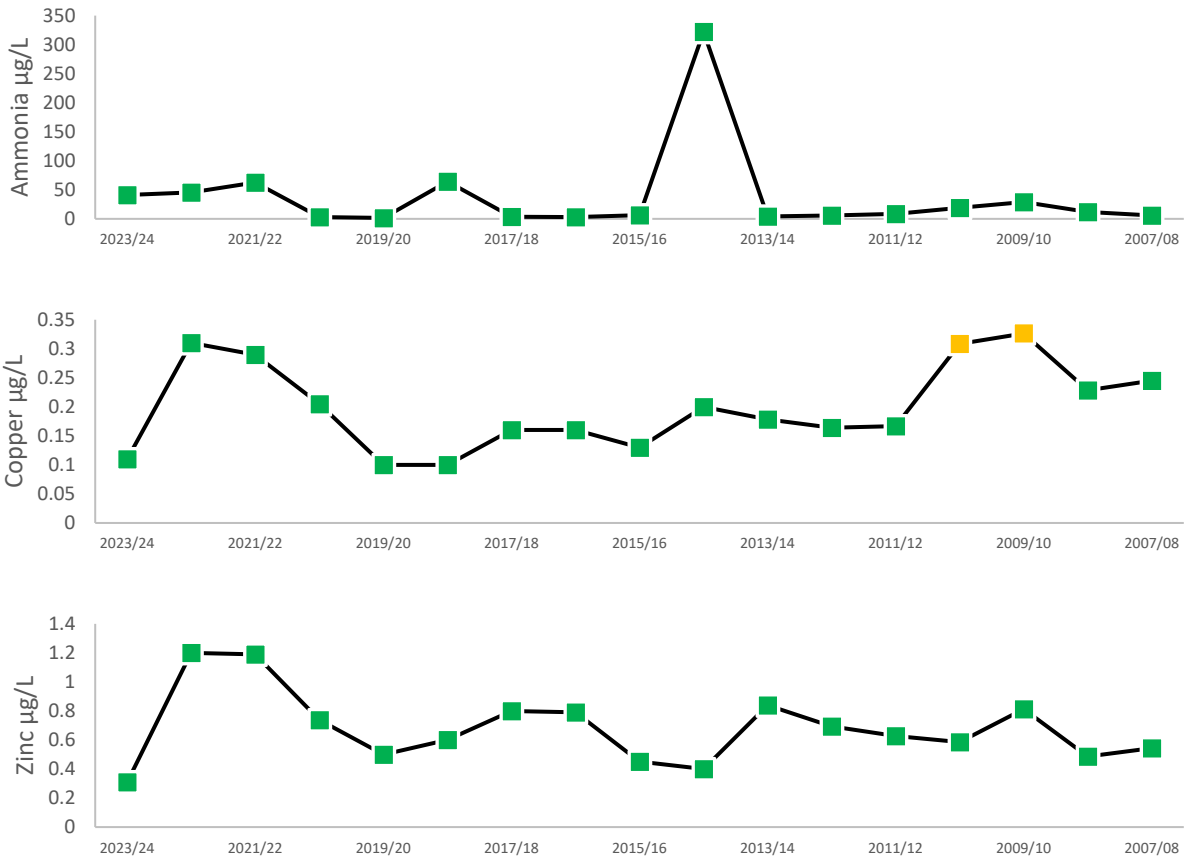
Notes

1. Assessment against ANZG (2018) guidelines was undertaken only for those toxicants where trigger levels were available.
2. TWW = Treated wastewater.
3. Initial dilution = 1:140 (predicted average value for Swanbourne outlet).
4. Contaminant dilution calculations were not performed (–) on any toxicants where TWW concentrations were below the analytical limit of reporting.
5. The trigger values for non-bioaccumulating toxicants are from ANZG (2018). The EPA has provided advice that in High Ecological Protection Area the 99% species protection guidelines should be used.
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.



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

Figure 10 Historical compliance of initial dilution calculations



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

Figure 11 Historical compliance of concentrations of non-bioaccumulating toxicants

2.1.3 Total toxicity of the mixture

The total toxicity of the mixture (TTM) is an indicator of the potential for cumulative toxic effects on marine organisms. For the combined effect of ammonia, copper and zinc following dilution (0.49, Table 7; ANZECC/ARMCANZ 2000) was less than the ANZG (2018) guideline value of 1.0 and the EQG (Table 6) for TTM (Table 7) was met. Total toxicity of the mixture has exceeded the EQG criteria on five occasions since 20007-2008 but there is no evidence of an upward trend (Figure 12).

Table 6 Environmental Quality Guideline for the total toxicity of the mixture

EQG	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:

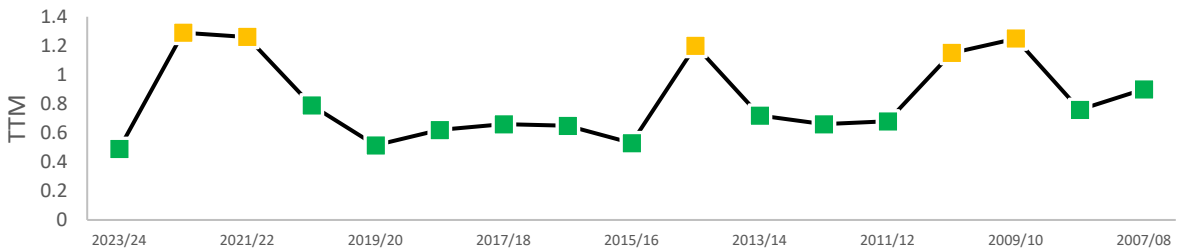
1. EQG = Environmental Quality Guideline; TTM = total toxicity of the mixture
2. TTM = Σ(Ci/EQGi) where Ci is the concentration of the relevant component (i) in the mixture and its associated EQGi for that component.

Table 7 Total toxicity of treated wastewater at the edge of the initial mixing zone associated with the Swanbourne ocean outlet

Toxicant	TWW concentration (µg/L)	Background concentration (µg/L)[1]	Dilution	Concentration after dilution (µg/L)	contaminant /guideline (µg/L)	TTM[2]
Ammonia	5500	1.5	1:140	41	0.08	0.49
Copper	4.6	0.08		0.11	0.37	
Zinc	22	0.15		0.31	0.04	

Notes:

1. Background concentrations for copper and zinc from McAlpine et al. (2005); Perth marine waters (pp.19). Surface background concentrations for ammonia calculated as median of reference site data from 2003–2023.
2. TTM = total toxicity of the mixture = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline, TWW = treated wastewater.
3. Guideline values are outlined in Table 5.



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

Figure 12 Historical compliance of total toxicity of the mixture

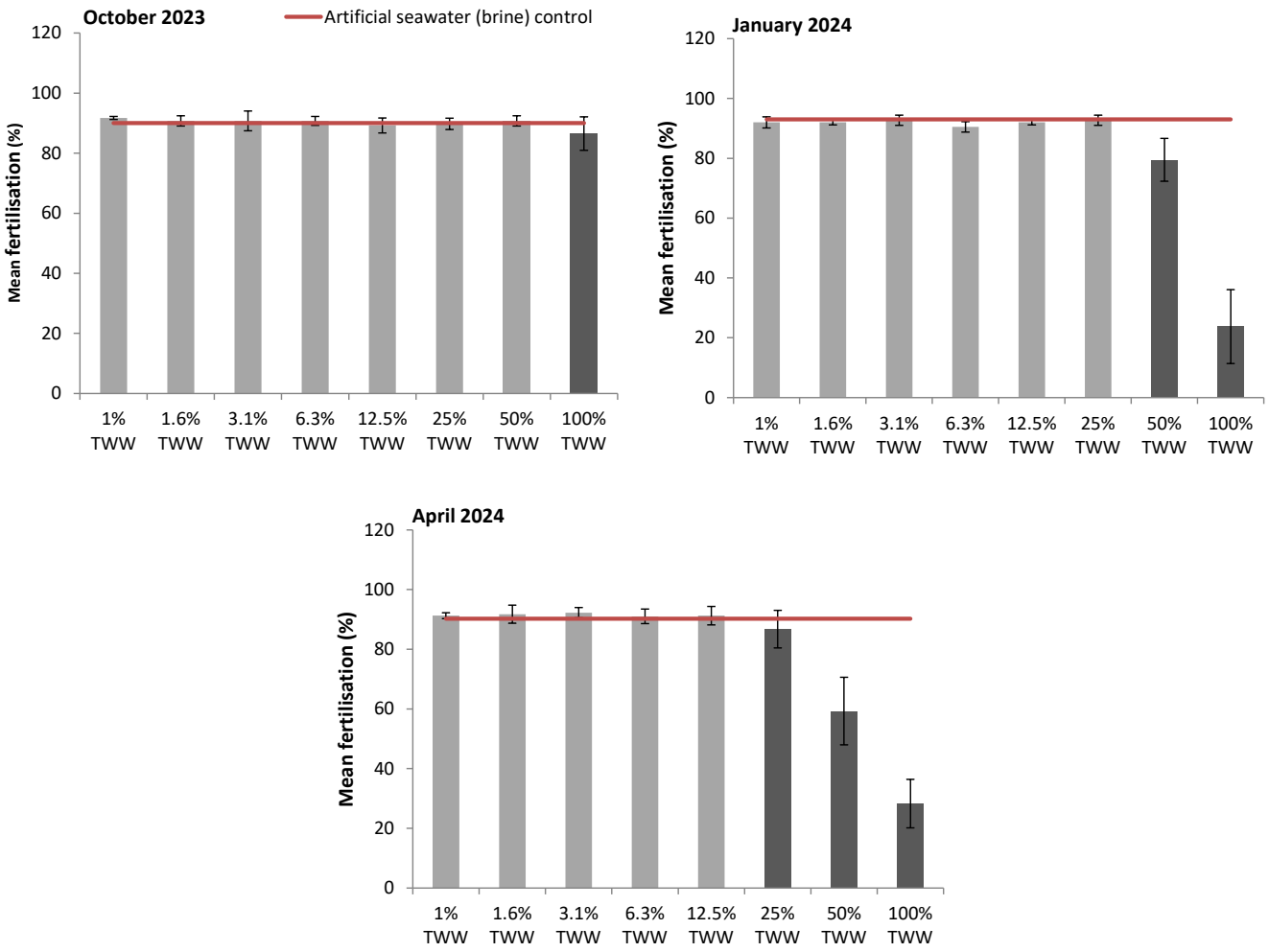
2.3 Whole of effluent toxicity (WET) testing

WET testing is useful for assessing the toxicity of potential contaminants without 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 concentration where no significant effect is observed; Appendix D).

In April 2024, sea urchin fertilisation was significantly lower in samples exposed to 25%, 50% and 100% TWW dilutions than the artificial seawater control (Figure 13). In January 2024, sea urchin fertilisation was significantly lower in samples exposed to 50% and 100% TWW dilutions than the artificial seawater control. In October 2023, sea urchin fertilisation was significantly lower in samples exposed to 100% TWW dilutions than the artificial seawater control (Figure 13). For all four sampling dates, the NOEC was greater than 1% TWW (Table 9) and the EQG for WET testing (Table 8) was met. The lowest annual NOEC (and highest apparent toxicity) has been variable since 2007-2008 without an identifiable trend (Figure 14).

Table 8 Environmental Quality Guideline 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).



Notes:

1. Error bars represent ±1 standard deviation; n = 4.
2. TWW = treated wastewater.
3. Light grey bars represent concentrations of 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.

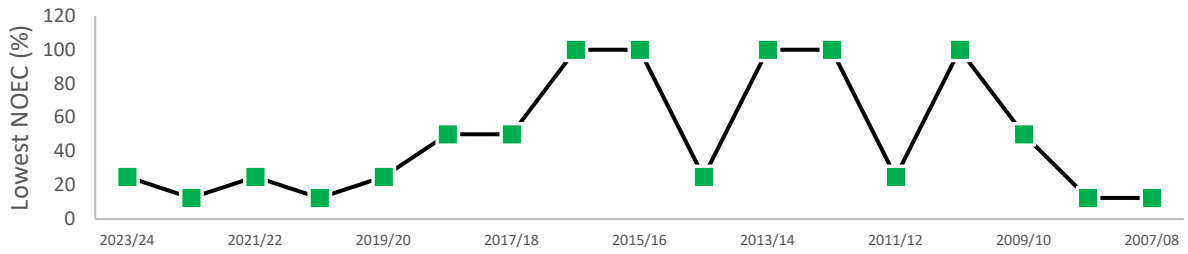
Figure 13 Comparison of whole effluent toxicity TWW dilution results to artificial seawater control for Swanbourne treated wastewater

Table 9 Calculated parameters from whole of effluent toxicity tests Swanbourne treated wastewater

Indicator	October 2023	January 2024	April 2024
NOEC (%)	100	50	25
Dilutions required to meet the NOEC	1	2	4
Dilutions required/dilution achieved	0.007	0.01	0.03
≤1	Yes	Yes	Yes

Notes:

1. NOEC = No Observed Effect Concentration.
2. Calculation based on 140 dilutions achieved after initial dilution. which is expected at the Low Ecological Protection Area boundary.



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

Figure 14 Historical compliance of No Observed Effect Concentration over time

3 Water quality monitoring – receiving environment

Nutrients, phytoplankton biomass and physical and chemical stressors were monitored approximately fortnightly from the beginning of December 2023 to the end of March 2024 (coinciding the summer non-river flow period) along a down-current gradient from the diffuser (Table 10; Appendix E). Wind direction, strength, current grid direction and cloud cover for each sampling occasion are provided in Table 11.

Table 10 Water quality monitoring sampling occasions for the Swanbourne ocean outlet between December 2023 and March 2024

Sample day	Date
1	04/12/2023
2	15/12/2023
3	11/01/2024
4	25/01/2024
5	07/02/2024
6	23/02/2024
7	01/03/2024
8	15/03/2024

Table 11 Weather conditions and current grid direction during Swanbourne water quality monitoring occasions

Date	Wind direction	Wind strength (knots)	Cloud cover (%)	Current grid (deg)
04/12/2023	WSW	5–8	30	N (21)
15/12/2023	E, ENE, ESE	3–10	10–20	W (274)
11/01/2024	SE,SSE,SSW	2–10	30–40	N (359)
25/01/2024	SSW	10–14	0	N (344)
07/02/2024	NE	5–10	0	SW (213)
23/02/2024	E	10–15	30	W (273)
01/03/2024	SE	10–12	10	W (242)
15/03/2024	E	10–16	30–60	NW (293)

Notes:

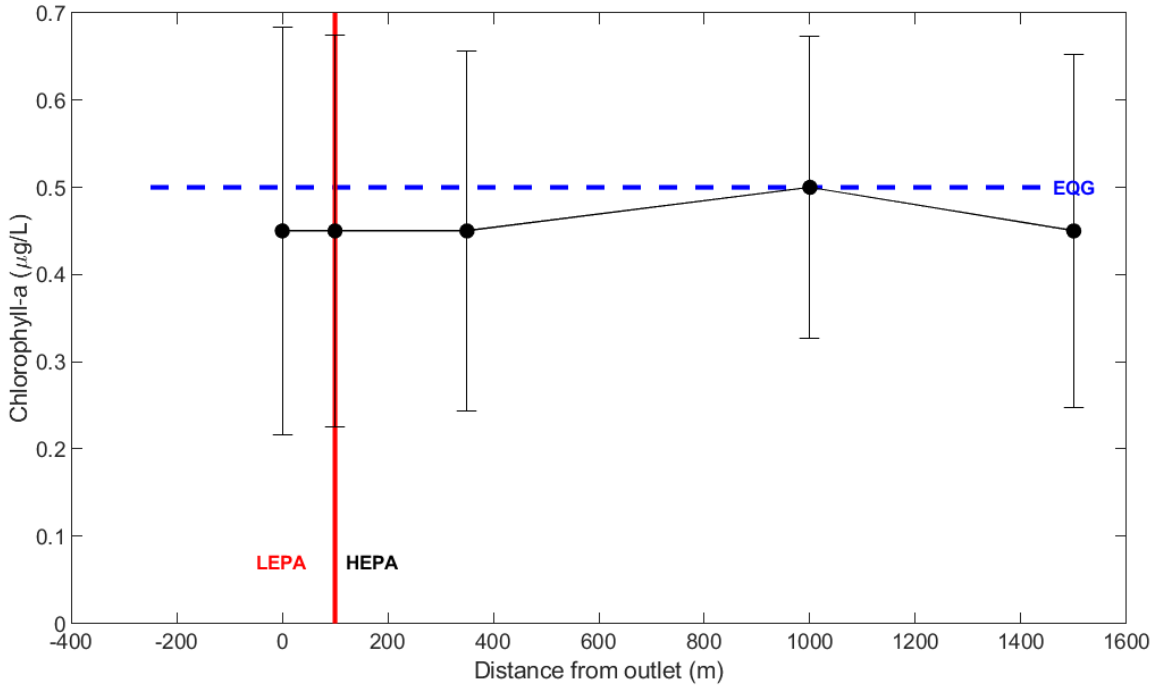
1. N = north, W = west, E = east, SW = south-west, SE = south-east, NW = north-west, NE = north-east, ENE = east north-east, ESE = east south-east, SSE = south south-east, SSW = south south-west, WSW = west south-west.
2. Winds are designated by the direction they come from while currents are designated by the direction they flow to.
3. Wind direction and strength are obtained from field observations.

3.1 Nutrient enrichment

The median chlorophyll–a concentration in the Swanbourne HEPA (≥100 m) was 0.5 µg/L and equal to the 80th percentile of historical reference site data (0.5 µg/L; Figure 15), meeting the EQG (Table 12, Appendix F). Median chlorophyll–a was higher in the 2023-2024 monitoring period than the proceeding 8 years (Figure 16). This increase is associated with a general increase in background concentration.

Table 12 Environmental Quality Guidelines for nutrients

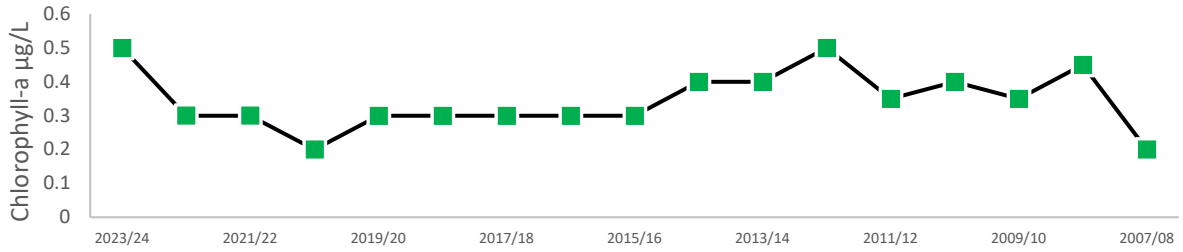
EQG	The median chlorophyll–a concentration in the High Ecological Protection Area (HEPA; 100 m and greater from the diffuser) during the non-river flow period is not to exceed the 80th percentile of historical reference site data.
	The median light attenuation coefficient in the HEPA during the non-river flow period is not to exceed the 80th percentile of historical reference site data.



Notes:

1. Error bars represent ±95% confidence intervals; n = 8.
2. Dark blue dashed line = Environmental Quality Guideline (EQG) is the 80th percentile of historical reference site data.
3. LEPA = Low Ecological Protection Area; HEPA = High Ecological Protection Area.
4. Data were pooled across eight sampling days (n=8) over December 2023–March 2024.

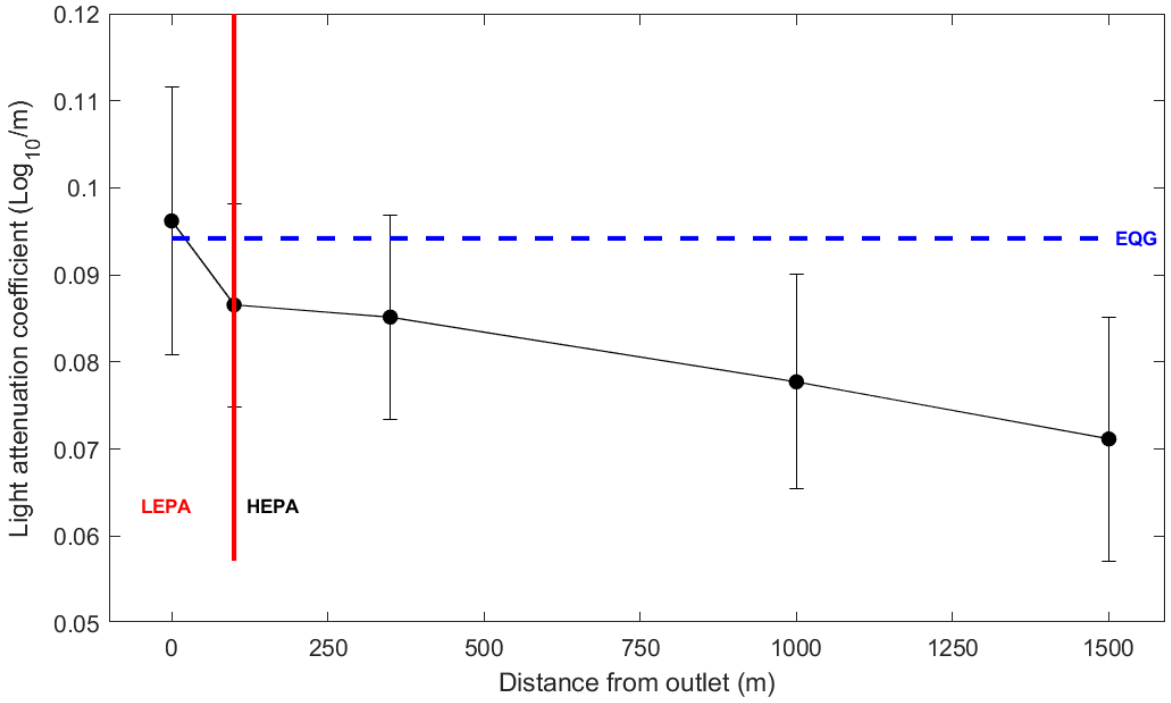
Figure 15 Median chlorophyll–a concentration at fixed monitoring sites down-current of the Swanbourne outlet during the summer monitoring period



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

Figure 16 **Median chlorophyll–a concentration over time**

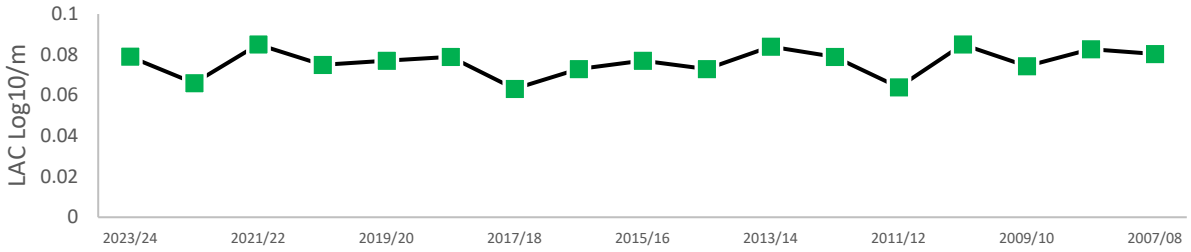
The median light attenuation coefficient (LAC) in the Swanbourne HEPA (≥100 m) was 0.079 Log_{10}/m and was less than the 80th percentile of historical reference site data (0.094 Log_{10}/m; Figure 17), meeting the EQG (Table 12). Light attenuation has not changed over the period monitoring has been completed (Figure 18).



Notes:

1. Error bars represent ±95% confidence intervals; n = 8.
2. Dark blue dashed line = Environmental Quality Guideline (EQG) is the 80th percentile of historical reference site data.
3. LEPA = Low Ecological Protection Area; HEPA = High Ecological Protection Area.
4. Data were pooled across eight sampling days (n=8) over December 2023 – March 2024.

Figure 17 **Median light attenuation coefficient at fixed distances down current of the Swanbourne outlet during the summer monitoring period**



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

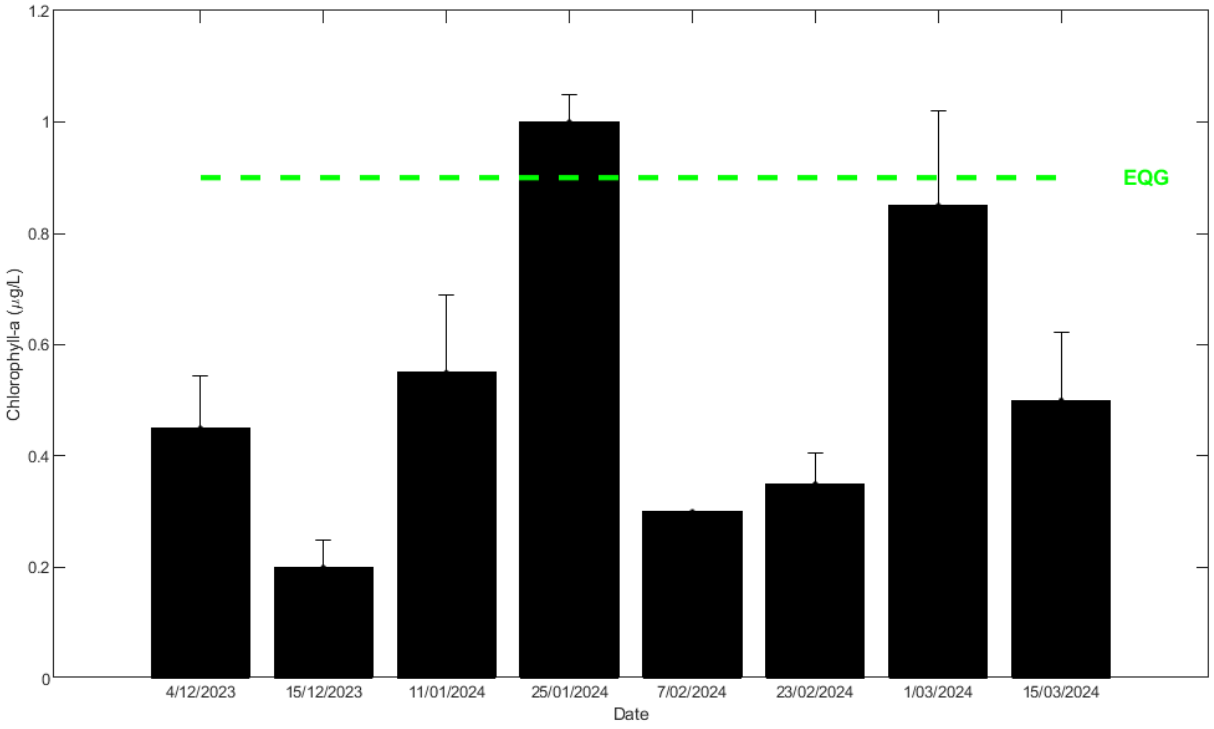
Figure 18 Median light attenuation coefficient over time

3.2 Phytoplankton biomass

Median chlorophyll–a concentration within the HEPA exceeded three times the median of historical reference sites (0.90 µg/L) on one sampling occasion during the summer monitoring period and EQG1 (Table 13) was not met (Figure 19). Median chlorophyll–a concentrations in the HEPA did not exceed 3-times the median of reference sites on more than 1 occasion in the 2023-2024 sampling season and EQS1 was met. The EQG has been exceeded 4 times historically (Figure 20). The EQG was exceeded on only on one occasion in 2022-2023 and 2023–24 meeting the EQS (requires exceedance on more than one occasions in both years) (Figure 21).

Table 13 Environmental Quality Guidelines for phytoplankton in receiving waters

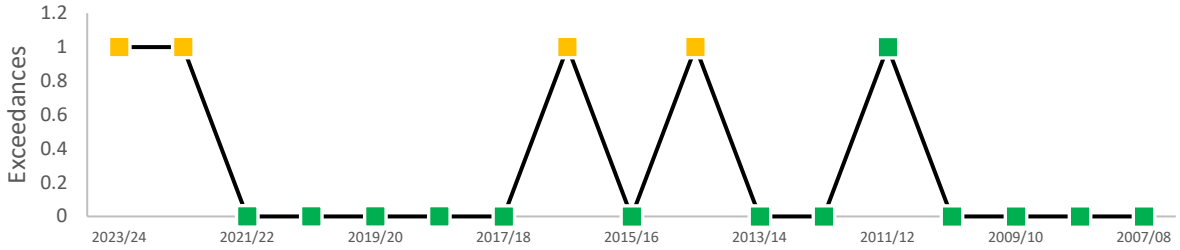
EQG1	Median phytoplankton biomass, measured as chlorophyll–a is not to exceed 3 times the median chlorophyll–a concentration of reference sites, on any occasion during the non-river flow period.
EQG2	Phytoplankton biomass measured as chlorophyll–a at any site does not exceed 3 times the median chlorophyll–a 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.
EQS2	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 and in two consecutive years.



Notes:

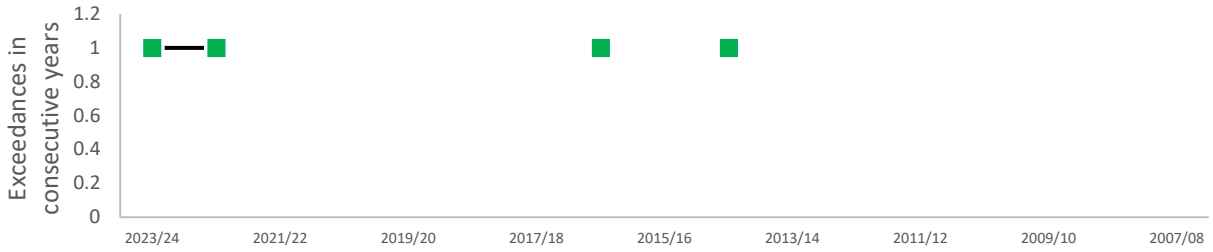
1. Error bars represent ±95% confidence intervals; n = 4.
2. Green dashed line = Environmental Quality Guideline (EQO) is 3-times the median chlorophyll–a concentration of historical reference site data.

Figure 19 **Median phytoplankton biomass at fixed sites ≥100 m down-current of the Swanbourne outlet during the summer monitoring period**



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

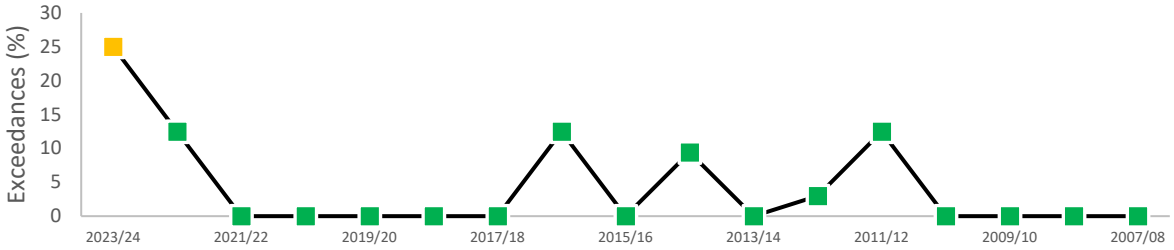
Figure 20 **Exceedance of three times the median chlorophyll–a concentration of reference sites on any occasion**



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

Figure 21 Exceedance of three times the median chlorophyll–a concentration of reference in on any occasion in two consecutive years

Phytoplankton biomass measured as chlorophyll–a exceeded three times the median of reference sites at two sites (100 m and 350 m) on two sampling occasions (25%) and at two sites (1000 m and 1500 m) on one occasion (12.5%) during the summer monitoring period and the EQG was met. Phytoplankton biomass measured as chlorophyll–a at any site exceeded three times the median chlorophyll–a concentration of historical reference sites on a maximum of 12.5% of occasions during the 2022/23 non river-flow period (Figure 22). As phytoplankton biomass at any site did not exceed three times the median chlorophyll–a concentration of historical reference sites on 25% or more occasions in two consecutive years EQS2 was met (Figure 22).



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

Figure 22 Percentage of occasions chlorophyll–a concentration exceeded 3 times reference site concentrations at any site

The exceedances of the EQGs described above were due to a gradual increase in the background chlorophyll–a concentration (and associated increase in light attenuation). The EQGs were met if assessed against the criteria based on the corresponding sampling period – that is, the water quality at the LEPA boundary was within the range measured at the reference sites during the same sampling event. The current approach to assessing compliance with the EQC is to compare against historical data collection over 16 years.

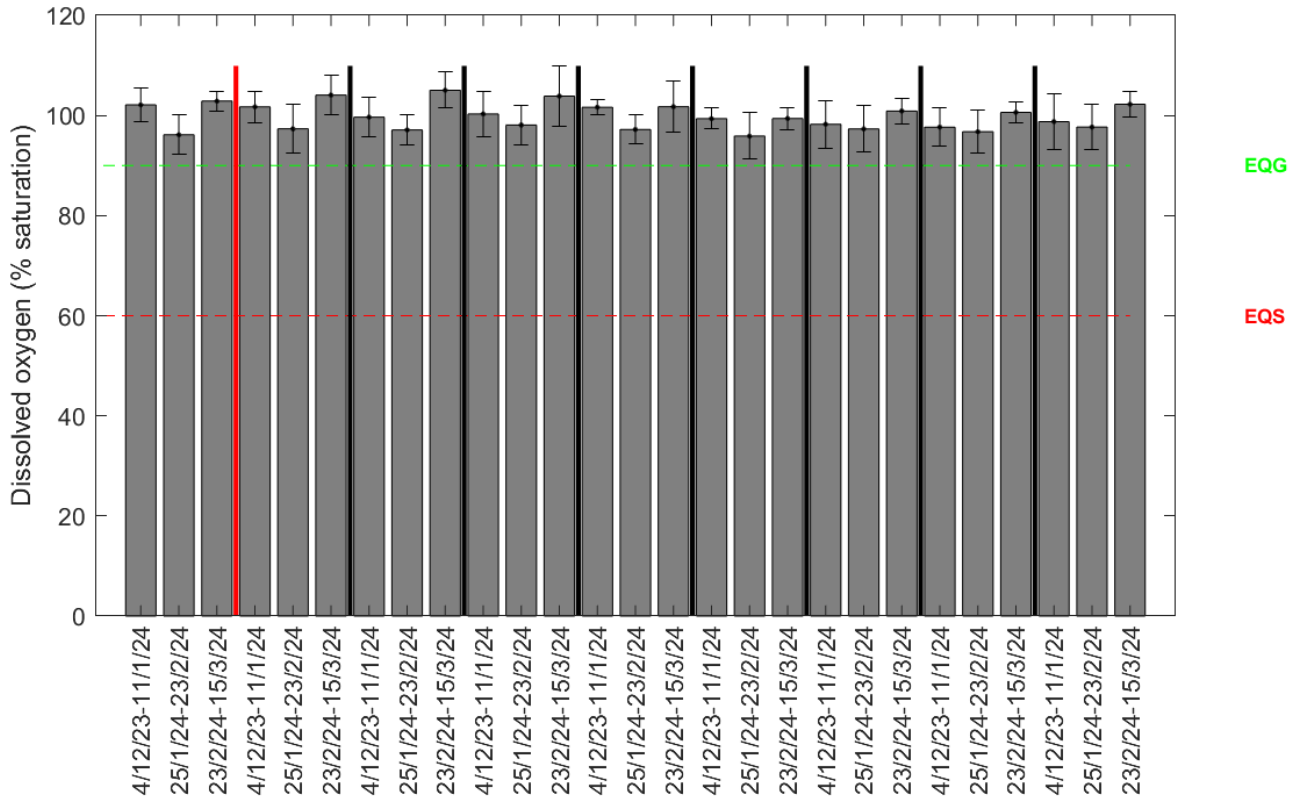
3.3 Physical-chemical stressors

3.3.1 Dissolved oxygen (DO)

Bottom water (0–0.5 m) DO concentration were >90% at all times throughout the summer monitoring period (Figure 23) and the EQG for organic enrichment (Table 14) was met. DO has not fallen below 90% for any 6 week period at any time (Figure 24).

Table 14 Environmental Quality Guideline for dissolved oxygen

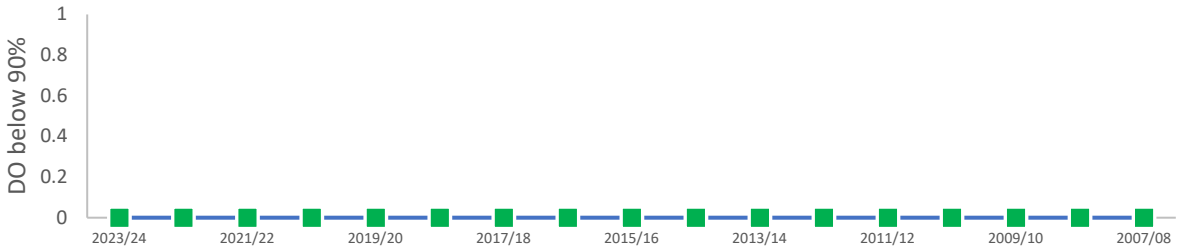
EQG	Median dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) must be greater than 90% saturation at any site for a defined period of not more than 6 weeks during the non-river flow period.



Notes:

1. Error bars ±95% confidence intervals; n = 40.
2. Dissolved oxygen (DO) measured 0–0.5 m above the seabed
3. Green dashed line = Environmental Quality Guideline (EQG) = 90% DO saturation; Red dashed line = Environmental Quality Standard (EQS) = 60% DO saturation.
4. LEPA = Low Ecological Protection Area; HEPA = High Ecological Protection Area.
5. Reference site data (SBR1–SBR4) are provided for contextual purposes only.

Figure 23 Median dissolved oxygen for defined periods of ≤6 weeks down current of the Swanbourne outlet during the summer monitoring period



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

Figure 24 Number of periods where DO was below 90% over time

3.3.2 Salinity

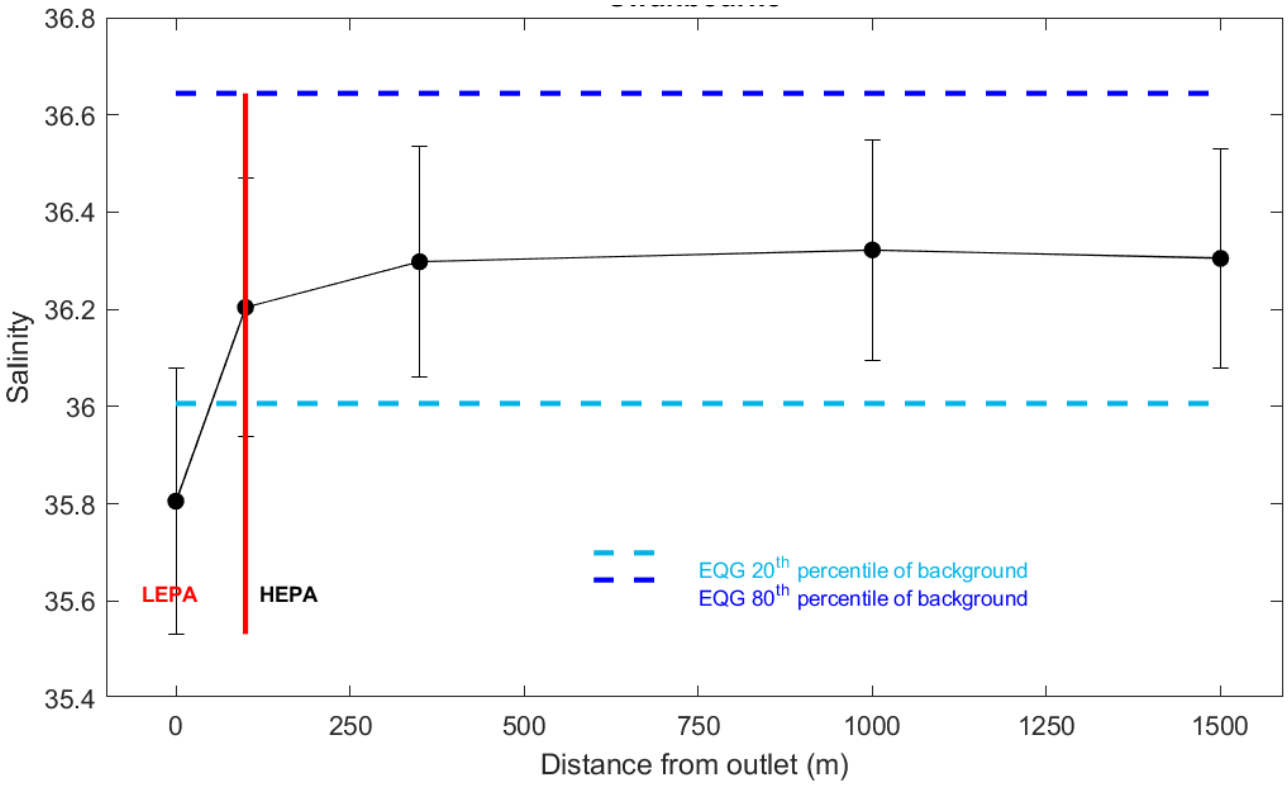
Median salinity was below the 20th percentile of the natural salinity range at the notional LEPA (100 m) site however exceeded the 20th percentile at the 350 m within the HEPA and therefore EQG was not met, triggering assessment against the EQS (Table 15 and Figure 25). There were no reports of deaths of marine organisms resulting from anthropogenically sourced salinity stress, thus the EQS (Table 15) was met. Median salinity was below the 20th percentile of the natural salinity range for the same period and the EQG exceeded on four occasions since 2007-2008 (Figure 26). The EQS was never exceeded (Figure 27).

Table 15 Environmental Quality Guideline 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:

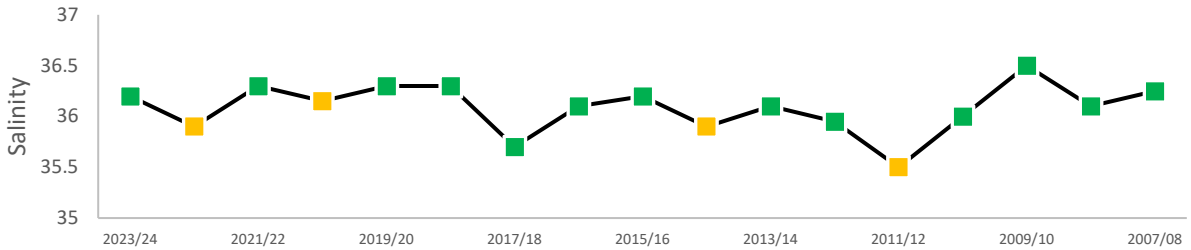
1. EQG = Environmental Quality Guideline; EQS = Environmental Quality Standard



Notes:

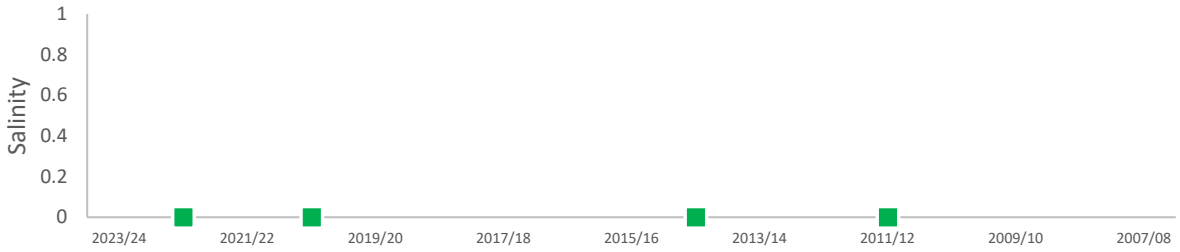
1. Error bars represent ±95% confidence intervals; n = 8.
2. Salinity measured in the top 0–0.5 m of the water column.
3. Dark blue line = 80th percentile of historical reference sites; light blue dashed line = 20th percentile of historical reference sites.
4. LEPA = Low Ecological Protection Area; HEPA = High Ecological Protection Area.
5. Data for each distance were pooled across eight sampling occasions (n=8) over December 2023–March 2024.

Figure 25 Median salinity down-current of the Swanbourne outlet during the summer monitoring period



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

Figure 26 Median salinity down-current of the Swanbourne outlet over time



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

Figure 27 Assessment against the EQS (when triggered) over time

4 Microbiological contaminants and algal biotoxins

4.1 Thermotolerant coliforms

TTC were sampled eight times over the 2023–2024 summer period (yielding a total of n = 40 samples). NHMRC (2008) and EPA (2005) guidelines 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 (NHMRC 2008). Assuming conditions have not changed, data collected over three summers were pooled to yield 120 samples.

The median concentration of TTC derived from three years of pooled sampled was equal to the limit of reporting (<10 CFU/100 mL; Table 17), meeting the EQG. Median concentration of TTC has never exceeded the limit of reporting (Figure 28). Over the three sampling periods, there were 4 instances where TTC exceeded 21 CFU/100 mL, representing 3.3% of samples and thus meeting the EQG (Table 16 and Table 18). The percentage of samples exceeding 21 CFU/100 mL has never been greater than 3.3% of samples and has never exceeded the 10% criteria (Figure 29).

Table 16 Environmental Quality Guideline for thermotolerant coliform concentrations

EQG	Median TTC concentrations at sites at the boundary of the OZI are not to exceed 14 CFU/100 mL with no more than 10% of the samples exceeding 21 CFU/100 mL as measured using the membrane filtration method

Note:

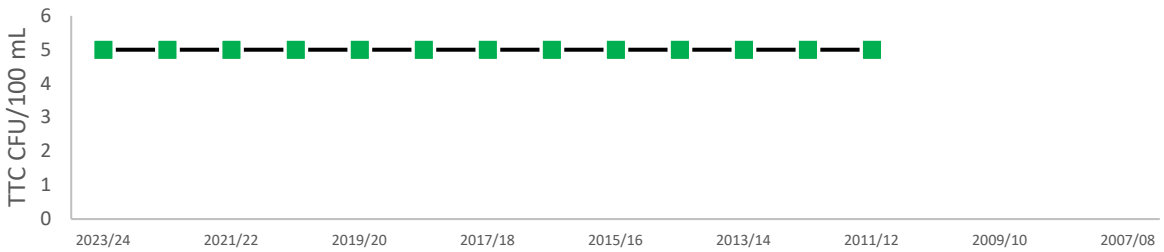
1. TTC = thermotolerant coliforms OZI = Observed Zone of Influence, CFU = colony forming units.

Table 17 **Median thermotolerant coliform concentration at the boundary of the Seafood Management Observed Zone of Influence for the Swanbourne outlet pooled over 2021–2024 sampling periods**

Sampling period	Median	Compliance
Dec 2021–Mar 2022 Dec 2022–Mar 2023 Dec 2023–Mar 2024	<10 CFU/100 mL	■

Note:

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



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

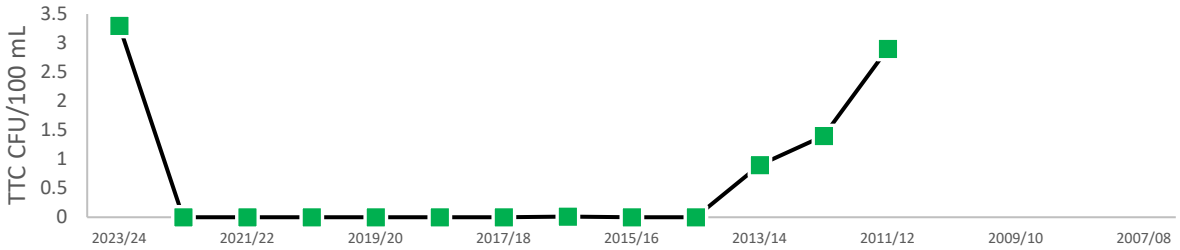
Figure 28 **Median thermotolerant coliforms over time**

Table 18 **Thermotolerant coliforms on the boundary of the Seafood Management Zone for Swanbourne outlet over 2023–2024 summer sampling periods that exceed 21 CFU/100 mL**

Sampling season	Date	Site	TTC Concentration (CFU/100 mL)	Compliance
2023–2024	11/01/2024	SB22	30	■
		SB23	60	
		SB24	100	
		SB25	70	
% total samples (n = 120) > 21 CFU/100 mL = 3.3%				

Notes:

1. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) and red (■) symbols represent an exceedance of the Environmental Quality Guideline (EQG) or Environmental Quality Standard (EQS), respectively.
2. CFU = colony forming units; EQG = Environmental Quality Guideline; TTC = thermotolerant coliforms.



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

Figure 29 Percent of samples exceeding 21 CFU/100 mL over time

4.2 Toxic phytoplankton species

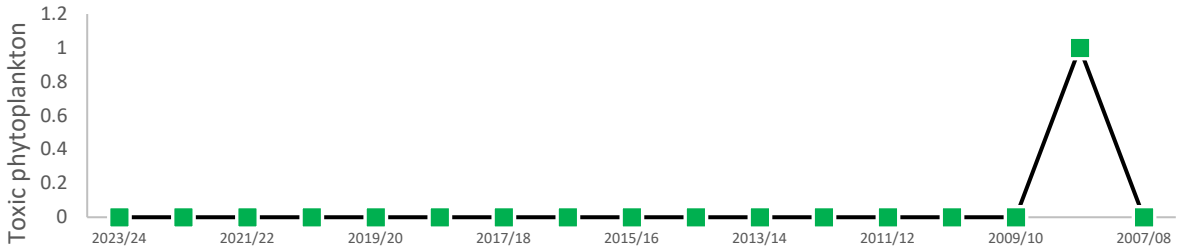
The toxic phytoplankton species *Gymnodinium* spp. potentially exceeded the Western Australian Shellfish Quality Assurance Program (WASQAP; Table 19) guideline value (1000 cells/L) at a reference site (4480 cells/L) on 4 December 2023 and a compliance site (1040 cell/L) on 11 January 2024. However, contemporary analysis reports the cumulative *Gymnodinium* spp. while the trigger is for a single species *Gymnodinium catenatum.* It is likely that the concentration of the single species at the impact site on 11 January 2024 met the EQG concentration (Table 23). There were no other instances where toxic phytoplankton species were present at densities greater than the WASQAP guideline values (Table 24; Appendix I) and the EQG (Table 19) for toxic phytoplankton species was met (Table 23). Toxic phytoplankton exceeding WASQAP concentrations have been present on 1 occasion historically (Figure 30).

Table 19 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. (1000 cells/L) • *Gymnodinium catenatum* (1000 cells/L[3]) • *Karenia brevis* (1000 cells/L) • *Karenia/Karlodinium/Gymnodinium* group[4] (250,000 cells/L) • *Prorocentrum lima* (500 cells/L) • *Pseudo-nitzchia* group[5] (500,000 cells/L)

Notes:

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 2000 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.



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

Figure 30 Exceedance of the toxic phytoplankton EQG over time

Table 20 Estimated cell densities of phytoplankton species known to produce toxins

Date	Site[1]	Species	Estimated density (cells/L)	WASQAP Guideline[2]	Compliance
04/12/2023	SBR3	*Gymnodinium* spp.	4480[6]	1000	N/A
		Karenia papilionaceae	80	250,000	
		Pseudo-nitzschia “delicatissima” group	160	500,000	
		Pseudo-nitzschia “seriata” group	80	500,000	
	SB24	*Gymnodinium* spp.	160	1000	
		Karenia papilionaceae	80	250,000	
		Pseudo-nitzschia “delicatissima” group	240	500,000	
		Pseudo-nitzschia “seriata” group	880	500,000	
15/12/2023	SBR2	*Gymnodinium* spp.	80	1000	N/A
		Pseudo-nitzschia “delicatissima” group	9440	500,000	
		Pseudo-nitzschia “seriata” group	960	500,000	
	SB28	*Gymnodinium* spp.	80	1000	
		Pseudo-nitzschia “seriata” group	880	500,000	
11/01/2024	SBR2	*Pseudo-nitzschia* delicatissima group	800	500,000	N/A
		Pseudo-nitzschia seriata group	400	500,000	
	SB24	*Gymnodinium* spp.	1040[6]	1000	
		Pseudo-nitzschia delicatissima group	1200	500,000	
		Pseudo-nitzschia seriata group	160	500,000	
25/01/2024	SBR2	*Pseudo-nitzschia* delicatissima group	25,200	500,000	N/A
		Pseudo-nitzschia seriata group	1680	500,000	
	SB21	*Pseudo-nitzschia* delicatissima group	4720	500,000	
		Pseudo-nitzschia seriata group	5200	500,000	
07/02/2024	SBR3	*Gymnodinium* spp.	80	1000	N/A
		Pseudo-nitzschia “delicatissima” group	4640	500,000	

Date	Site[1]	Species	Estimated density (cells/L)	WASQAP Guideline[2]	Compliance
		Pseudo-nitzschia "seriata" group	880	500,000	
	SB29	*Gymnodinium* spp.	160	1000	
		Pseudo-nitzschia "delicatissima" group	160	500,000	
		Pseudo-nitzschia "seriata" group	80	500,000	
23/02/2024	SBR4	*Pseudo-nitzschia* "delicatissima" group	5920	500,000	N/A
		Pseudo-nitzschia "seriata" group	1200	500,000	
	SB27	*Pseudo-nitzschia* "delicatissima" group	4480	500,000	
		Pseudo-nitzschia "seriata" group	400	500,000	
1/03/2024	SBR3	*Pseudo-nitzschia* "delicatissima" group	4240	500,000	N/A
		Pseudo-nitzschia "seriata" group	960	500,000	
	SB28	*Pseudo-nitzschia* "delicatissima" group	2240	500,000	
		Pseudo-nitzschia "seriata" group	2080	500,000	
15/03/2024	SBR3	*Pseudo-nitzschia* delicatissima group	400	500,000	N/A
		Pseudo-nitzschia seriata group	480	500,000	
	SB24	*Pseudo-nitzschia* delicatissima group	640	500,000	
		Pseudo-nitzschia seriata group	480	500,000	

Notes:

1. Samples were analysed for one monitoring site and one reference site per sampling occasion.
2. Western Australian Shellfish Quality Assurance Program (WASQAP): Operations Manual 2011. (DoH & DoF 2007).
3. – = no toxic species detected, NA = not applicable.
4. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met; amber (■) symbol represents an exceedance of the Environmental Quality Guideline (EQG).
5. Karenia/Karlodinium/Gymnodinium group trigger from DoH, DPIRD and Industry (2020).
6. Not an EQG exceedance at SBR3 on 0/12/2023 as the sample was from the reference site. Low-level exceedance reported on 11/01/2024 assessed concentration against guideline for total *Gymnodinium* spp count comprised of multiple different species and is likely not a true exceedance.

4.1 Faecal pathogens (*Enterococci* spp.)

Samples were collected eight times over the 2023–2024 summer monitoring period (yielding a total of n = 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 (2021–2024) were pooled to yield 120 samples. The EQG for primary and secondary contact recreation are outlined in Table 21.

Table 21 Environmental Quality Guidelines for contact recreation

Primary[1]	**EQG1**	The 95th percentile bacterial content of marine waters should not exceed 200 *Enterococci* MPN/100 mL
Secondary[2]	**EQG2**	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.

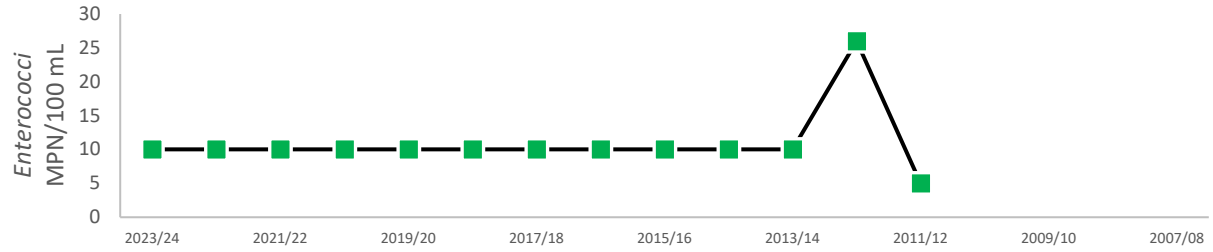
Over the past three summers, the 95th percentile of *Enterococci* spp. concentrations at the boundary of the OZI for the Swanbourne ocean outlet was 10 MPN/100 mL and both the primary (<200 MPN/100 mL) and secondary (<2000 MPN/100 mL) contact recreation EQG for faecal pathogens in water were met (Table 22). The 95th percentile *Enterococci* spp. concentrations have varied little since 200-2008 (Figure 31).

Table 22 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 2021–Mar 2022 Dec 2022–Mar 2023 Dec 2023–Mar 2024	10 MPN/100 mL	■	■

Notes:

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



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

Figure 31 **95th percentile *Enterococci* spp. concentrations over time**

4.2 Phytoplankton cell concentrations

The concentrations of phytoplankton cells are compared to the EQC for toxic algae in marine recreational water. Table 22 presents the specific EQC values for toxic algae in marine recreational water as outlined in EPA (2017).

Table 23 **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
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

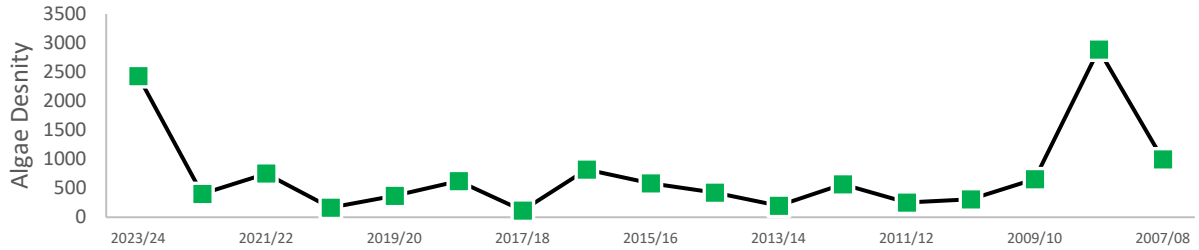
Notes:
1. EQG = Environmental Quality Guideline, EQS = Environmental Quality Standard.

The density of phytoplankton was below 10,000 cells/mL at each of the individual monitoring sites during the 2023–2024 monitoring period, (Table 22). The EQG for phytoplankton concentrations was met. Algal density has not historically exceeded the EQG criteria (Figure 32).

Table 24 **Estimated phytoplankton total cell densities collected at fixed monitoring sites for contact recreation down-current of the Swanbourne outlet**

Date	Site	Total density (cells/mL)	Compliance
04/12/2023	SB5	2429	
15/12/2023	SB11	173	
11/01/2024	SB6	167	
25/01/2024	SB6	1235	■
07/02/2024	SB14	189	
23/02/2024	SB10	14	
01/03/2024	SB11	228	
15/03/2024	SB8	39	

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



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

Figure 32 Algal density over time

5 Aesthetics

Aesthetic quality was assessed fortnightly via a questionnaire completed by field personnel on eight occasions during the non-river flow period (Table 25). On each occasion, the questionnaire was completed at one location on 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 25 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.	

The field surveys found algae/plant material visible on the surface on 25% of occasions (Table 26). No dead marine organisms were visible on any occasion (Table 26). There was noticeable colour variation on 37.5% of occasions (Table 26). There were no films or oil on the surface, noticeable odour or floating debris on any sampling occasion (Table 26). 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 (0.0876 Log_{10}/m) was slightly higher than at 1500 m distance from the outlet (0.0778 Log_{10}/m) suggesting that light was more quickly attenuated at 350 m than 1500 m (Table 27). Overall water clarity was decreased by ~13% and therefore the EQG (natural visual clarity of the water should not be reduced by more than 20%) that the natural visual clarity of the water should not be reduced by more than 20% was met.

Table 26 **Aesthetic observations and measurements at selected sites down-current of the Swanbourne ocean outlet**

Date	Site	Algae/ plant material?	Dead marine organisms?	Secchi depth (m)	Colour variation?	Oil or other films?	Floating debris?	Odour?	Cotton Buds?
04/12/2023	SB7	No	No	5.2	No	No	No	No	No
15/12/2023	SB11	Yes	No	11.9	No	No	No	No	No
11/01/2024	SB6	No	No	4.7	Yes	No	No	No	No
25/01/2024	SB7	No	No	4.5	Yes	No	No	No	No
07/02/2024	SB12	Yes	No	11	No	No	No	No	No
23/02/2024	SB10	No	No	9.5	No	No	No	No	No
01/03/2024	SB12	No	No	4.5	Yes	No	No	No	No
15/03/2024	SB9	No	No	9.5	No	No	No	No	No

Table 27 **Light attenuation coefficient at sites 350 m and 1500 m down-current from the Swanbourne ocean outlet**

Date	Light attenuation coefficient (Log^{10}/m)	
	350 m (site SBT-350 m)	1500 m (site SBT – 1500 m)
04/12/2023	0.0946	0.0704
15/12/2023	0.0703	0.0564
11/01/2024	0.0942	0.1006
25/01/2024	0.1207	0.1151
07/02/2024	0.0737	0.0719
23/02/2024	0.0761	0.0626
01/03/2024	0.0951	0.0805
15/03/2024	0.0760	0.0652
Mean	**0.0876**	**0.0778**

6 Shoreline monitoring

6.1 Thermotolerant coliforms

TTC were sampled at eight shoreline monitoring sites eight times over the 2023–2024 summer period (yielding a total of n =n 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 2022–2023 and 2023–24) were pooled to yield 128 samples.

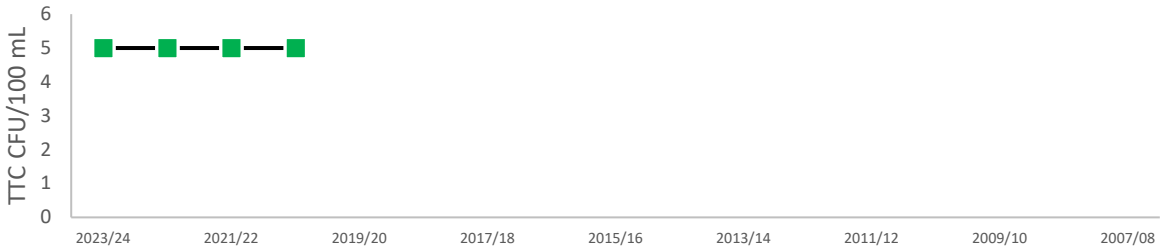
The shoreline sites are not formally assessed against the EQC but the median TTC concentrations derived from the 128 samples was at the LoR (Table 28) (<10 CFU/100 mL; Table 28) and less than the 14 CFU/100 mL criteria (Table 16). Median thermotolerant coliforms in shoreline samples were <10 CFU/100 mL since shoreline monitoring commenced (Figure 33). TTC concentrations exceeded 21 CFU/100 mL in 1.6% of samples and were below the 10% criteria (Table 28). TTC concentrations exceeded 21 CFU/100 mL in between 1.6 and 5% of samples since 2007-2008 and were below the 10% criteria at all times (Figure 34).

Table 28 **Median thermotolerant coliform concentrations at the shoreline monitoring sites for the Swanbourne outlet pooled over for 2022–2024 sampling periods**

Sampling period	Median	%>21 CFU/100 mL	Informal comparison to the criteria
Dec 2022–Mar 2023 Dec 2023–Mar 2024	<10 CFU/100 mL	1.6%	■

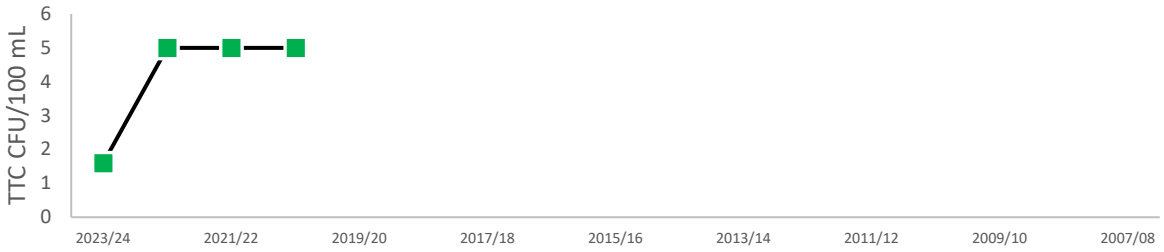
Notes:

1. Green symbols (■) indicate the Environmental Quality Guideline (EQG) were met.
2. Thermotolerant coliform results below the limit of reporting (<10 CFU/100 mL) were halved (=5 CFU/100 mL) to calculate the median.
3. Environmental Quality Criteria are based on EPA (2017).



1. Environmental Quality Criteria (EQC): Green (■) symbols indicate the Environmental Quality Guideline (EQG) was met; amber (■) and red (■) symbols represent an exceedance of the EQG or Environmental Quality Standard (EQS), respectively.
2. Sampling commenced in 2020-2021.

Figure 33 **Median thermotolerant coliforms over time**



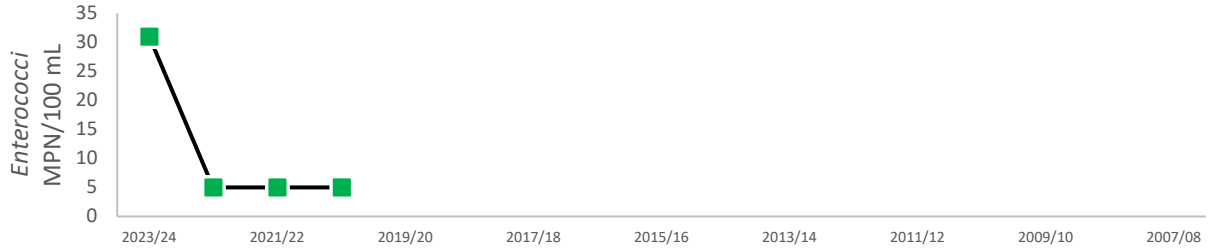
1. Environmental Quality Criteria (EQC): Green (■) symbols indicate the Environmental Quality Guideline (EQG) was met; amber (■) and red (■) symbols represent an exceedance of the EQG or Environmental Quality Standard (EQS), respectively.
2. Sampling commenced in 2020-2021.

Figure 34 Percent of samples exceeding 21 CFU/100 mL over time

6.2 Faecal pathogens (*Enterococci* spp.)

Samples were collected eight times at eight shoreline monitoring sites over the 2023–2024 summer monitoring period (yielding a total of n = 64 samples) for faecal pathogens analyses. NHMRC guideline and EPA (2005) recommend 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 2022–23 and 2023–2024) were pooled to yield 128 samples.

Shoreline sites are not formally assessed against the EQC but over the 2023–2024 summer monitoring period, the 95th percentile of *Enterococci* spp. concentrations at the shoreline monitoring sites for the Swanbourne ocean outlets was 31 MPN/100 mL (Table 29), and below both the primary and secondary (<200 and <2000 MPN/100mL, respectively) contact recreation EQGs (Table 21). The 95th percentile *Enterococci* spp. concentrations at the shoreline monitoring sites were at the limit of reporting at all other times since monitoring began (Figure 35).



1. Environmental Quality Criteria (EQC): Green (■) symbols indicate the Environmental Quality Guideline (EQG) was met; amber (■) and red (■) symbols represent an exceedance of the EQG or Environmental Quality Standard (EQS), respectively.
2. Sampling commenced in 2020-2021.

Figure 35 95th percentile *Enterococci* spp. concentrations over time

Table 29 **The 95th percentile of *Enterococci* spp. concentrations at the shoreline monitoring sites for the Swanbourne ocean outlet pooled over the 2022–2024 sampling periods**

Sampling period	95th percentile	Informal comparison to the criteria	
		Primary contact	Secondary contact
Dec 2022–Mar 2023 Dec 2023–Mar 2024	31 MPN/100 mL	■	■

Notes:

1. MPN = most probable number of *Enterococci* spp.
2. *Enterococci* spp. concentrations below the limit of reporting (<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.

7 References

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