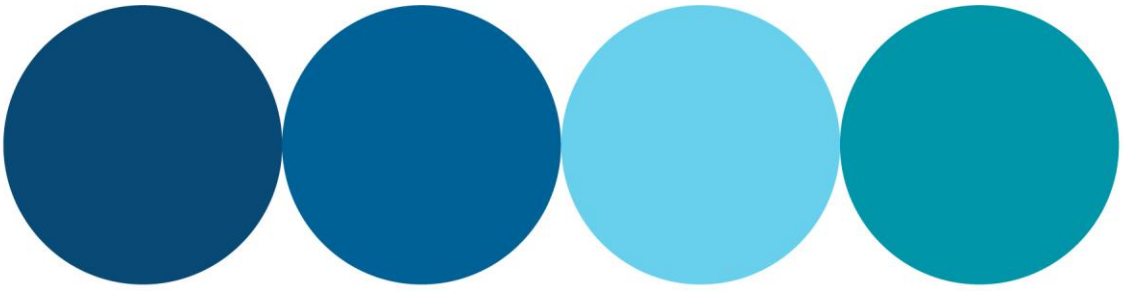
Perth Long Term Ocean Outlet Monitoring Program (PLOOM)

2019-2020 Annual Report

Swanbourne



WATER CORPORATION

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Document history

Distribution

Revision	Author	Recipients	Organisation	No. copies & format	Date
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Review

Revision	Reviewer	Intent	Date
A	M Lourey	Editorial and technical review	10/07/2020
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BMT Commercial Australia Pty Ltd has prepared this report in accordance with our Integrated Management System, in compliance with OHSAS18001, ISO14001 and ISO9001.

Status

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

Approved for final release:

Author
Date: 27/07/2020

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Date: 27/07/2020

Contents

Acronyms

ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
CFU	Colony forming unit
DoH	Western Australian Department of Health
EPA	Environmental Protection Authority
EQC	Environmental Quality Criteria
EQG	Environmental Quality Guideline
EQMF	Environmental Quality Management Framework
EQO	Environmental Quality Objective
EQS	Environmental Quality Standard
EV	Environmental Value
HEPA	High ecological protection area
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
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

Executive Summary

This report documents the findings of the 2019–2020 Swanbourne ocean monitoring program. Results are reported in the context of the Environmental Quality Management Framework (EQMF) described in EPA (2017). The results are summarised in Report Card format (Table ES 1). The report card contains colour-coded results, with the individual colours representing the extent to which the Environmental Quality Criteria (EQC) were met (Table ES 2 -Table ES 4).

Table ES 1 Summary report card legend

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

Note:

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

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

Environmental quality indicator		EQC	Comments	Compliance
Toxicants in treated wastewater (TWW)	Bioaccumulating toxicants	EQG	Concentrations of cadmium and mercury in the undiluted TWW stream were below the limit of reporting and the ANZG (2018) 80% species protection guideline	
	Non-bioaccumulating toxicants and initial dilution	EQG	Initial dilution of 1:174 was sufficient to reduce non-bioaccumulating contaminant concentrations to below their ANZG (2018) 99% species protection guidelines	
	Total toxicity of the mixture (TTM)	EQG	The TTM for the additive effect of ammonia, copper and zinc after initial dilution (0.515) was below the ANZG (2018) guideline value of 1.0	
	Whole of effluent toxicity testing	EQG	The lowest NOEC during the reporting period was 25%. Only four dilutions with background seawater are required to achieve this NOEC which is lower than the dilutions typically	

			achieved at the LEPA boundary.	
Nutrient enrichment	Chlorophyll-a	EQG	Median chlorophyll-a concentration within the high ecological protection area (HEPA) (0.30 µg/L) was lower than the 80th percentile of historical reference site concentrations (0.5 µg/L).	■
	Light attenuation coefficient (LAC)	EQG	Median LAC within the HEPA (0.077 Log_{10}/m) was lower than the 80th percentile of historical reference sites (0.094 Log_{10}/m).	■
Phytoplankton blooms	Phytoplankton biomass (measured as chlorophyll-a)	EQG	There were no instances where median chlorophyll-a concentrations in the HEPA exceeded 3-times the median of reference sites.	■
			Chlorophyll-a did not exceed 3 times the median concentrations of reference sites at any site on any occasion.	
Physical chemistry	Organic enrichment	EQG	Dissolved oxygen saturation remained above 90% saturation at all times.	■
	Salinity	EQG	Median salinity at individual sites within the HEPA was within the 20th and 80th percentile of reference site data	■

Notes:

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

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

Environmental quality indicator		Comments	Compliance
Microbial contaminants	Thermotolerant coliforms (TTC)	Median TTC concentrations derived from 115 samples collected over the 2017–2018, 2018–2019 and 2019–2020 sampling seasons was at the limit of detection (<10 CFU/100 mL) and les than 14 CFU/100 mL	■
		The 90th percentile was equal to the limit of detection (<10 CFU/100 mL), and less than 21 CFU/100 mL	■
Algal biotoxins	Toxic phytoplankton species	Toxic phytoplankton species were not recorded in excess of Western Australian Shellfish Quality Guidelines during the 2019–2020 monitoring.	■

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. TTC results below the analytical detection limit (<10 CFU/mL) were halved (=5 CFU/mL) to calculate median value.

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

Environmental Quality Indicator		EQC	Comments	Compliance
Faecal streptococci	*Enterococci* spp.	EQG (primary contact)	The 95th percentile of *Enterococci* spp. concentrations (10 MPN/100 mL) was lower than the 200 MPN/100 ml EQG	■
		EQG (secondary contact)		
Algal biotoxins	Phytoplankton (cell concentration)	EQG	Estimated total phytoplankton cell count at individual sites were <10 000 cells/mL at each site and sampling occasion during 2019–2020 monitoring.	■

Note:

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

Introduction

Document purpose

This annual report documents the findings of the 2019–2020 ocean monitoring around the Swanbourne ocean outlet. Monitoring was completed according to Western Australia's Environmental Quality Management Framework (EQMF; EPA 2016).

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).

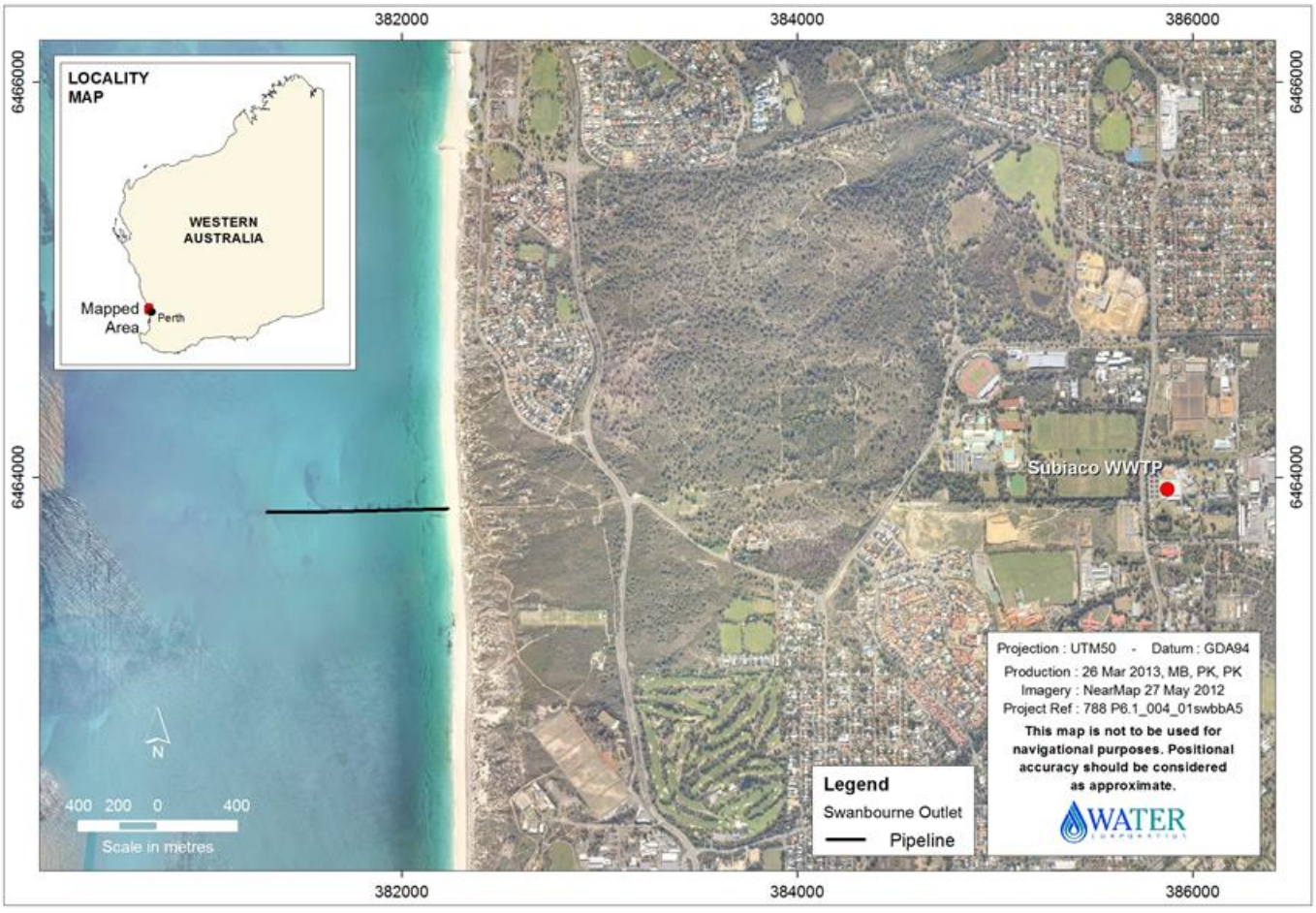
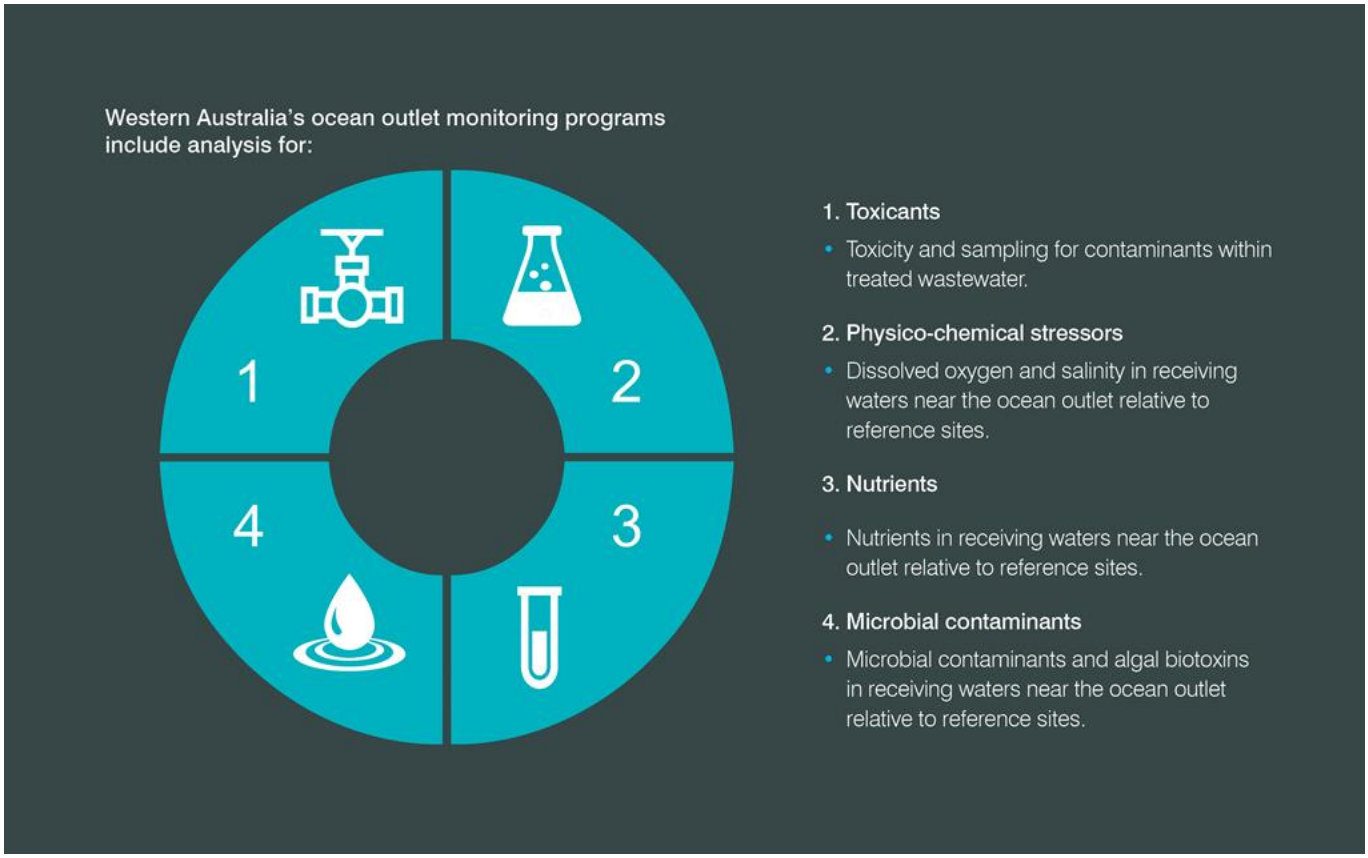


Figure 1 **Location of the Subiaco water resource recovery facility (WRRF) and Swanbourne ocean outlet**

Potential stressors in treated wastewater



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 (also known as direct toxicity assessment).

Physico-chemical stressors

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

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

Nutrients

TWW contains elevated concentrations of biologically the available nutrients ammonia, nitrite, nitrate and orthophosphate. At times, the addition of nutrients may stimulate phytoplankton growth beyond natural levels, which can lead to shading of photosynthetic organisms such as seagrasses and/or macroalgae. The potential for shading is measured using in-water measures of chlorophyll-a (a proxy for phytoplankton biomass) and light attenuation (a measure for water clarity).

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

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.

Environmental management approach

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

Source: GoogleEarth

Figure 2 Aerial image of Swanbourne ocean outlet

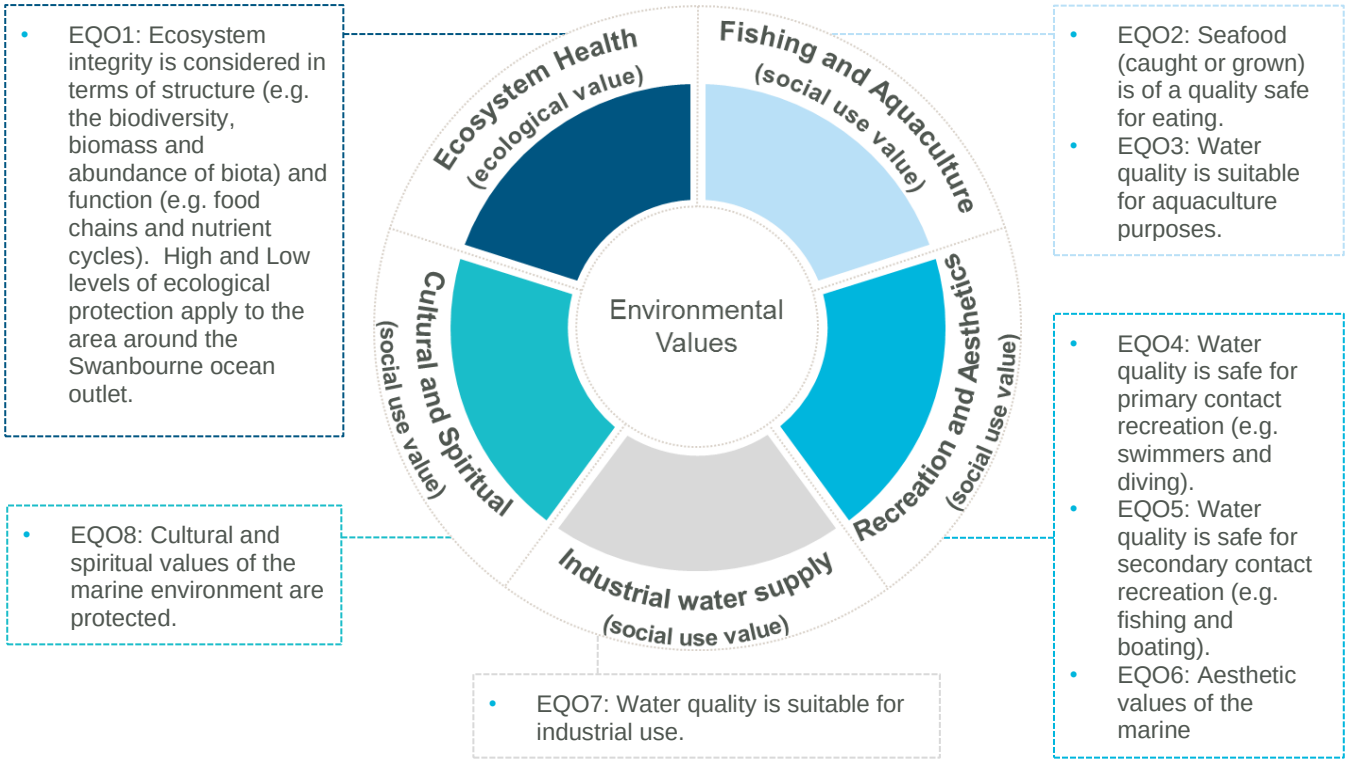
The ocean monitoring program is consistent with the approach advocated under the State Government's EQMF, which is applied to Western Australia's coastal waters (EPA 2016).

The EQMF is based on:

- identifying **Environmental Values** (EVs) (Figure 3)
- establishing and spatially defining **Environmental Quality Objectives** (EQOs) that need to be maintained to ensure the associated EVs are protected (Figure 4)
- monitoring and managing to ensure the EQOs are achieved and/or maintained in the long-term in the areas they have been designated
- establishing **Environmental Quality Criteria** (EQC) which are quantitative benchmarks or 'trigger values' against which monitoring results can be compared.

There are two levels of EQC:

1. **Environmental Quality Guidelines** (EQGs) are quantitative, investigative triggers which, if met, indicate there is a high degree of certainty the associated EQO has been achieved. If the guideline is not met a more detailed assessment against the EQS is triggered.
2. **Environmental Quality Standards** (EQSs) are management triggers which, if exceeded, signify the EQO is at risk of not being met and that a management response may be required.



Source: EPA (2016)

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

'Maintenance of Ecosystem Integrity' EQO

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

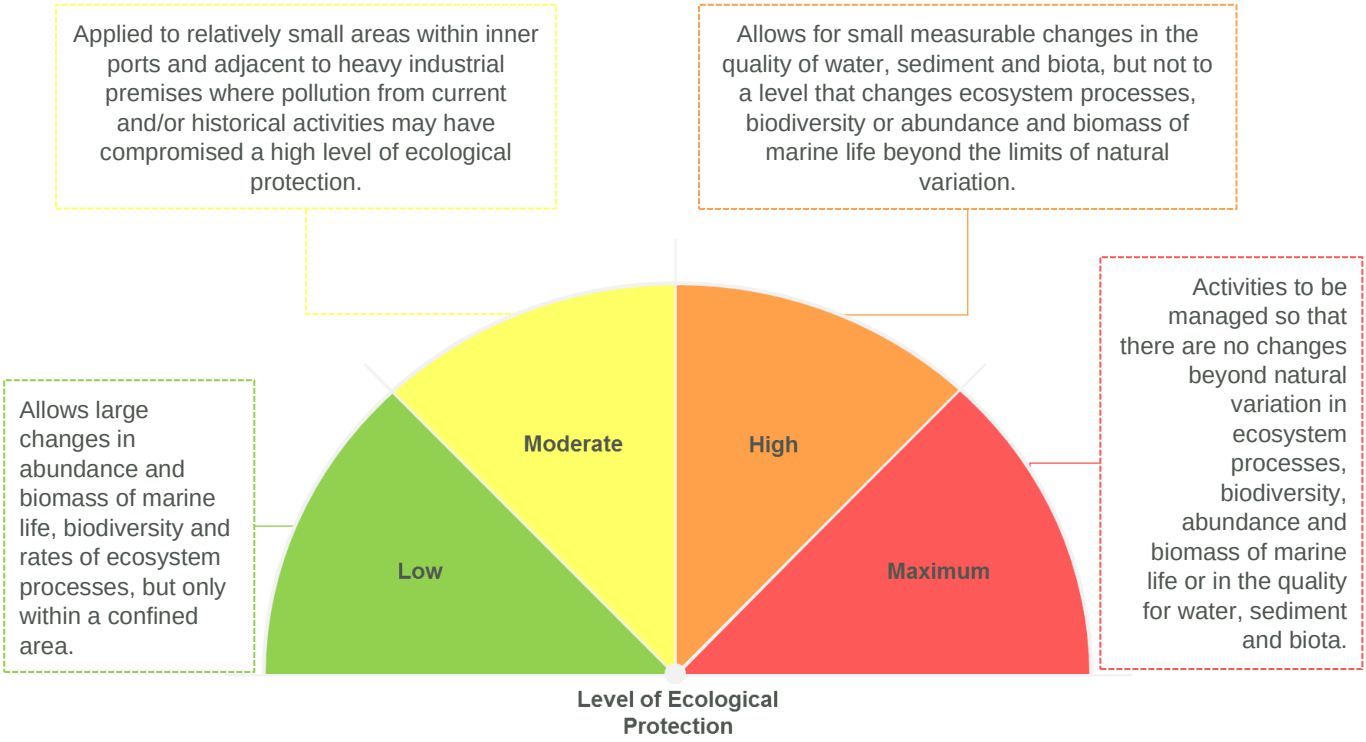


Figure 4 Level of Ecological Protection

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

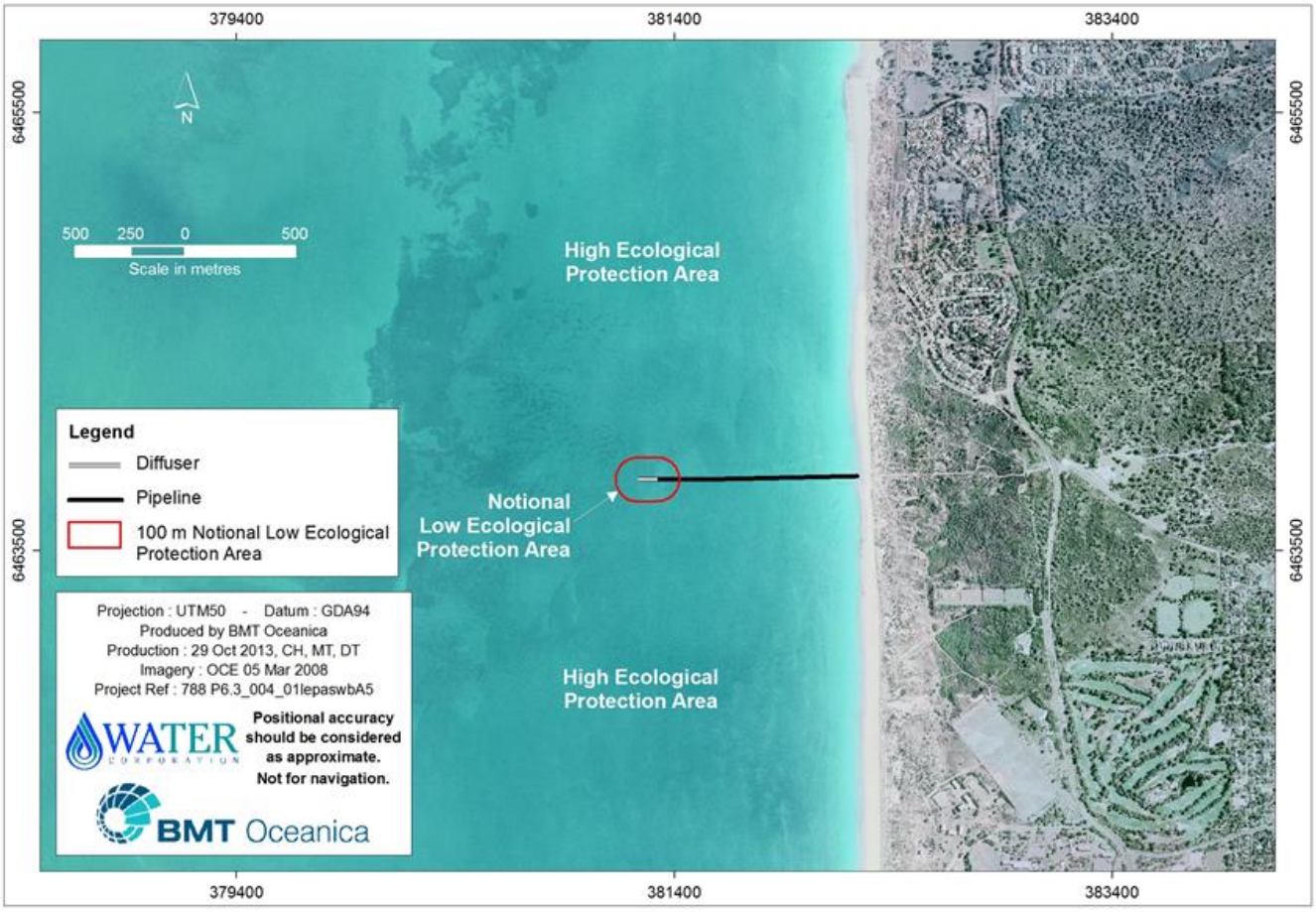


Figure 5 Swanbourne ocean outlet notional ecological protection boundaries

'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. 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.

'Maintenance of Primary and Secondary Contact Recreation' EQOs

The primary and secondary contact EQOs support swimming and boating activities, respectively. The EQOs apply throughout Perth's coastal waters, except for areas around the ocean outlets where water quality may not be suitable for swimming.

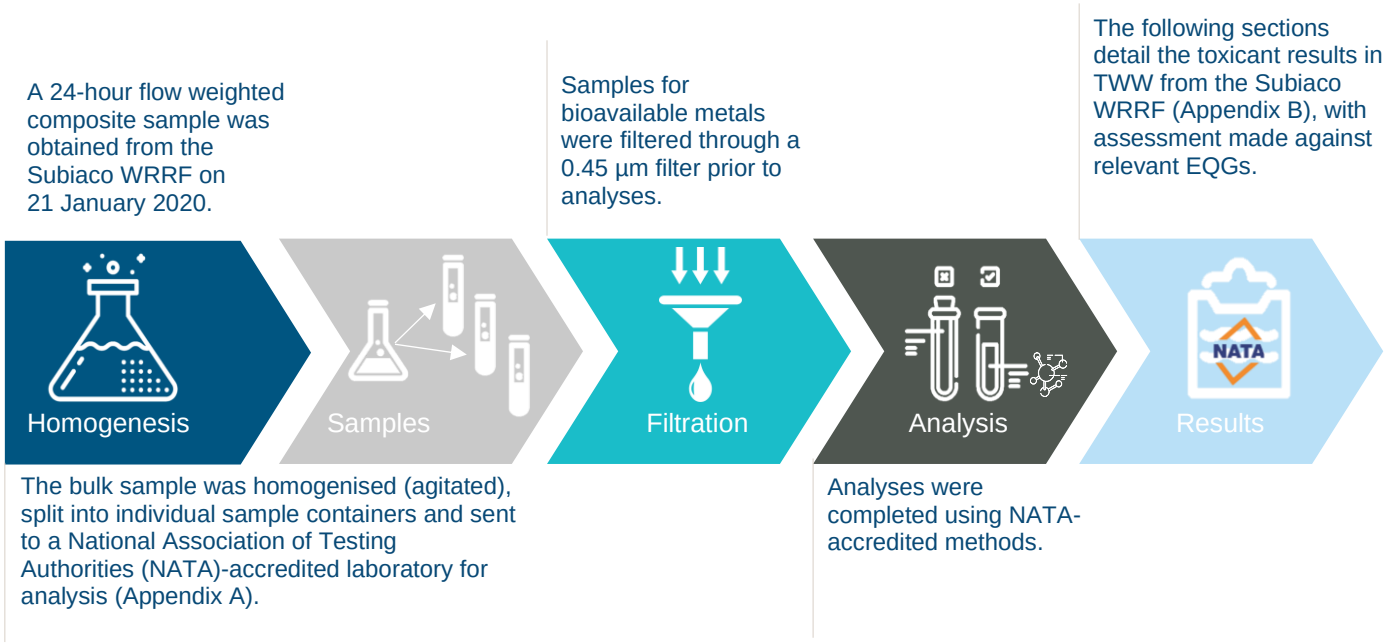
A formal area where primary contact recreation is not recommended has not been established for the Swanbourne outlet. However, an informal zone has been developed for the Swanbourne outlet encompassing the area containing elevated microbiological concentrations – this was derived from ten years of field data. 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.

Toxicants in treated wastewater

Comprehensive treated wastewater characterisation

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

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



Bioaccumulating toxicants

The EQG for bioaccumulating toxicants (cadmium and mercury) in the TWW is outlined in Table 1.

Table 1 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

Concentrations of cadmium and mercury (i.e. bioaccumulating toxicants) in the TWW sample were both below the analytical limit of reporting (<0.1 µg/L; Table 3) and the EQG for bioaccumulating toxicants was met.

Non-bioaccumulating toxicants

The EQG for non-bioaccumulating toxicants in the TWW is outlined in Table 2.

Table 2 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 (with the exception of cobalt, where the 95% guideline trigger level will apply) is achieved at the boundary of the low ecological protection area (LEPA) (i.e. a high level of protection is met beyond a 100 m radius of the diffuser).

Note:

1. EQG = Environmental Quality Guideline

Non-bioaccumulating toxicant concentrations were generally below the analytical limit of reporting except for ammonia, copper, nickel and zinc (Table 3). After initial dilution of 1:174 (a conservative estimate of the dilution expected a the LEPA boundary; Appendix C), contaminant concentrations of ammonia, copper, nickel and zinc were below ANZG (2018) 99% species protection guidelines (Table 3) and the EQG for non-bioaccumulating toxicants was met.

Table 3 Toxicants in the Swanbourne TWW stream compared with relevant guideline trigger levels after initial dilution

Toxicant	Swanbourne TWW concentration (µg/L)	Concentration after initial dilution (µg/L)	Trigger (µg/L)
Ammonia-N	23	1.6	500
Cadmium*	<0.1	–	36
Chromium*	<1	–	0.14 (Cr VI)
Copper*	9	0.1	0.3
Lead*	<1	–	2.2
Mercury*	<0.1	–	1.4
Nickel*	3	0.5	7
Silver*	<0.8	–	0.8
Zinc*	62	0.5	7
Chloropyrifos	<0.1	–	0.0005
Endrin	<0.01	–	0.004
Endosulfan sulfate	<0.01	–	0.005
Benzene	<1	–	500
Naphthalene	<0.01	–	50
Benzo(g,h,i)perylene	<0.01	–	50

Notes:

1. Assessment against ANZG (2018) 99% species protection guideline values was undertaken only for those toxicants where trigger levels were available.
2. TWW = Treated wastewater
3. Initial dilution = 1:174 (predicted average value for Swanbourne outlet). Contaminant dilution calculations were not performed (–) on any toxicants where concentrations were below the analytical limit of reporting.
4. The trigger values for marine waters are from ANZG (2018). The EPA has provided advice that in WA waters where a high level of protection applies, 99% species protection levels should be used.
5. The bioaccumulating toxicants cadmium and mercury must meet the 80% species protection guidelines at the diffuser (i.e. prior to initial dilution), and therefore a diluted concentration was not calculated.
6. Analytical limits for Chloropyrifos were not low enough to confirm exceedance of, or compliance with, the ANZG (2018) guidelines. Until detection limits required for direct comparison can be attained by commercial laboratories, WET testing will provide a test of the toxicity of the wastewater stream (See Appendix D).
7. Trigger values are for endosulfan, not endosulfan sulfate (ANZG 2018).
8. *= dissolved metals 0.45 µm filtered.

Total toxicity of the mixture (TTM)

The potential for cumulative toxic effects on marine organisms was assessed after initial dilution as per ANZG (2018). The EQG for the total toxicity of the mixture (TTM) is outlined in Table 4.

Table 4 Environmental Quality Guideline for the total toxicity of the mixture

EQG	Where there are mixtures of toxicants, the TTM at a single site or for a defined area, should not exceed 1, using the TTM formula.

Source EPA (2017)

Notes:

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

The TTM for the combined effect of ammonia, copper and zinc following initial dilution (0.515; Table 5), was less than the ANZG (2018) guideline value of 1.0, and the EQG for TTM was met.

Table 5 Total toxicity of treated wastewater (TWW) at the edge of the initial mixing zone associated with the Swanbourne ocean outlet

Natural concentrations in Perth's coastal waters			Initial dilution of TWW with seawater	Total toxicity of the mixture (TTM)
Ammonia	Copper	Zinc		
23	9	62	1:174	0.515

Notes:

1. Background concentrations for copper and zinc from McAlpine et al. (2005); Perth marine waters (99. 19; Table 12). Surface background concentration for ammonia calculated as median of reference site data from 2004–2019 (BMT, unpublished data).
2. TMM = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline.

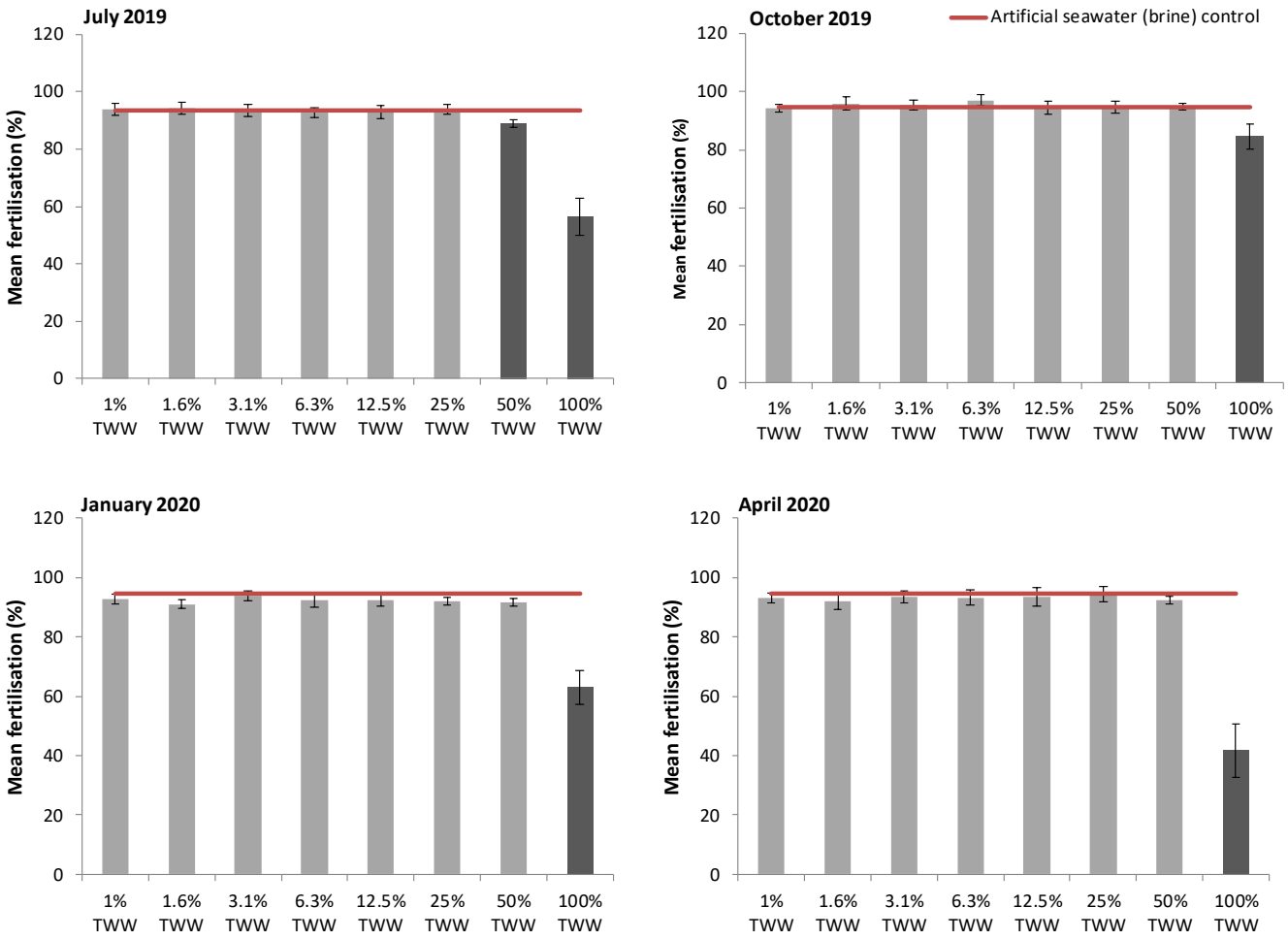
Whole of effluent toxicity (WET) testing

WET testing is useful for assessing toxicity in the absence of reliable guidelines, for toxicants that occur in low concentrations, or where the toxicity effects of contaminants are poorly understood. Fertilisation success in sea urchins (*Heliocidaris tuberculata*) exposed to salt adjusted dilutions (1.0, 1.6, 3.1, 6.3, 12.5, 25, 50, and 100%) of TWW was used to calculate a No Observed Effect Concentration (NOEC; the highest wastewater concentration where no significant effect is observed) (Appendix D). The EQG for the whole of effluent toxicity (WET) testing is outlined in Table 6.

Table 6 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 100-fold dilution) DRNOEC = number of dilutions required to achieve the no observed effects concentration (NOEC). Breaching the above triggers investigations against the EQS, which would comprise the full suite of WET tests (minimum of five species from four trophic groups).

In October 2019, February 2020 and April 2020, sea urchin fertilisation was significantly lower than the artificial seawater control when exposed to 100% TWW concentration (with all other concentrations not significantly different to the control; Figure 6). In July 2019, sea urchin fertilisation was significantly lower than the artificial seawater control when exposed to 50 and 100% TWW concentrations (with all other concentrations not significantly different to the control; Figure 6). The NOEC was greater than 1% in TWW (i.e. ≤100-fold dilution) in all four samples (Table 7; Appendix D), and the EQG for WET testing was met.



Notes:

1. Error bars represent ± standard deviation
2. TWW = treated wastewater
3. Light grey bars represent concentrations of treated wastewater (TWW) at which there is no observed significant effect on fertilisation. Dark grey bars represent concentrations of TWW that acted to significantly reduce the success of sea urchin fertilisation.

Figure 6 Comparison of whole of effluent toxicity TWW dilution results to artificial seawater control

Table 7 Calculated parameters from whole of effluent toxicity tests

Indicator	July 2019	October 2019	January 2020	April 2020
NOEC	25%	50%	50%	25%
Dilutions required to meet the NOEC	4	2	2	4
Dilutions required/dilutions achieved	0.023	0.011	0.011	0.023
≤1	Yes	Yes	Yes	Yes

Note:

1. NOEC = No Observed effect concentration.

Water quality monitoring – receiving environment

Nutrients, phytoplankton biomass and physical and chemical stressors were monitored approximately fortnightly from the beginning of December 2019 to the end of March 2020 (coinciding the summer non-river flow period) along a down-current gradient away from the diffuser (Table 8; Appendix E and Appendix F).

Table 8 Water quality monitoring dates near the Swanbourne ocean outlet between December 2019 and March 2020

Sample day	Date
1	10/12/2019
2	17/12/2019
3	7/01/2020
4	23/01/2020
5	07/02/2020
6	21/02/2020
7	6/03/2020
8	20/03/2020

Wind direction, strength, current direction grid and cloud cover on the day of sampling were recorded (Table 9).

Table 9 Weather and current grid during water quality monitoring near the Swanbourne ocean outlet

Date	Wind direction	Wind strength (knots)	Cloud cover (%)	Current grid
10/12/2019	SE	2-4	10	SW
17/12/2019	SW	10-12	20	N
7/01/2020	SW	2-4	0	SE
23/01/2020	SW	12-16	30	NE
07/02/2020	SW	5	60	S
21/02/2020	E	5-10	100	W
6/03/2020	SW	10-12	50	NE
20/03/2020	E	6-10	100	SW

Notes:

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

Nutrient enrichment

The EQGs for nutrient enrichment in receiving waters are outlined in Table 10.

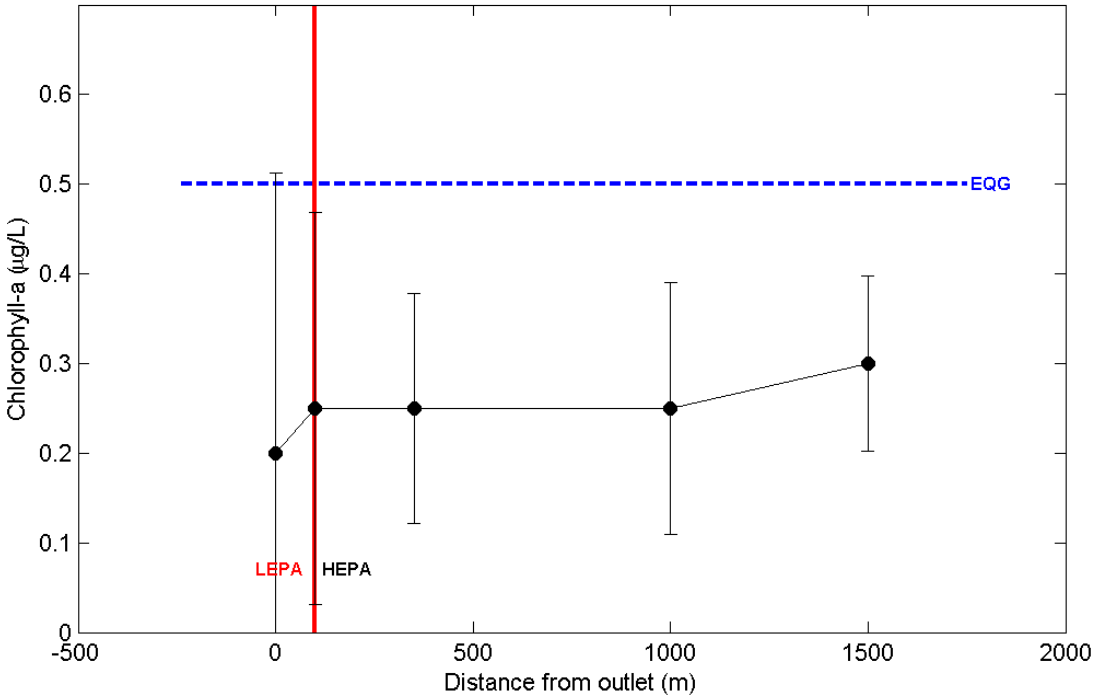
Table 10 Environmental quality guidelines for nutrients

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

Note:

1. EQG = Environmental Quality Guideline

The median chlorophyll-a concentration in the Swanbourne HEPA (≥100 m) was 0.30 µg/L and below the 80th percentile of historical reference site data (0.5 µg/L; Figure 7), meeting the EQG (Table 10).

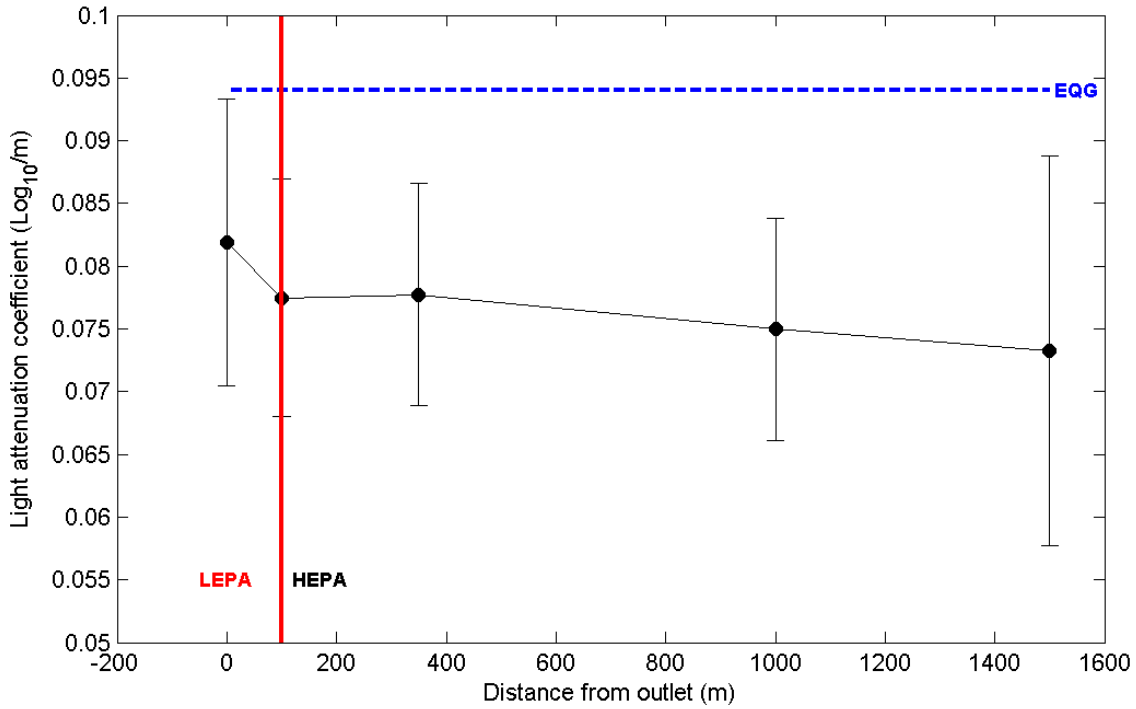


Notes:

1. Error bars represent ±95% confidence intervals.
2. Environmental Quality Guideline (EQG) is the 80th percentile of historical reference site data (0.5 µg/L chlorophyll-a).
3. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
4. Data for each distance were pooled across eight sampling days over December 2019–March 2020; (Appendix G).

Figure 7 Median chlorophyll-a concentrations obtained at fixed monitoring sites above and down-current of the Swanbourne outlet during the summer monitoring period

The median light attenuation in the Swanbourne HEPA (100 m plus) was 0.077 Log_{10}/m and lower than the 80th percentile of historical reference site data (0.094 Log_{10}/m; Figure 8), meeting the EQG.



Notes:

1. Error bars represent ±95% confidence intervals
2. Environmental Quality Guideline (EQG) is the 80th percentile of historical reference site data (0.094 Log10/m)
3. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
4. Data for each distance were pooled across seven sampling days over December 2019–March 2020.

Figure 8 Median light attenuation coefficient obtained at fixed monitoring sites above and down-current of the Swanbourne outlet during the summer monitoring period

Phytoplankton blooms

The EQGs for phytoplankton blooms in receiving waters are outlined in Table 11.

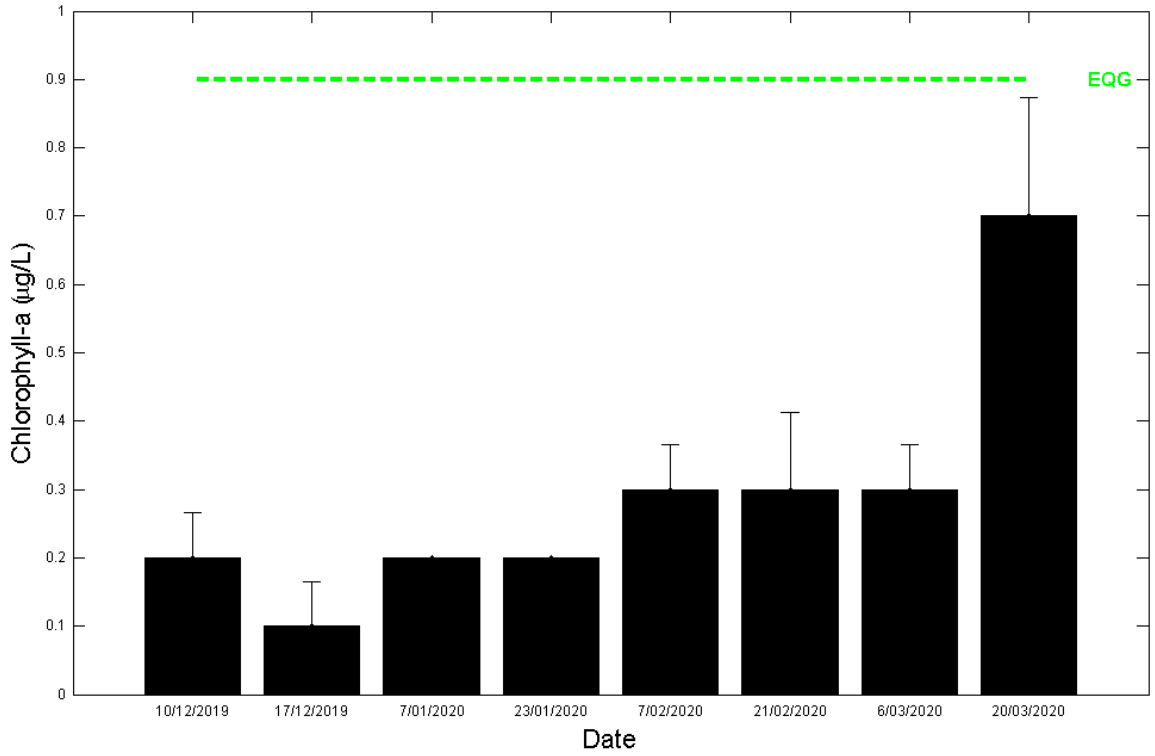
Table 11 Environmental Quality Guidelines for phytoplankton in receiving waters

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.

Note:

1. EQG = Environmental Quality Guideline

Median chlorophyll-a concentration within the HEPA did not exceed three times the median of reference sites (0.9 µg/L; Figure 9) on any sampling occasion during the summer monitoring period and the EQG1 was met. Phytoplankton biomass, measured as median chlorophyll-a at any site, did not exceed three times the median of reference sites, on any sampling occasion during the summer monitoring period meeting the requirements of EQG2 (<25% of occasions).



Notes:

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

Figure 9 Median phytoplankton biomass during the summer monitoring period, pooling data from fixed sites ≥100 m down-current of the Swanbourne ocean outlet

Physical-chemical stressors

Dissolved oxygen (DO)

The EQG for DO is outlined in Table 12.

Table 12 Environmental Quality Guidelines for dissolved oxygen

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

Note:

1. EQG = Environmental Quality Guideline

Bottom (0-0.5 m) DO saturation levels near the outlet were >90% at all times throughout the summer survey period (Figure 10) and the EQG for organic enrichment was met.

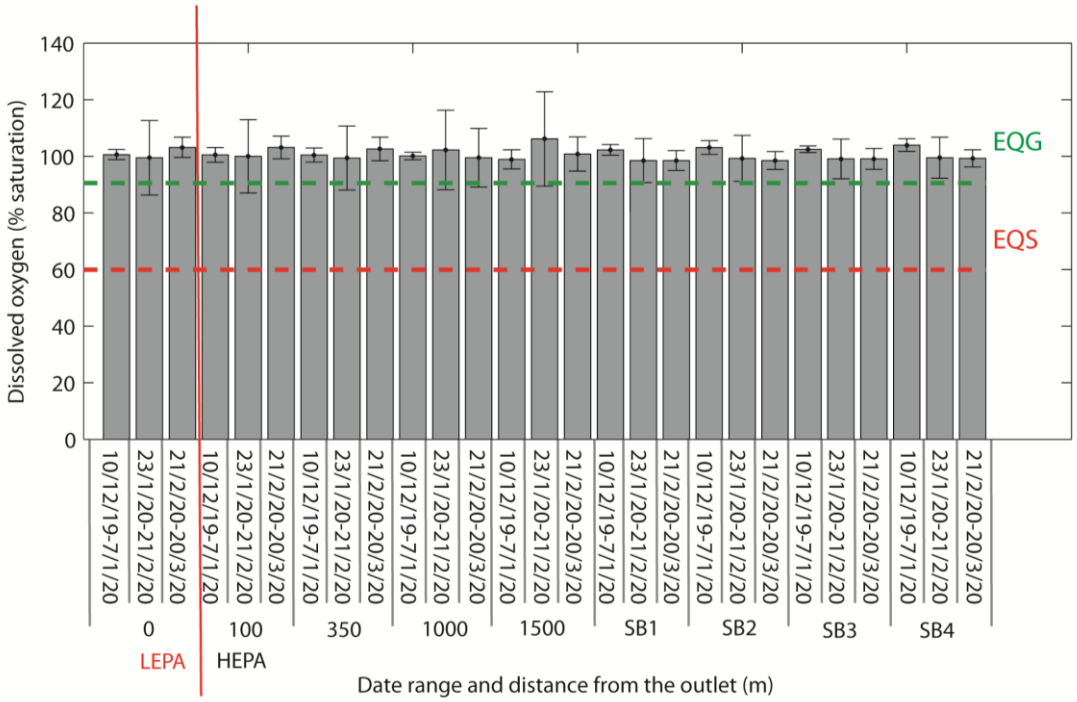


Figure 10 Median dissolved oxygen for defined period of ≤6 weeks during the summer monitoring period

Salinity

The EQG for salinity is outlined in Table 13.

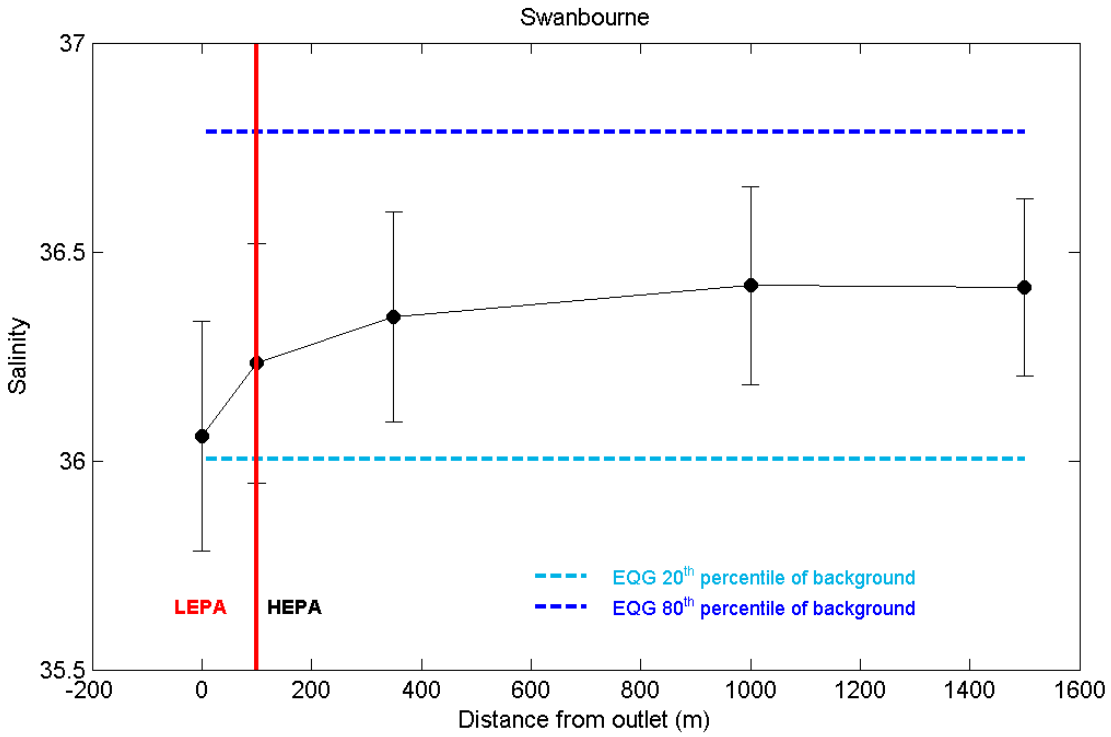
Table 13 Environmental Quality Guideline for salinity

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.

Note:

1. EQG = Environmental Quality Guideline

Median salinity at individual sites within the HEPA ranged from 36.2331 at 100 m from the outlet to 36.4194 at 1000 m from the outlet and were between the 20th (36.0028) and 80th (36.7871) percentiles of the natural salinity range at all sites within the notional HEPA (at 100, 350, 1000 and 1500 m from the outlet; Figure 11) over the summer monitoring period meeting the EQG (Table 13).



Notes:

1. Error bars represent ±95% confidence intervals.
2. Salinity measured 0–0.5 m below the sea surface.
3. Dark blue dashed line = 80th percentile background Environmental Quality Guideline
4. Light blue dashed line = 20th percentile background Environmental Quality Guideline
5. LEPA = notional low ecological protection area; HEPA = high ecological protection area.
6. Data for each distance was pooled across seven sampling occasions over December 2019–March 2020.

Figure 11 Median salinity compared to the 20th and 80th percentile of reference site data during the summer monitoring period

Microbiological contaminants and algal biotoxins

Thermotolerant coliforms

TTC were sampled eight times over the 2019–2020 summer period (yielding a total of 40 samples). NHMRC (2008) guidelines and EPA (2005) require a minimum of 100 samples for accurate assessment of the EQC. Data from multiple years can be pooled where there are less than 100 samples provided local pollution conditions have not changed (NHMRC 2008). Assuming conditions have not changed, data collected over three summers (since 2017–2018) were pooled to yield 115 samples. The EQG for thermotolerant coliforms is outlined in Table 14.

Table 14 Environmental Quality Guideline for thermotolerant coliforms

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

Notes:

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

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

Table 15 Median and 90th percentile thermotolerant coliform concentrations at the fixed monitoring sites for the Swanbourne ocean outlet for 2017–2020 and comparison to the EQC

Sampling period	Median	90th Percentile	Compliance
Dec 2017–Mar 2018 Dec 2018–Mar 2019 Dec 2019–Mar 2020	<10 CFU/100 mL	<10	■

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) and Environmental Quality Standard (EQS), respectively.
2. Thermotolerant coliform results below the analytical detection limit (<10 CFU/100 mL) were halved (=5 CFU/100 mL) to calculate the median and 90th percentile (Appendix H).
3. Environmental Quality Criteria are based on EPA (2017).

Toxic phytoplankton species

The EQG for toxic phytoplankton species is outlined in Table 16.

Table 16 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* spp. (200 cells/L) • *Gymnodinium catenatum* (1000 cells/L) • *Karenia brevis* (1000 cells/L) • Karenia/Karlodinium/Gymnodinium group (250 000 cells/L) • *Dinophysis* spp. (1000 cells/L) • *Prorocentrum lima* (500 cells/L) • *Pseudo-nitzchia* delicatissima group (500 000 cells/L) • *Pseudo-nitzchia* seriata group (50 000 cells/L)

Note:

1. Marine Biotoxin Monitoring and Management Plan 2016: Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH 2016).

There were no instances where toxic phytoplankton species were present at densities greater than the Western Australian Shellfish Quality Assurance Program (WASQAP; DoH 2016) guideline values (Table 17; Appendix I).

Table 17 Estimated cell densities of phytoplankton species known to produce toxins

Date	Site[1]	Species	Estimated density	WASQAP Guideline[2]	Compliance
10/12/2019	SB29	*Pseudo nitzschia* “seriata group”	372	50 000	■
	SBR3	No toxic species recorded	-	-	na
17/12/2019	SB23	*Pseudo nitzschia* “delicatissima group”	960	500 000	■
		Gymnodinium spp.	160	250 000	
	SBR3	*Gymnodinium* spp.	80	250 000	na
		Pseudo nitzschia “delicatissima group”	1760	500 000	
7/01/2020	SB17	*Gymnodinium* spp.	160	250 000	■
		Pseudo nitzschia spp.	1360	500 000	
	SBR3	*Pseudo nitzschia* spp.	1520	-	na
23/01/2020	SB19	*Pseudo nitzschia* “delicatissima group”	640	500 000	■
		Gymnodinium spp.	1280	250 000	
	SBR3	*Pseudo nitzschia* “delicatissima group”	10240	-	na
7/02/2020	SB30	*Pseudo nitzschia “delicatissima group”*	240	500 000	■
		Gymnodinium spp.	480	250 000	
	SBR3	*Pseudo nitzschia “delicatissima group”*	480	-	na
		Gymnodinium spp.	240	-	
21/02/2020	SB28	No toxic species recorded	-	-	■
	SBR3	*Pseudo nitzschia “delicatissima group”*	560	-	na
6/03/2020	SB19	*Pseudo nitzschia “delicatissima group”*	800	500 000	■
		Gymnodinium spp.	80	250 000	
	SBR3	*Pseudo nitzschia “delicatissima group”*	7200	-	na
		Gymnodinium spp.	80	-	
20/03/2020	SB29	*Pseudo nitzschia “delicatissima group”*	117600	500 000	■
		Pseudo nitzschia “seriata group”	48080	50 000	
	SBR3	*Pseudo nitzschia “delicatissima group”*	86160	–	na
		Pseudo nitzschia “seriata group”	42400	–	
		Gymnodinium spp.	80	–	

Notes:

1. Samples were analysed for one monitoring site and one reference site per sampling occasion. Reference results are not applicable (na) to compliance.
2. Marine Biotoxin Monitoring and Management Plan 2016: Western Australian Shellfish Quality Assurance Program (WASQAP) (DoH 2016).
3. Green (■) symbols indicate the Environmental Quality Criteria (EQC) were met.

Faecal streptococci (Enterococci spp.)

Samples were collected eight times over the 2019–2020 summer monitoring period (yielding a total of 40 samples) for faecal streptococci 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 were pooled to yield 115 samples. The EQG for primary and secondary contact recreation are outlines in Table 18.

Table 18 Environmental quality guidelines for contact recreation

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

Notes:

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

Over the past three summers, the 95th percentile of Enterococci spp. concentrations at the boundary of the observed zone of influence for the Swanbourne ocean outlet was 10 MPN/100 mL (Table 19) 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 19 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 (MPN/100 mL)	Compliance	
		Primary contact	Secondary contact
Dec 2017–Mar 2018 Dec 2018–Mar 2019 Dec 2019–Mar 2020	10	■	■

Phytoplankton cell concentrations

The EQG for phytoplankton cell concentrations are outlined in Table 20.

Table 20 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

Phytoplankton densities at individual sites monitored during 2019–2020 were below 10 000 cells/mL, meeting the EQG (Table 21).

Table 21 Estimated phytoplankton total cell densities collected at one of the fixed monitoring sites for contact recreation down-current of the Swanbourne outlet

Date	Site	Total density (cells/mL)	Compliance
10/12/2019	SB13	4	
17/12/2019	SB7	9	
7/01/2020	SB1	5	
23/01/2020	SB5	35	
7/02/2020	SB14	3	
21/02/2020	SB11	8	
6/03/2020	SB5	16	
20/03/2020	SB13	369	

Note:

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

References

ANZG (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

DoH (2016) Marine Biotoxin Monitoring and Management Plan: Western Australian Shellfish Quality Assurance Program (WASQAP). Department of Health, Perth, Western Australia, May 2016

EPA (2017) Environmental Quality Criteria Reference Document for Cockburn Sound – A supporting document to the State Environmental (Cockburn Sound) Policy 2015. Environmental Protection Authority, Perth, Western Australia, April 2017

EPA (2016) Technical Guidance Protecting the Quality of Western Australia's Marine Environment. Environmental Protection Authority, Perth, Western Australia, December 2016

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

McAlpine KW, Wenziker KJ, Apte SC, Masini RJ (2005) Background quality for coastal marine waters of Perth, Western Australia. Department of Environment, Report No. 117, Perth, Western Australia, March 2005

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

Appendices

The following Appendices are available from Water Corporation on request:

Appendix A Analytical laboratories

Appendix B Treated wastewater laboratory results

Appendix C Initial dilution model output

Appendix D Whole of effluent toxicity testing results

Appendix E Detailed methodologies

Appendix F Site coordinates

Appendix G Nutrients results

Appendix H Microbiology results

Appendix I Phytoplankton results