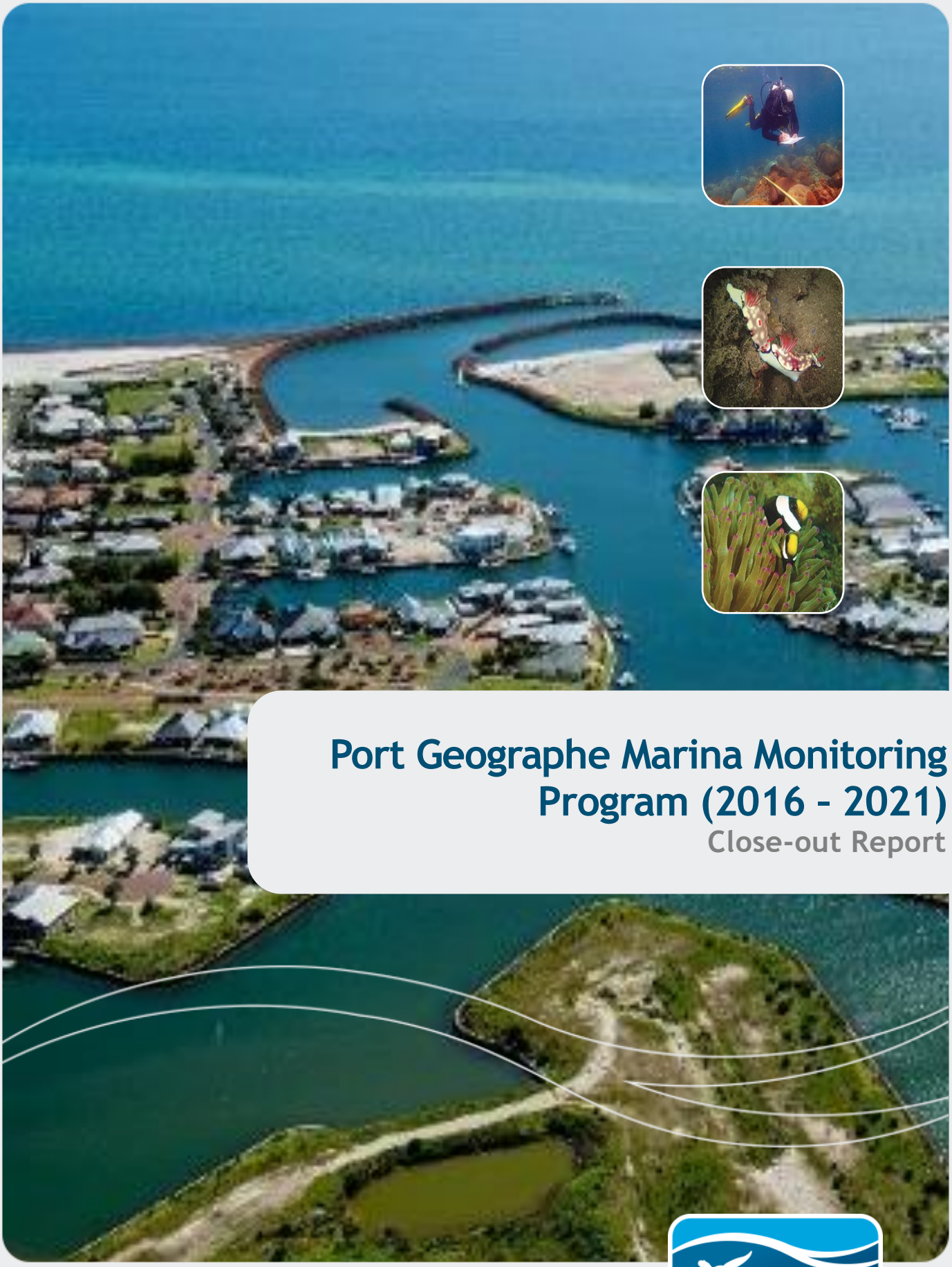


Port Geographe Marina Monitoring Program (2016 - 2021)

Close-out Report

CLIENT: Department of Transport
STATUS: Rev 0 **REPORT No.:** R210044
ISSUE DATE: 3 November 2021

O2 MARINE

Important Note

This report has been prepared for the sole use of the Department of Transport (herein, 'the client'), for a specific site (herein 'the site', the specific purpose specified in Section 1 of this report (herein 'the purpose'). This report is strictly limited for use by the client, to the purpose and site and may not be used for any other purposes.

Third parties, excluding regulatory agencies assessing an application in relation to the purpose, may not rely on this report. O2 Marine waives all liability to any third-party loss, damage, liability or claim arising out of or incidental to a third-party publishing, using or relying on the facts, content, opinions or subject matter contained in this report.

O2 Marine waives all responsibility for loss or damage where the accuracy and effectiveness of information provided by the Client or other third parties was inaccurate or not up to date and was relied upon, wholly or in part in reporting.

WA Marine Pty Ltd t/as O2 Marine
ACN 168 014 819
Originating Office – Southwest
Suite 5, 18 Griffin Drive, Dunsborough WA 6281
T 1300 739 447 | info@o2marine.com.au

Version Register

Version	Status	Author	Reviewer	Change from Previous Version	Authorised for Release (initials and dated)	
Draft	A	J. Abbott	C. Lane		CML	4/6/2021
Final	0	J. Abbott	C. Lane	Minor Edits	CML	3/11/2021

Transmission Register

Controlled copies of this document are issued to the persons/companies listed below. Any copy of this report held by persons not listed in this register is deemed uncontrolled. Updated versions of this report if issued will be released to all parties listed below via the email address listed.

Name	Email Address
Samuel Mettam	mailto:Samuel.Mettam@transport.wa.gov.au

Executive Summary

O2 Marine implemented a five-year water quality monitoring program at the Port Geographe Artificial Waterways in Busselton, Western Australia. The program was implemented between February 2016 and January 2021 and monitored a variety of Environmental Quality Indicators to assess the Environmental Values of the artificial waterways and the adjacent waters of Geographe Bay. These Environmental Values were: 'Ecosystem Health', 'Fishing', 'Recreation and Aesthetics' and 'Cultural and Spiritual'.

Overall, the results from the five-year monitoring program indicated that Environmental Quality Objectives are generally achieved and Environmental Values of the artificial waterways and adjacent waters of Geographe Bay are adequately protected. However, there is potential in certain conditions, and without ongoing management, that water quality is likely to deteriorate to a level at which the Environmental Values of the artificial waterways are compromised.

The primary risk to the Environmental Values (particularly ecosystem health) of the artificial waterways is reduced flushing of the waterways, which occurs when sediment and wrack accumulate in the entrance channel following annual winter storms. Reduced water flows through the entrance channel severely diminish the ability of the natural tidal flows to effectively flush the entire artificial waterway system. As the waters warm during spring and summer, this reduced flushing creates conditions which are conducive to supporting algal blooms, reducing dissolved oxygen levels and ultimately leading to fish kills. Nevertheless, monitoring over the past five years has shown that, when timed right, maintenance dredging to remove any accumulated sediment and wrack material from the entrance channel is an effective management tool to mitigate this risk. Therefore, future maintenance dredging should be targeted to occur in early spring before water temperatures begin to increase in summer.

In addition, the program identified that historically accumulated and residual wrack that is decomposing in sediments of Inlet West and Lower Inlet West, poses a significant ongoing threat to the environmental values of the artificial waterways.

Acronyms and Abbreviations

Acronyms/Abbreviation	Description
ANZECC	Australia and New Zealand Environment Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AWBMP	Artificial Water Body Management Plan
BRG	Bridge
CE	Canal East
CER	Coastal East Reference
CHL	Channel
Chl α	Chlorophyll α
CW	Canal West
CWR	Coastal West Reference
DEC	Department of Environment and Conservation
DER	Department of Environment Regulation
DWER	Department of Water and Environmental Regulation
DO	Dissolved Oxygen
DoH	Department of Health
DoT	Department of Transport
ENT	Entrance
EPA	Environmental Protection Authority
EPBC	Environment Protection and Biodiversity Conservation
EQC	Environmental Quality Criteria
EQG	Environmental Quality Guideline
EQI	Environmental Quality Indicator
EQMF	Environmental Quality Management Framework
EQO	Environmental Quality Objective
EQS	Environmental Quality Standard
EV	Environmental Value
HEPA	High Ecological Protection Area
IW	Inlet West
LAG	Lagoon
LEP	Level of Ecological Protection
LIW	Lower Inlet West
MAR	Marina
MCE	Mid Canal East
MEPA	Moderate Ecological Protection Areas
MET	Marina Entrance
MIE	Marina Inlet East
NATA	National Association of Testing Authorities
NTU	Nephelometric turbidity units
PSU	Practical Salinity Units

Acronyms/Abbreviation	Description
SAP	Port Geographe Artificial Waterways – Routine Sampling and Analysis Plan
UCE	Upper Canal East
UCW	Upper Canal West
UMCE	Upper Mid Canal East
VCP	Village Centre Pond
WA	Western Australia

Table of Contents

Figures

Tables

Appendices

1. Introduction

1.1. Background

Port Geographe is a private residential canal estate with a commercial marina, public boat ramps, with access to Geographe Bay, located in Busselton, Western Australia (WA). Due to environmental, social and economic issues associated with the original coastal structures, the WA State Government funded a structural reconfiguration in 2012. This work was administered by the WA Department of Transport (DoT) and completed in 2015. As part of the reconfiguration of the coastal structures, the DoT has coastal management responsibilities for the Port Geographe foreshore under Ministerial Statement 990. In addition to these conditions, the DoT has an agreement with the City of Busselton to preserve access to the artificial waterways and maintain water quality. In fulfilling the obligations of this agreement, the DoT undertakes routine water quality monitoring and sampling in the Port Geographe artificial waterways and areas of interface with Geographe Bay.

Water quality monitoring has been undertaken at Port Geographe since 2005 with due consideration of a draft *Port Geographe Stages 1 – 10 Artificial Water Body Management Plan* (AWBMP) (Cardno 2011) associated with the original development. Following recommendations from the Department of Environment and Conservation (DEC) and Port Geographe Expert Working Party (PGEWP) in 2007 and 2008, it was agreed that the most appropriate guidelines for the assessment of the water quality within Port Geographe were a set of site specific Environmental Quality Criteria (EQC) based on methods described within the *State Environmental (Cockburn Sound) Policy 2015 (Government of WA, 2015)*. These guidelines would be utilised to monitor water quality within 'the Port Geographe development', however, would remain dynamic and would change in accordance with further water quality monitoring undertaken at Port Geographe.

Routine water quality monitoring undertaken by the DoT between 2014 and 2016 was conducted in accordance with the Port Geographe *Interim Artificial Water Body Management Plan* (Interim AWBMP 2014), which was adapted from the AWBMP. In March 2016, O2 Marine undertook a comprehensive review of the Interim AWBMP and the water quality data collected to date. Several recommendations were provided to the DoT to refine the monitoring program aimed at addressing key risks and creating more effective management of water quality within the artificial waterways. The recommendations adopted by the DoT were then incorporated into the *Port Geographe Artificial Waterways – Routine Sampling and Analysis Plan (SAP)* (O2 Marine 2017), which replaced the water quality monitoring programme described within the Interim AWBMP. The SAP was implemented in March 2017, with all water quality results collected from this point through to 2020 assessed in accordance with the Environmental Quality Management Framework (EQMF) described in the SAP (O2 Marine 2017). This report should be read in conjunction with the SAP (O2 Marine 2017).

1.2. Environmental Quality Framework

The EQMF described in the SAP was established to protect and maintain the Environmental Values (EVs) of the Port Geographe Artificial Waterways and adjacent waters of Geographe Bay. In accordance with the *State Environmental (Cockburn Sound) Policy* Government of WA (2015), five EVs and eight corresponding Environmental Quality Objectives (EQOs) are expected to apply throughout

WA coastal waters. Of these, the EVs and corresponding EQOs that are considered most applicable to the Port Geographe artificial waterways and adjacent waters of Geographe Bay are shown Table 1. The Environmental Quality Indicators (EQIs) also shown in Table 1 are measurable parameters selected to monitor changes in environmental quality for each EQO.

Table 1 Environmental Values, Objectives, and Indicators for Port Geographe Water Quality Programme

Environmental Values	Environmental Quality Objectives	Environmental Quality Indicators
Ecosystem Health	EQO1: Maintenance of ecosystem integrity. EQO1 is split into four sub-objectives, being Maximum, High, Moderate and Low Levels of Ecological Protection (LEPs) (Refer below).	Chlorophyll-α Dissolved Oxygen Water Temperature Salinity pH
Fishing	EQO2: Seafood (caught) is of a quality safe for human consumption. ^	Measured through assessment of EQI for EQO3
Recreation & Aesthetics	EQO3: Water quality is safe for primary contact recreation (e.g. swimming and diving). * EQO4: Water quality is safe for secondary contact recreation (e.g. fishing and boating). ^	Toxic & Nuisance Phytoplankton Pathogenic Bacteria (i.e. *E. coli*, faecal enterococci & thermotolerant coliforms) pH
	EQO5: Aesthetic values of the marine environment are protected.	Faunal deaths Visual Clarity & Colour Oil/debris Odour
Cultural & Spiritual	EQO6: Cultural and spiritual values of the marine environment are protected.	Measured through assessment of EQI for EQO1, EQO3, EQO4 & EQO5

^ The consumption of seafood caught in the artificial waterways is not recommended by the DoT.

* The DoT does not recommend recreational swimming in the artificial waterways as they are primarily for the movement of recreational vessels. The exceptions to this are the four beach areas within the artificial waterways where recreational swimming is expected. Recreational swimming in the village centre pond (VCP), the upper canal area ~175m east of site MCE and the upper canal area south of the pedestrian bridge is not permitted. Refer to the Routine Water Quality SAP (O2 Marine 2017) for further details.

In accordance with The Government of WA (2015), the objective for 'Ecosystem Health' is spatially allocated into four Levels of Ecological Protection (LEPs): Maximum, High, Moderate and Low. Each LEP area is assigned a set of Environmental Quality Criteria (EQC) that represent environmental quality thresholds of 'acceptability' and allow areas important for conservation to be maintained within the limits of natural variation, whilst recognising that societal uses may preclude either a 'Maximum' or 'High' LEP limit from being achieved within other areas. The SAP identifies the following two LEP designations that are applicable to Port Geographe monitoring area:

- **Moderate Ecological Protection Area (MEPA):** All artificial waterways extending into Geographe Bay to 250 m beyond the entrance to Port Geographe; and
- **High Ecological Protection Area (HEPA):** Adjacent coastal waters in Geographe Bay beyond 250 m from the entrance to the Port Geographe to the Ngari Capes Marine Park boundary.

It should be noted that waters within the Ngari Capes Marine Park are likely afforded a 'Maximum' LEP, however these waters are outside the spatial extent of this water quality programme. There are no areas within the Port Geographe artificial waterways and adjacent coastal waters which have been afforded a 'Low' LEP.

1.2.1. Environmental Quality Criteria

Ecosystem Health

The numerical and narrative Environmental Quality Guideline (EQG) and Environmental Quality Standard (EQS) applicable to *'Ecosystem Health'* and corresponding EQO1: *'Maintenance of ecosystem integrity'* are presented in the SAP. In accordance with the SAP (O2 Marine 2017), a correction factor is used to convert temperature, salinity and pH data collected from coastal reference sites in Geographe Bay to acceptable values within Port Geographe artificial waterways. These correction factors are derived using the seasonal median of the artificial waterway locations minus the median of the coastal reference sites from data obtained within the last three years. This correction factor is applied to the median data recorded at each individual monitoring location and compared against reference site data for the relevant season. The correction factor has been applied to allow for acceptable conditions within a canal system rather than direct comparison with an open coastal water body such as Geographe Bay, which has fundamentally different dynamics to a canal system.

Fishing

Whilst it is recognised that the EV 'Fishing' and the corresponding EQO2: '*Seafood (caught) is of a quality safe for human consumption*' are applicable to the Port Geographe artificial waterways, the DoT does not recommend consuming seafood caught within these artificial waterways. Furthermore, no specific EQG and EQS have been derived for assessment against EQO2. Rather, this EV and corresponding EQO are addressed through assessment of EQI against EQO3: '*Water quality is safe for primary contact recreation (e.g. swimming and diving)'*. In this manner, where EQO3 is deemed to be achieved, then EQO2 would also be achieved.

Recreation and Aesthetics

The numerical and narrative EQG and EQS applicable to the EQOs for the EV 'Recreation & Aesthetics' (i.e. EQO3, EQO4 & EQO5) are presented in the SAP. Although these EQOs should be assessed for all areas of the artificial waterways, the DoT recommends that primary contact recreation activities (i.e. swimming) within the artificial waterways should only occur in designated areas.

Cultural & Spiritual Values

Inclusion of the EV, *'Cultural and Spiritual values'* recognises the cultural and spiritual values of Geographe Bay to the area's indigenous people. However, consistent with the *State Environmental (Cockburn Sound) Policy* Government of WA (2015) and ANZECC/ARMCANZ (2000), no specific EQC are provided for assessment against EQO6: *'Cultural and spiritual values of the marine environment are protected'.* In the absence of EQC for this value, ensuring that the quality of these waters is sufficient to maintain ecosystem integrity (EQO1), protect the quality of seafood (EQO2), allow people to recreate safely (EQO3 & EQO4), and maintain aesthetic values (EQO5), is considered to protect cultural and spiritual values within Port Geographe waters.

1.3. Objectives

The objective of this report is to summarise the key findings across the five-year monitoring program (February 2016 – January 2021) undertaken at Port Geographe by O2 Marine on behalf of the DoT. This document identifies key trends in water quality and potential environmental risks (in relation to the EQMF described above) posed by water quality on the environmental values of the Port Geographe artificial waterways and adjacent waters of Geographe Bay.

It is noted that, recommendations for ongoing management of the artificial waterways are outside of the scope of this report.

2. Monitoring Program 2016 - 2021

2.1. Monitoring Schedule

O2 Marine commenced routine water quality monitoring within The Port Geographe Marina in February 2016, implementing 10 monthly events per year to January 2021.Monitoring was not undertaken in June and September (except 2017 when September was sampled instead of October), as the risk to detrimental water quality is low during these cooler months. **Appendix A** outlines all monitoring events between February 2016 and January 2021, the date of sampling, and any specific comments in relation to monitoring methods. A single, additional 'reactive management' monitoring event was undertaken in August 2017 at site CE, this additional monitoring was implemented in response to notably low dissolved oxygen (DO) levels in the area.

2.2. Monitoring locations

Between February and May 2016, seven artificial waterway locations and two reference sites in Geographe bay were monitored. These sites were UCE, UCW, BRG, LCE[1], CHL, LAG, MAR and the two reference sites CWR and CER.

From July 2017 onwards, eight artificial waterway sites and one High Ecological Protection Area (HEPA) / Moderate Ecological Protection Area (MEPA) site were added to the existing monitored sites. The now 15 monitoring sites within the artificial waterway were categorised to 'Upper' and 'Lower' in relation to their proximity to the ocean. The additional monitoring locations were UMCE, CW, MCE, IW, LIW, MIE, VCP[2], and HEPA/MEPA boundary site ENT. Figure 1 presents the monitoring locations and Physico-chemical Profiles

During each monitoring event, a YSI probe was used to measure water column profiles at all 18 monitoring locations. Measurements were recorded at 0.25m intervals until 0.25m above the seabed. The parameters included:

- Depth (m);
- Water temperature (^{o}C);
- pH;
- Salinity (psu);
- Turbidity (NTU); and
- Dissolved oxygen (% saturation & mg/L).

[1] *'LCE' was changed to 'CE' in July 2017.*

[2] *Whilst VCP is listed and analysed as an artificial waterway site, the water quality characteristics are not directly comparable to the remaining artificial waterway sites as it is a semi-enclosed pond.*

2.2.1. Water Sampling

samples (laboratory testing) were collected at select sites (UCE, UCW, BRG, CE, MAR, LAG, CHL, VCP, CER and CWR) during each event.

Depth integrated water samples were collected at 11 sites during each monitoring event (UCE, UCW, BRG, CE, CHL, LAG, MAR, VCP, CWR and CER). Samples were collected via a 12-volt water pump, decanted into laboratory supplied containers and chilled until delivery to a NATA accredited laboratory for testing of the following parameters:

- Total Phosphorus;
- Total Nitrogen;
- Chlorophyll-a;
- Microbiology (Thermotolerant coliforms, E coli and Faecal enterococci); and
- Phytoplankton (enumeration and identification).

Table 3 identifies the coordinates of each monitoring location.

2.3. Sampling Methods

Water quality monitoring was undertaken at 18 locations (15 within the marina and three in Geographe Bay). Table 3 identifies the site names, locations and identifies which parameters were routinely monitored at each site.

2.3.1. Visual Observations

Visual observations were monitored at each of the 18 sites every event. These observations included parameters such as the presence of seagrass wrack, odours, nuisance organisms and records of fauna deaths and were monitored as indicators associated to EQG5 *'Aesthetic values of the marine environment are protected'*. Each of the parameters (A – F) were given a score out of five which corresponded to the level of impact (Table 2).

Table 2 Water Quality Observation Assessment and Score Matrix

Parameter	REF	1	2	3	4	5
Nuisance organisms (Surface coverage %)	**A**	Nil	1-10	11-50	51-80	100+
Large-scale deaths (Marine fauna)	**B**	Nil	1-10	11-51	51-81	100+
Oil/Film (Surface coverage)	**C**	Nil	1-10%	11-50%	51-80%	81-100%
Colour (Munsell Scale)	**D**	No Change	2 points	5 points	8 points	>10 Points
Natural reflectance (Diminished)	**E**	81-100%	51-80%	11-50%	1-10%	Nil
Seagrass Wrack (Surface coverage)	**F**	Nil	1-10%	11-50%	51-80%	81-100%
Odour	**F**	Nil	Slight	Moderate	Strong	Offensive

2.3.2. Physico-chemical Profiles

During each monitoring event, a YSI probe was used to measure water column profiles at all 18 monitoring locations. Measurements were recorded at 0.25m intervals until 0.25m above the seabed. The parameters included:

- Depth (m);
- Water temperature (^{o}C);
- pH;
- Salinity (psu);
- Turbidity (NTU); and
- Dissolved oxygen (% saturation & mg/L).

2.3.3. Water Sampling

samples (laboratory testing) were collected at select sites (UCE, UCW, BRG, CE, MAR, LAG, CHL, VCP, CER and CWR) during each event.

Depth integrated water samples were collected at 11 sites during each monitoring event (UCE, UCW, BRG, CE, CHL, LAG, MAR, VCP, CWR and CER). Samples were collected via a 12-volt water pump, decanted into laboratory supplied containers and chilled until delivery to a NATA accredited laboratory for testing of the following parameters:

- Total Phosphorus;
- Total Nitrogen;
- Chlorophyll-a;
- Microbiology (Thermotolerant coliforms, E coli and Faecal enterococci); and
- Phytoplankton (enumeration and identification).

Table 3 Port Geographe Monitoring Locations and Sampling Tasks

Site Name	Site Reference	Level of Ecological Protection	Historical Site Reference[1]	Latitude	Longitude	Routine Sampling Tasks			
						Aesthetic Observations	Physico-chemical Water Column Profiling	Water Sample Laboratory Analysis	Phytoplankton Sample Collection
Artificial Waterways Monitoring Locations – Upper (MEPA)									
Upper Canal East	UCE	Moderate	Site 11	S 33° 38.132	E 115° 23.877	X	X	X	
Upper Mid Canal East*	UMCE	Moderate	-	S 33° 38.204	E 115° 23.623	X	X		
Upper Canal West	UCW	Moderate	Site 8	S 33° 38.298	E 115° 23.363	X	X	X	
Canal West*	CW	Moderate	LCW	S 33° 38.199	E 115° 23.363	X	X		
Bridge	BRG	Moderate	Site 2	S 33° 37.144	E 115° 23.517	X	X	X	X
Canal East	CE	Moderate	Site 1 & LCE	S 33° 37.974	E 115° 23.893	X	X	X	
Mid Canal East*	MCE	Moderate	-	S 33° 38.076	E 115° 23.661	X	X		
Artificial Waterways Monitoring Locations – Lower (MEPA) (Including Village Centre Pond)									
Inlet West*	IW	Moderate	UIW	S 33° 38.084	E 115° 23.431	X	X		
Lower Inlet West*	LIW	Moderate	-	S 33° 37.978	E 115° 23.377	X	X		
Marina Inlet East*	MIE	Moderate	-	S 33° 37.978	E 115° 23.732	X	X		
Marina	MAR	Moderate	Site 4	S 33° 37.878	E 115° 23.662	X	X	X	X
Marina Entrance*	MET	Moderate	-	S 33° 37.930	E 115° 23.457	X	X		
Lagoon	LAG	Moderate	Site 16	S 33° 37.770	E 115° 23.386	X	X	X	X
Channel	CHL	Moderate	Site 17	S 33° 37.804	E 115° 23.337	X	X	X	
Village Centre Pond*	VCP	Moderate	Pond	S 33° 37.883	E 115° 23.764	X	X	X	X
HEPA/MEPA Boundary Monitoring Location									
Entrance*	ENT	High	-	S 33° 37.603	E 115° 23.323	X	X		
Coastal Reference Locations (HEPA)									
Coastal West Reference	CWR	High	Site 7	S 33° 37.9380	E 115° 22.6160	X	X	X	X
Coastal East Reference	CER	High	Site 18	S 33° 37.1130	E 115° 24.3580	X	X	X	

* ***Not sampled until July 2016***

Figure 1 Port Geographe Water Quality Monitoring Locations (some locations not included in 2015/2016 monitoring period).

3. Key Findings

3.1. Visual Observations

The vast majority of the observations recorded between 2015 and 2020 scored the minimum score 'nill', meaning no recorded impact. On rare occasions seagrass wrack was reported at '1 – 10%' at varying sites throughout the five-year program. As these findings were not common and not confined to one location, it does not infer detrimental impacts to water quality.

Odour is the one parameter that was regularly recorded at a 'slight' or 'moderate' level. However, the elevated levels were only observed at two particular sites, LAG and CHL (Figure 1). These sites are adjacent to each other and are located just inside the marina entrance. Two reasons why the odour score was regularly elevated at these locations are:

1. The presence of decaying seagrass located on the seabed within the channel, the lagoon area of the marina and to the west of the entrance breakwater. The decay process involves increased bacterial respiration and therefore reduced oxygen levels in water and sediments. Hydrogen Sulfide, also a by-product of decomposition is the source of the 'rotten egg' smell (Bergquist et al 2003).
2. The break wall in-between CHL and LAG is a popular roosting location for seabirds. The presence of a variety of birds species and their excrement contribute to the slight/moderate odour recordings.

No 'Large Scale deaths (marine fauna)' were observed by O2 Marine throughout the five-year monitoring program. However, in December 2020, O2 Marine was informed by the DoT of a fish kill event within the marina waterways. In the subsequent monitoring events, efforts were made to confirm the fish deaths, but none were observed.

Based on the five-year monitoring program results, Odour, as an environmental quality indicator, does pose a low risk to Recreation and Aesthetics (EQO5) and Cultural and Spiritual values (EQO6) at monitoring locations CHL and LAG.

Large scale deaths, as an Environmental Quality Indicator poses a risk to Ecosystem Health (EQO1), Fishing (EQO2), Recreation (EQO3 & EQO4) and Aesthetics (EQO5), and Cultural and Spiritual values (EQO6). All remaining observation parameters (Table 3) do not pose a risk to EQO5 or EQO6.

3.2. Physico-Chemical Parameters

3.2.1. Temperature

Water temperatures recorded at all sites over the five-year monitoring period indicate typical seasonal trends with rare EQG exceedances reported. Of the few EQG exceedances recorded, temperature results were marginally above or below the seasonal EQG criteria (typically less than 1.5 degrees Celsius). Temperature trends within the marina were comparable to ocean waters (summer maximums

and winter minimums). Marina waters did record marginally larger temperature ranges compared to ocean waters, likely a result of reduced flushing.

Based on the five-year monitoring program results, water temperature, as an environmental quality indicator, is considered to achieve the Environmental Quality Objectives for both Ecosystem Health (EQO1) and Spiritual and Cultural values (EQO6).

Appendix B includes water temperature graphs with seasonal EQG criteria for the five-year monitoring program.

3.2.2. pH

Monitoring results for pH did not identify clear seasonal trends. pH values were marginally lower within the marina when compared to the two reference sites within Geographe Bay, with mean values of 8.14, 8.18 and 8.34 for the upper waterway, lower waterway and reference sites respectively. Rare, marginal EQG exceedances were recorded throughout the monitoring program. Exceeding values were typically less than 0.3 above or below the rolling seasonal EQG value.

Based on the five-year monitoring program results, pH, as an environmental quality indicator, is considered to achieve the Environmental Quality Objectives for Ecosystem Health (EQO1) and Spiritual and Cultural values (EQO6).

Appendix C includes pH graphs with seasonal EQG criteria for the five-year monitoring program.

3.2.3. Salinity

Salinity data recorded over the five-year monitoring period indicates seasonal trends were present, with summer maximums and winter minimums. These trends are typical to temperate climates with increased freshwater inputs during winter rainfall events. As with temperature results above, the overall range in salinity is larger within the marina when compared to the reference sites. This is likely related to the reduced flushing rates and the increased evaporation capacity (during summer) experienced in the semi-enclosed marina compared to the more stable marine environment of Geographe Bay. EQG exceedances for salinity were rare and typically less than 1 ppt above or below the rolling seasonal criteria. One exception was the elevated salinity values recorded across all 18 sites during the July 2019 monitoring event. This widespread elevation is likely related to an instrument calibration error, rather than a true representation of salinity concentrations.

Based on the five-year monitoring program results, salinity, as an environmental quality indicator, is considered to achieve the Environmental Quality Objectives for Ecosystem Health (EQO1) and Spiritual and Cultural values (EQO6).

Appendix D includes salinity graphs with seasonal EQG criteria for the five-year monitoring program.

3.2.4. Dissolved Oxygen

The five-year monitoring program identified a consistent difference in dissolved oxygen (DO) concentrations between marina waters and the ocean waters of Geographe Bay. Mean concentrations for the lower artificial waterway (74.3%) and the upper artificial waterway (82.8%) were consistently lower than mean concentrations of the reference sites (101%) and ENT (100%). Figures 1 – 3 below show that a defined seasonal trend is evident at the three sites within Geographe Bay (CWR, CER and

ENT), with maximum concentrations recorded during summer and minimum concentrations during winter. Conversely, the 15 monitoring locations within the marina recorded sporadic DO concentrations with no defined seasonal trend.

The lowest DO concentrations were consistently recorded at five marina monitoring locations in close proximity to the marina entrance (MET, LIW, IW, LAG and CHL). Mean DO concentrations for these sites over the five-year monitoring period were 68.9%, 68.1%, 72%, 73.4% and 76.4% respectively. The likely cause of the reduced DO levels in these areas of the marina relates to the decomposition of organic material (seagrass) that builds up in the marina entrance. As described above, this decomposition process uses up oxygen levels in the water and sediment. Consistent low DO levels at these sites resulted in a regular breach of the EQG (refer Table 3 of O2 Marine 2017). These conditions have likely attributed to reduced aesthetic conditions (odour) in the area.

In addition to the frequent EQG exceedances, DO was also observed to decline below the EQS criteria of 60% for two or more consecutive surveys at CE, CHL, LIW, MET and MIE on at least one occasion per location. In these instances, it has been assumed that DO concentrations remained below the EQS for a period of more than one week, thus indicating an exceedance of the EQS. This assumption is supported by results recorded during reactive monitoring undertaken at CE during October/November 2018, where a telemetered DO sensor showed DO concentrations remained below 60% for a four-week period.

Only one critical impact occurred during the program as a result of low DO levels, where a fish kill event was observed at LIW by a member of the public and reported to the Department of Transport. Fish kills can potentially occur when DO levels become critically low in closed aquatic systems. However, in a semi-enclosed or open marine environment coastal fish begin to avoid areas where DO is less than 45% (EPA, 2000). Therefore, while DO concentrations are low, observed conditions at the monitored sites over the five-year monitoring period indicate concentrations were not at a critical level where fish begin to avoid the area.

Throughout the five-year monitoring program, it was discussed with the DoT that the best management action in relation to addressing the low DO levels was maintenance dredging of the channel to remove the build-up of decomposing organic material and promote marina flushing. This activity was scheduled annually, and therefore no further management was required in addition to the regular monthly monitoring (physico-chemical parameters, water sampling, marine fauna observations etc). Timing of this activity was considered to be crucial to ensure that this risk was effectively mitigated before waters begin warming during spring.

Based on the five-year monitoring program results, dissolved oxygen, as an environmental quality indicator, does pose a high risk to Ecosystem Health (EQO1) and Spiritual and Cultural values (EQO6), particularly at five sites within the lower artificial waterway (MET, LIW, IW, LAG and CHL). Ongoing management (i.e. timing of maintenance dredging of the marina entrance in early spring) is required to ensure EQO1 and EQO6 are consistently achieved.

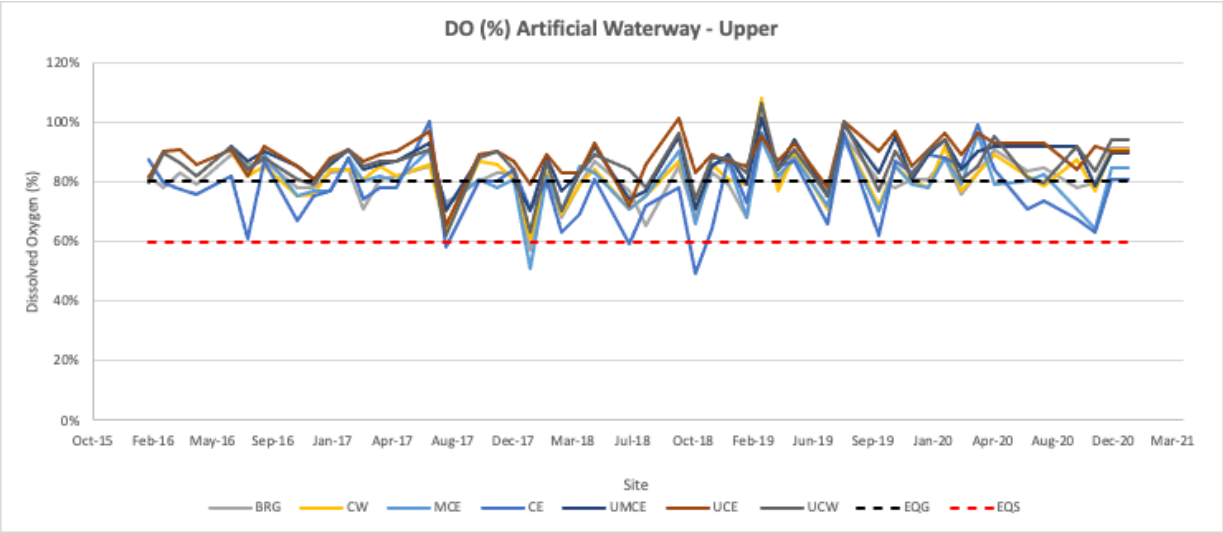


Figure 2 **Dissolved Oxygen, Upper Artificial Waterway (February 2016 – January 2021).**

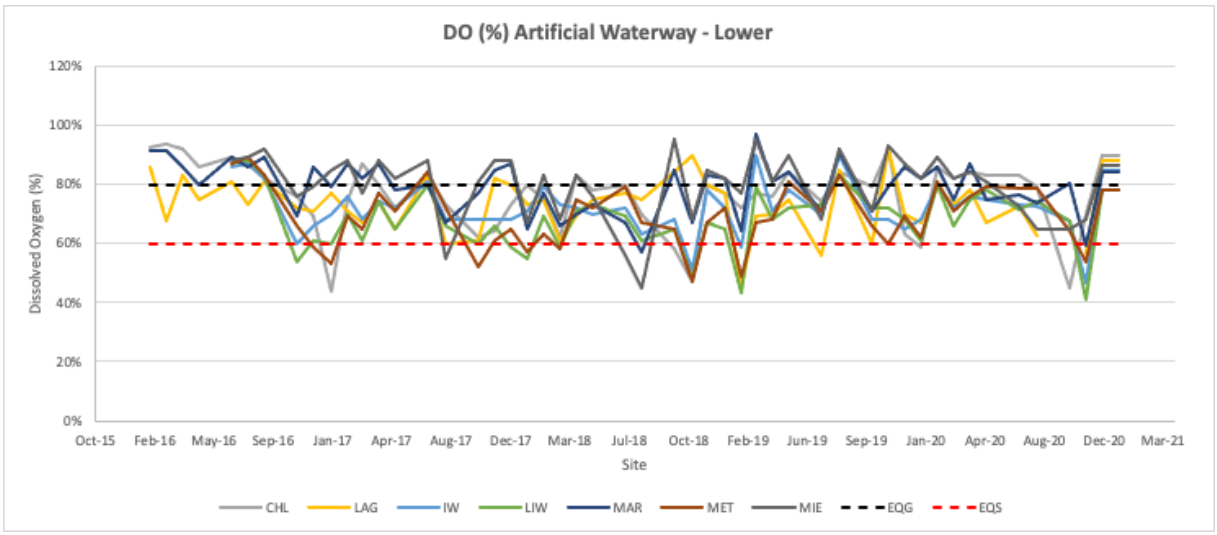


Figure 3 **Dissolved Oxygen, Lower Artificial Waterway (February 2016 – January 2021).**

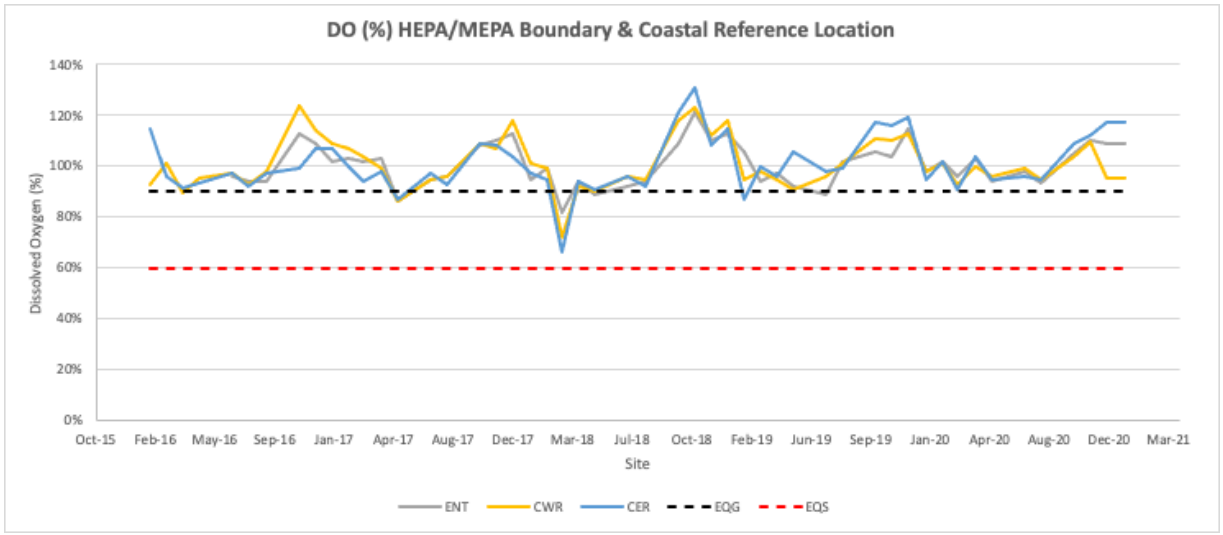


Figure 4 **Dissolved Oxygen, HEPA/MEPA Boundary and Reference Sites (February 2016 – January 2021).**

3.3. Water Sampling Results

3.3.1. Total Phosphorus

Total Phosphorus concentrations were variable both inside the Port Geographe Marina and at reference sites within Geographe Bay. No distinct seasonal trend was observed. Across the five-year monitoring period Total Phosphorus concentrations were generally lower at the reference sites when compared to the marina waters. This is expected as nutrient inputs from wastewater, gardens and marina facilities will not dissipate within the semi-enclosed marina as efficiently when compared to the open ocean environment. The ANZG (2018) guidelines for nearshore waters within Australia Southwest, suggest 20 μg/L as a default guideline value. Figure 5 indicate that median Total Phosphorus concentrations were generally comparable to these guideline values, with only brief periods above, particularly between February 2018 and February 2019, and again at the lower artificial water way in November 2020.

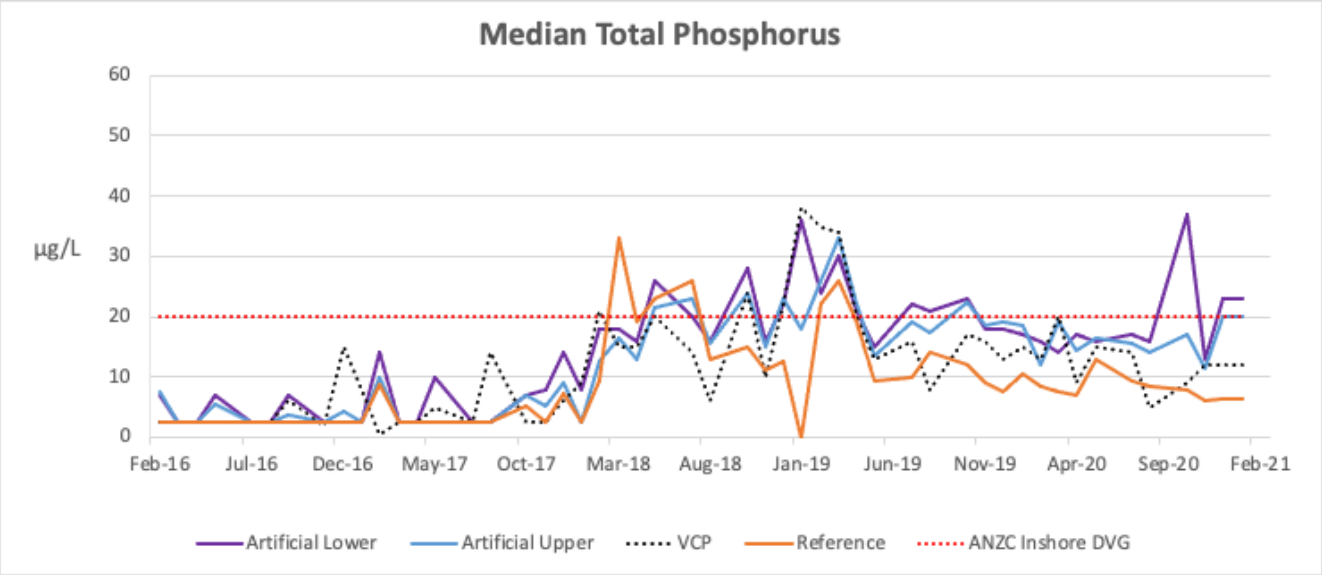


Figure 5 **Median Total Phosphorus results for the Artificial Waterway (upper and lower), VCP and Reference sites (2016 – 2021).**

Total Phosphorus concentrations have been monitored to better understand water quality characteristics; however, Total Phosphorus is not an environmental indicator for any of the EQOs described in Table 1. Therefore, specific results are not included in the assessment of Environmental Values of the Port Geographe artificial waterways.

3.3.2. Total Nitrogen

Total Nitrogen concentrations recorded within the marina, and at reference sites within Geographe Bay recorded temporary fluctuations, however, were generally comparable to the ANZG (2018) guideline value for nearshore waters in the Southwest of Australia (230 μg/L). Overall, slightly higher Total Nitrogen concentrations were recorded within marina waters when compared to references sites in the open ocean. Site VCP recorded several notable spikes in March 2016 (640 g/L), January 2017 (740 g/L) and February 2019 (540 g/L). VCP is a small enclosed 'pond' and has reduced flushing capacity, and therefore any direct nutrient inputs to the system will result in notably elevated concentrations. However, results show each of these spikes were short lived, with concentrations returning to normal levels during the following monitoring round (Figure 6).

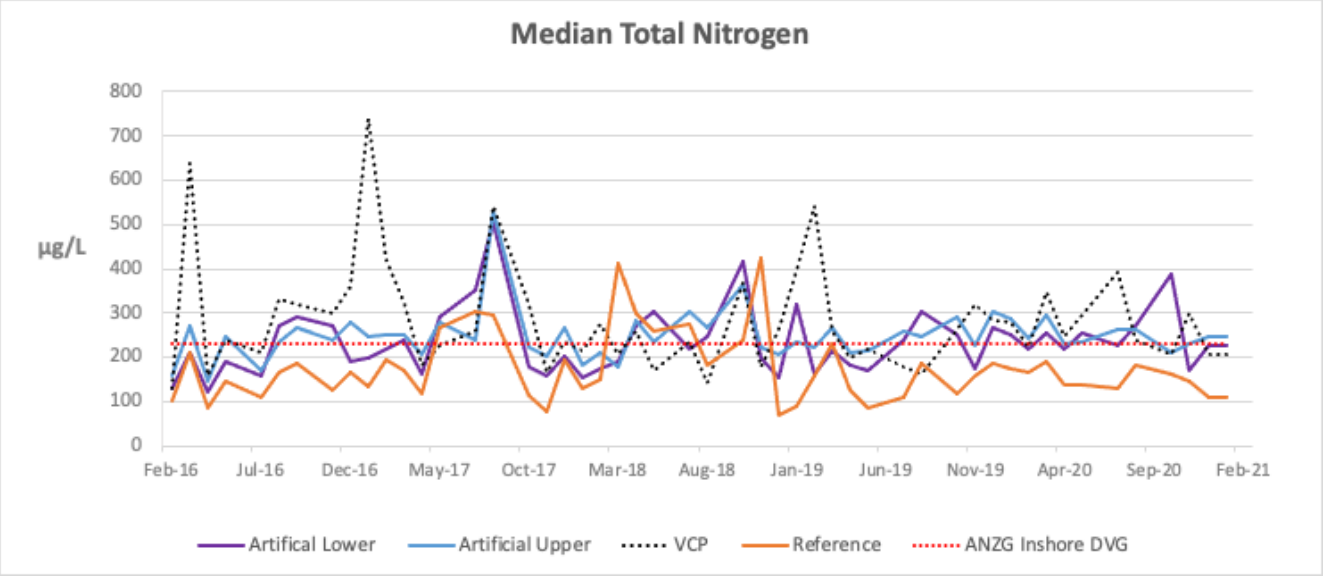


Figure 6 **Median Total Nitrogen results for the Artificial Waterway (upper and lower), VCP and Reference sites (2016 – 2021).**

Total Nitrogen concentrations have been monitored to better understand water quality characteristics; however, Total Nitrogen is not an environmental indicator for any of the EQOs described in Table 1**. Therefore, specific results are not included in the assessment of Environmental Values of the Port Geographe artificial waterways.**

3.3.3. Chlorophyll-a

Chlorophyll-a results recorded over the five-year monitoring period show concentrations were generally higher at marina location (i.e. MAR) when compared to the two reference sites in Geographe Bay (Figure 7). The majority of Chlorophyll-a results were below the numerical EQG seasonal criterion (calculated based on reference site data). Rare, sporadic elevations were recorded in the lower (and to a lesser extent the upper) areas of the artificial waterways over the five-year period. However, these elevations typically did not persist for consecutive monitoring events. Monitoring site VCP recorded several elevated readings over the five-year period, however only on three occasions did concentrations exceed the seasonal EQG criteria.

One site (LAG) did exceed the EQS criteria, whereby the EQG numerical value was exceeded at the same site, during the same season for consecutive years (Spring - 2017, 2018 and 2019). The elevated Chlorophyll-a levels at LAG in Spring are linked to the warm change in conditions from Winter to Spring, following a period of fresh (nutrient rich) water entering the semi-enclosed LAG location.. These conditions are conducive to rapid aquatic plant growth and photosynthesis.

Best practice management in this circumstance would be to increase flushing to marine waters. The DoT had committed to annual maintenance dredging immediately adjacent to LAG which was aimed at creating a safe navigable channel, increasing flushing, and removing excess organic matter. Therefore, management actions were in place at the time of the EQS exceedance to help reduce the impacts of increased Chlorophyll-a levels.

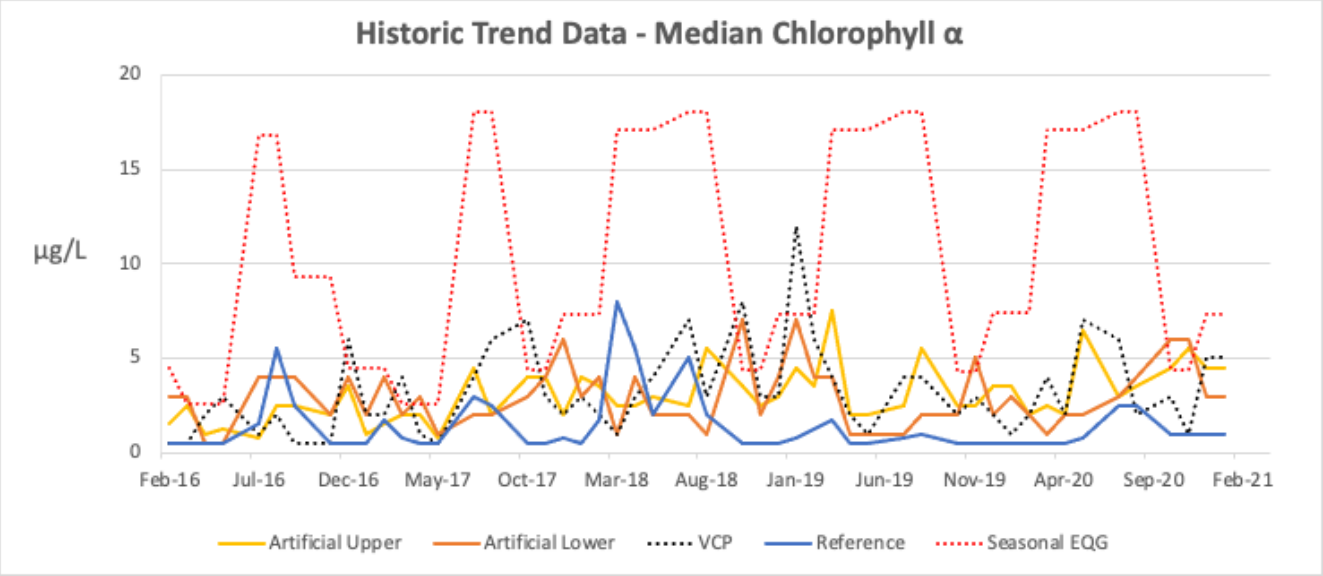


Figure 7 **Median Chlorophyll-a results for the Artificial Waterway (upper and lower), VCP and Reference sites (2016 – 2021).**

Based on the five-year monitoring program results, Chlorophyll-a, as an environmental quality indicator, does pose a low risk to Ecosystem Health (EQO1) and Spiritual and Cultural values (EQO6). However, this risk is largely confined to monitoring location LAG. Ongoing management (i.e. maintenance dredging of the marina entrance) is recommended to ensure EQO1 and EQO6 are maintained.

3.3.4. Microbial Analysis

To ensure the marina waters were safe for human contact, potentially harmful bacteria were sampled and analysed monthly at 11 locations. Sample concentrations of Thermotolerant coliforms, *E. coli* and Faecal enterococci remained low throughout the five-year monitoring program. At no time was the primary or secondary contact EQG exceeded at any site (200 cfu/100ml and 2000 cfu/100ml respectively). A maximum concentration of 110 cfu/100ml for Thermotolerant coliforms and Faecal enterococci was recorded in April 2016, while the highest *E. coli* concentration was recorded at reference site CWR in August 2018 (93 cfu/100ml). No seasonal trends were evident throughout the monitoring program. It should be noted, that while results indicate all sites are acceptable for primary contact, the artificial waterway is predominantly for the navigation of vessels, and swimming is not recommended, except at four designated beaches.

Based on the five-year monitoring program results, Thermotolerant coliforms, *E.coli* and Faecal enterococci, is considered to achieve the Environmental Quality Objectives for Fishing (EQO2), Recreation and Aesthetics (EQO3 and EQO4) and Spiritual and Cultural values (EQO6).

Appendix E includes microbial results for Thermotolerant coliforms, Ecoli and Faecal enterococci for the five-year monitoring program.

3.3.5. Phytoplankton

Phytoplankton enumeration and identification was undertaken at five sites (BRG, LAG, MAR, VCP, and CWR) during each monitoring event between February 2016 and January 2021. Total phytoplankton data is presented in Figure 8. Results indicate that total algal abundance across all sites is typically low,

with only one exceedance of the primary contact EQG value (10,000 cells/mL) at LAG during the December 2016 monitoring event. No exceedances of the EQG for secondary contact were recorded at any site. Furthermore, the EQS (10,000 cells/mL) was not exceeded at any site. Phytoplankton abundance results indicate a decreasing trend between 2017 and 2021 across all sites.

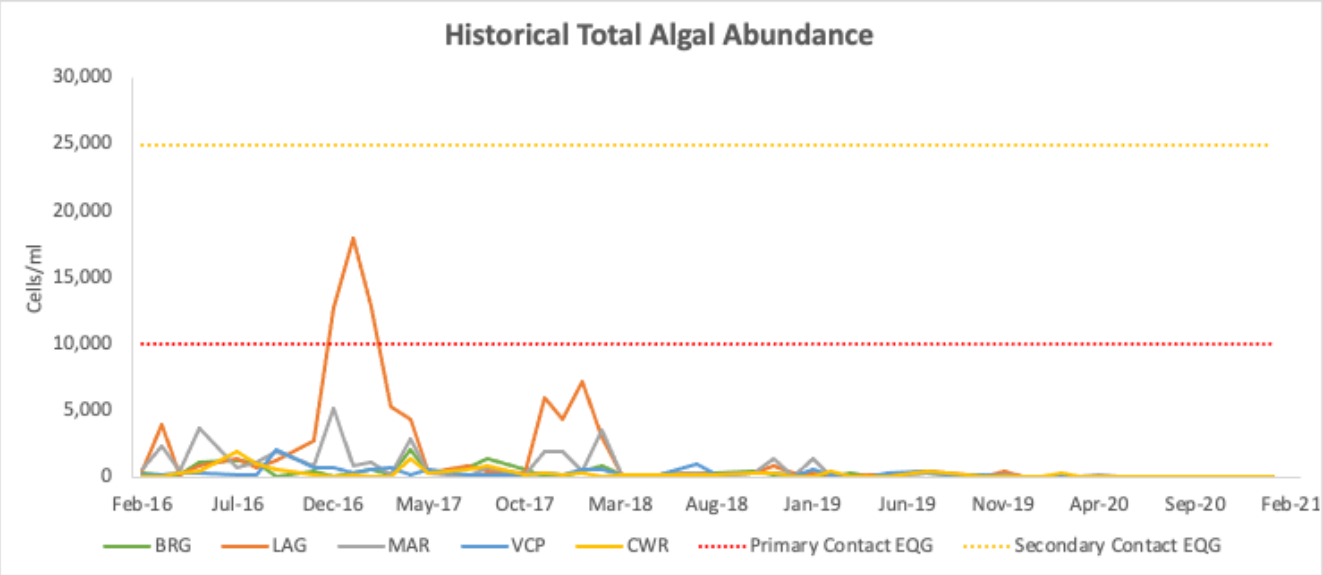


Figure 8 **Total Phytoplankton abundance 2016 – 2021**

On rare occasions throughout the five-year monitoring period, DOHWA (2017) watch-list species, (specifically Cyanobacteria) were detected at each of the five monitoring sites. Each site recorded Cyanobacteria in concentrations above the DOHWA Watch List Trigger Levels of 5,000 cells/L (Table 4). All sites (except MAR) recorded rare sporadic elevations; MAR was the only site to record a regular period of elevated Cyanobacteria concentrations (concentrations were elevated on five occasions over eight monitoring events between May 2016 and January 2016). Since this period, only one elevation has been recorded (January 2019).

Despite these elevations, no reports of irritation or algal poisoning related to people using the artificial waterways were recorded. Reference site CWR also recorded Cyanobacteria concentrations above the DOHWA Watch List Trigger Level on two occasions (April 2016 and February 2020), this indicates that potentially hazardous algal concentrations are not restricted to the artificial waterways.

Table 4 **Cyanobacteria Concentrations recorded between February 2016 and May 2021.**

Site	Event	DOHWA Trigger Level (cells/L)	Value (cells/L)
LAG	April 2016	>5000	27468
	December 2019		9840
BRG	November 2017		11904
	April 2020		160
	May 2020		2240
MAR	May 2016		1569456
	July 2016		147168
	September 2016		1431360

Site	Event	DOHWA Trigger Level (cells/L)	Value (cells/L)
	December 2016		310716
	February 2017		154980
	January 2019		1153200
	February 2020		1440
VCP	December 2016		4032
	December 2017		186
	January 2019		262074
	December 2019		160
	February 2020		15040
CWR	April 2016		33516
	May 2016		252
	January 2020		880
	February 2020		299600

Based on the five-year monitoring program results, Toxic and Nuisance Phytoplankton, as an environmental quality indicator, does pose a low risk to Recreation and Aesthetics (EQO3 and EQO4) and Cultural and Spiritual values (EQO6). However, this risk has been observed to be reducing in the artificial waterways between 2016 and 2021. Ongoing management (i.e. maintenance dredging of the marina entrance), and the regulation of primary contact within the marina is recommended to ensure EQO3, EQO4 and EQO6 are maintained.

4. Conclusions

The primary risk to the environmental values of the artificial waterways is associated with reduced flushing rates as a result of accumulated sediment and wrack material in the entrance channel. Monitoring indicates that when the channel is maintained to the design depth this risk is substantially reduced. The key environmental quality indicator for this risk is DO in water; when DO levels remain low for a sustained period of time, water and sediment conditions can become anoxic which is detrimental to marine life and the recreation and aesthetic values of the waterway. Increased flushing also reduces the potential for toxic algal blooms. Whilst this was not observed as a significant risk throughout the monitoring program, with the majority of elevated algal concentrations generally short lived; there is an ongoing risk that elevated algal concentrations could lead to toxic blooms under certain circumstances. Blooms typically occur in calm, sunny conditions with ample nutrient concentrations.

In addition to reduced flushing, monitoring results indicate that historically accumulated and residual wrack that is decomposing in sediments of IW and LIW, poses a significant ongoing risk to ecosystem health within the artificial waterways.

The recreation and aesthetic values of the artificial waterways are also at risk due to a 'slight' to 'moderate' odour regularly recorded near the marina channel opening (Sites CHL and LAG). This odour is related in part to the large amount of seabird life roosting on the adjacent rock wall, but primarily caused by the decomposition of organic material which has accumulated on the western beach adjacent to the entrance channel.

Whilst it is recognised that the EV 'Fishing' and the corresponding EQO2: '*Seafood (caught) is of a quality safe for human consumption*' are applicable to the Port Geographe artificial waterways, the DoT does not recommend consuming seafood caught within these artificial waterways. Furthermore, no specific EQG and EQS have been derived for assessment against EQO2. Rather, this EV and corresponding EQO are considered to be addressed through assessment of EQI against EQO3: '*Water quality is safe for primary contact recreation (e.g. swimming and diving)'*. EQO3 was 'at risk' of not being achieved in VCP indicating that EQO2 is 'at risk' of not being achieved.

5. Reference List

ANZECC/ARMCANZ (2000). Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy No 4, Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of Australia and New Zealand, Canberra, ACT.

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

Bergquist. D, Baker. S, and Julian. D. (2003). Toxic sulfide concentrations in the sediment and water column of the Suwannee River estuary and its influence on hard clam survival. Project Number PD 03 5.

DOHWA (2017). EQC for toxic algae in marine recreational water (Version 2). Water Unit, Environmental Health Directorate, Department of Health, WA. Printed 27 Oct 2017.

EPA (2000, November). Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras. Washington DC: Office of Water: Office of Science and Technology.

Government of Western Australia (2005). State Environmental (Cockburn Sound) Policy 2005, Western Australia, State Environmental Policy Series 01, pp30.

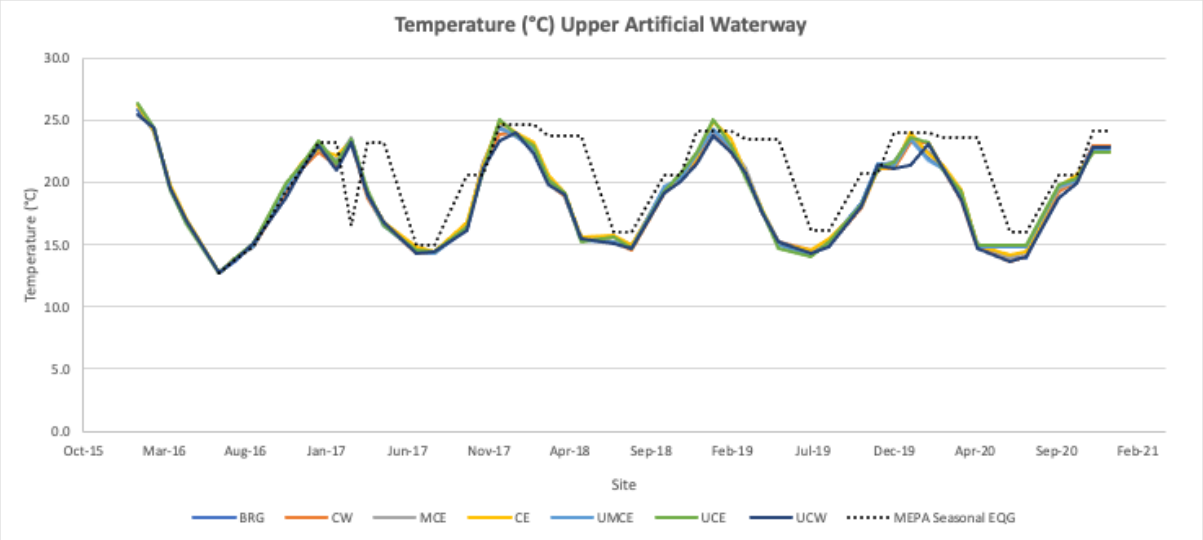
O2 Marine (2017) Port Geographe Artificial Waterways – Routine Sampling and Analysis Plan. Prepared on behalf of the West Australian Department of Transport. April 2017. pp28

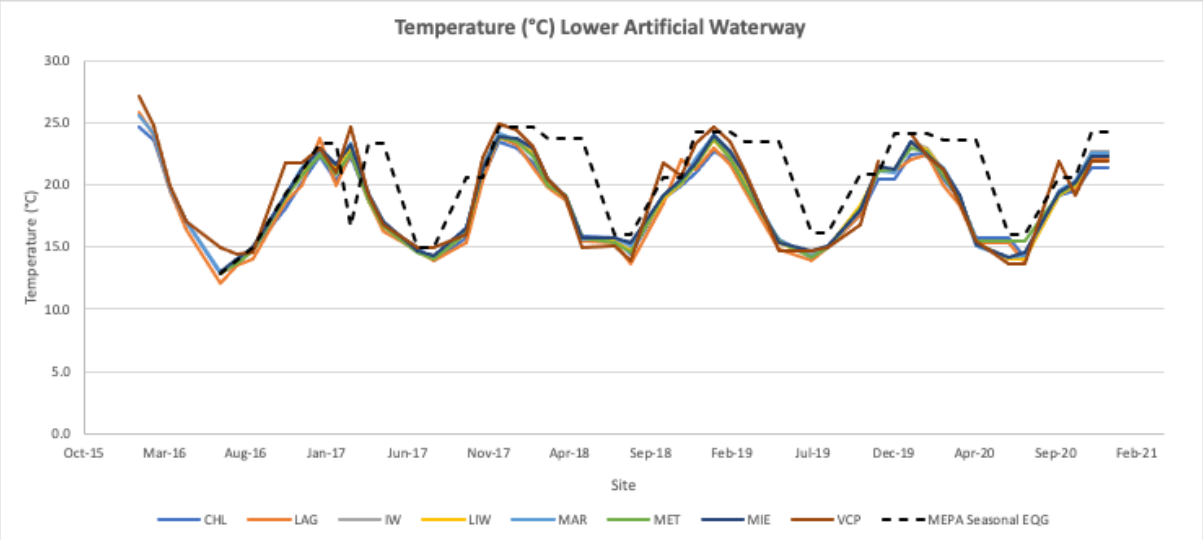
Appendix A Water Quality Monitoring Schedule

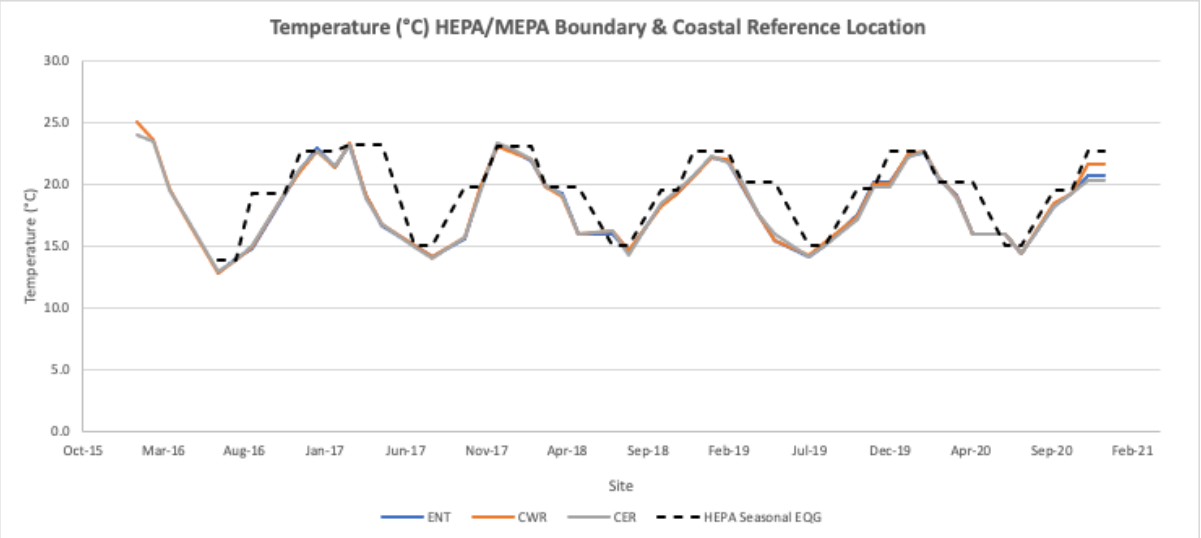
Event	Date	Comments
2015 / 2016		
1	11th February 2016	First sampling round undertaken by O2 Marine. Laboratory testing switched to ALS and Dalcon. Sampling undertaken in accordance with Interim AWBMP requirements.
2	15th March 2016	Sampling undertaken in accordance with Interim AWBMP requirements.
3	12th April 2016	Sampling undertaken in accordance with Interim AWBMP requirements.
4	9th May 2016	Sampling undertaken in accordance with Interim AWBMP requirements.
2016 / 2017		
1	13th July 2016	Sampling undertaken in accordance with Interim AWBMP requirements.
2	16th August 2016	Sampling undertaken in accordance with Interim AWBMP requirements.
3	8th September 2016	Sampling undertaken in accordance with Interim AWBMP requirements. CWR was relocated to be just outside the N'gari Capes Marine Park Boundary as per recommendation made by O2 Marine in the Monitoring Program Review (O2 Marine 2016) and accepted by DoT in May 2017.
4	9th November 2016	Sampling undertaken in accordance with Interim AWBMP requirements. Validation water quality profiling undertaken at previous and new CWR monitoring locations to validate that the results recorded between sites are representative.
5	13th December 2016	Sampling undertaken in accordance with Interim AWBMP requirements.
6	3rd January 2017	Sampling undertaken in accordance with Interim AWBMP requirements. Maintenance dredging activities temporarily ceased during summer holidays on 3rd January 2017.
7	8th February 2017	Sampling undertaken in accordance with Interim AWBMP requirements. Maintenance dredging activities moved to the outer edge of the Port Geographe entrance channel.
8	8th March 2017	Sampling undertaken in accordance with Interim AWBMP requirements. Maintenance dredging activities moved to the outer edge of the Port Geographe entrance channel.
9	12th April 2017	Sampling undertaken in accordance with the SAP (O2 Marine 2017) requirements. Maintenance dredging activities completed.
10	17th May 2017	Sampling undertaken in accordance with the SAP (O2 Marine 2017) requirements.
2017 / 2018		
1	26th July 2017	Sampling undertaken in accordance with SAP (O2 Marine 2017).
2	21st August 2017	Sampling undertaken in accordance with SAP (O2 Marine 2017)
3	4th October 2017	Sampling undertaken in accordance with SAP (O2 Marine 2017). Installed dissolved oxygen telemetered instrument at site CE. Dredging operational
4	15th November2017	Sampling undertaken in accordance with SAP (O2 Marine 2017). Removed dissolved oxygen telemetered instrument at CE. Dredging operational
5	12th December 2017	Sampling undertaken in accordance with SAP (O2 Marine 2017). CHL sample location moved 20 m west due to maintenance dredging operations.
6	17th January 2018	Sampling undertaken in accordance with SAP (O2 Marine 2017).
7	20th February 2018	Sampling undertaken in accordance with SAP (O2 Marine 2017).
8	27th March 2018	Sampling undertaken in accordance with SAP (O2 Marine 2017).
9	30th April 2018	Sampling undertaken in accordance with SAP (O2 Marine 2017).
10	29th May 2018	Sampling undertaken in accordance with the SAP (O2 Marine 2017).
2018 / 2019		
1	31st July 2018	Sampling undertaken in accordance with SAP (O2 Marine 2017).
2	30th August 2018	Sampling undertaken in accordance with SAP (O2 Marine 2017)
3	15th October 2018	Sampling undertaken in accordance with SAP (O2 Marine 2017).
4	14th November2018	Sampling undertaken in accordance with SAP (O2 Marine 2017).
5	20th December 2018	Sampling undertaken in accordance with SAP (O2 Marine 2017).
6	22nd January 2019	Sampling undertaken in accordance with SAP (O2 Marine 2017).
7	19th February 2019	Sampling undertaken in accordance with SAP (O2 Marine 2017).
8	25th March 2019	Sampling undertaken in accordance with SAP (O2 Marine 2017).
9	30th April 2019	Sampling undertaken in accordance with SAP (O2 Marine 2017).

10	28th May 2019	Sampling undertaken in accordance with SAP (O2 Marine 2017).
2019 / 2020		
1	31st July 2019	Sampling undertaken in accordance with SAP (O2 Marine 2017).
2	29th August 2019	Sampling undertaken in accordance with SAP (O2 Marine 2017).
3	7th October 2019	Sampling undertaken in accordance with SAP (O2 Marine 2017).
4	13th November2019	Sampling undertaken in accordance with SAP (O2 Marine 2017).
5	17th December 2019	Calibration issue with YSI, affecting salinity and temperature results.
6	22nd January 2020	Sampling undertaken in accordance with SAP (O2 Marine 2017).
7	2nd & 12th February 2020	Sampling was undertaken across two (2) separate days due to poor weather.
8	19th March 2020	Sampling was undertaken in accordance with SAP (O2 Marine 2017)
9	28th April 2020	Sampling was undertaken in accordance with SAP (O2 Marine 2017)
10	31st May 2020	Sampling was undertaken in accordance with SAP (O2 Marine 2017)
2020 / 2021		
1	9th July 2020	Sampling undertaken in accordance with SAP (O2 Marine 2017).
2	19th August 2020	Sampling undertaken in accordance with SAP (O2 Marine 2017).
3	13th October 2020	Site LAG was not sampled, due to dredging activities.
4	11th November 2020	Sampling undertaken in accordance with SAP (O2 Marine 2017).
5	10th December 2020	Sampling undertaken in accordance with SAP (O2 Marine 2017).
6	17th January 2021	Site LAG was not sampled, due to dredging activities. Final monitoring event.

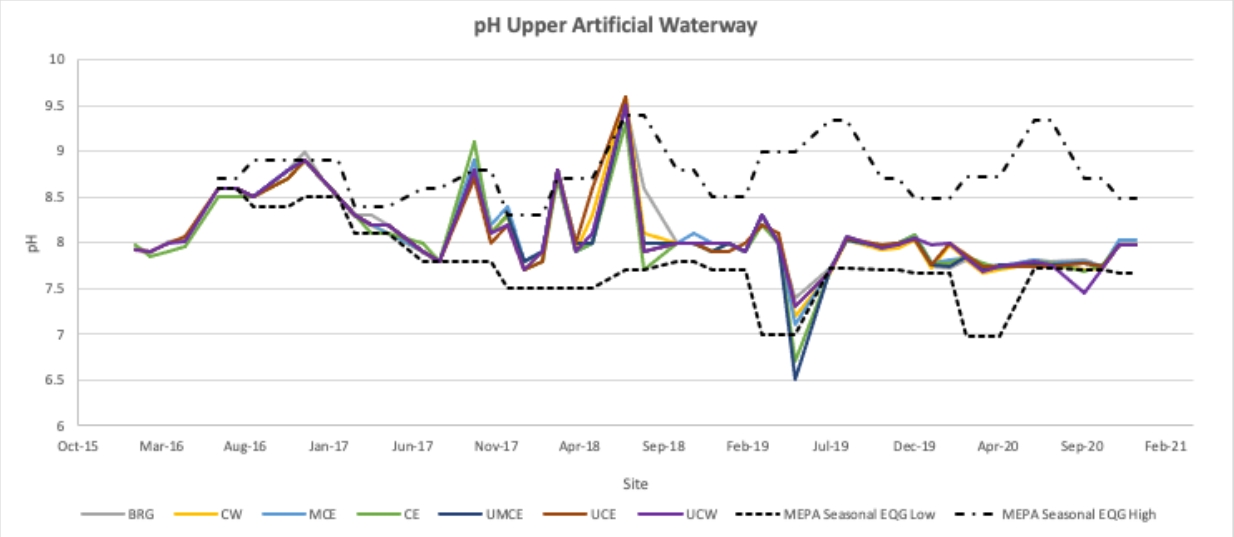
Appendix B Temperature Results (2016 – 2021)

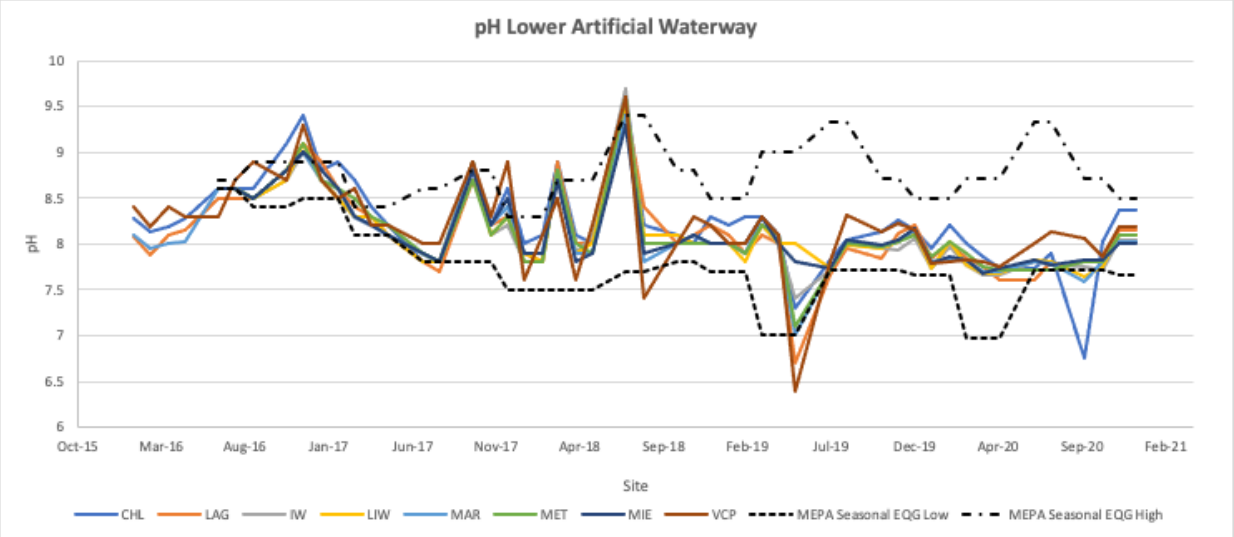


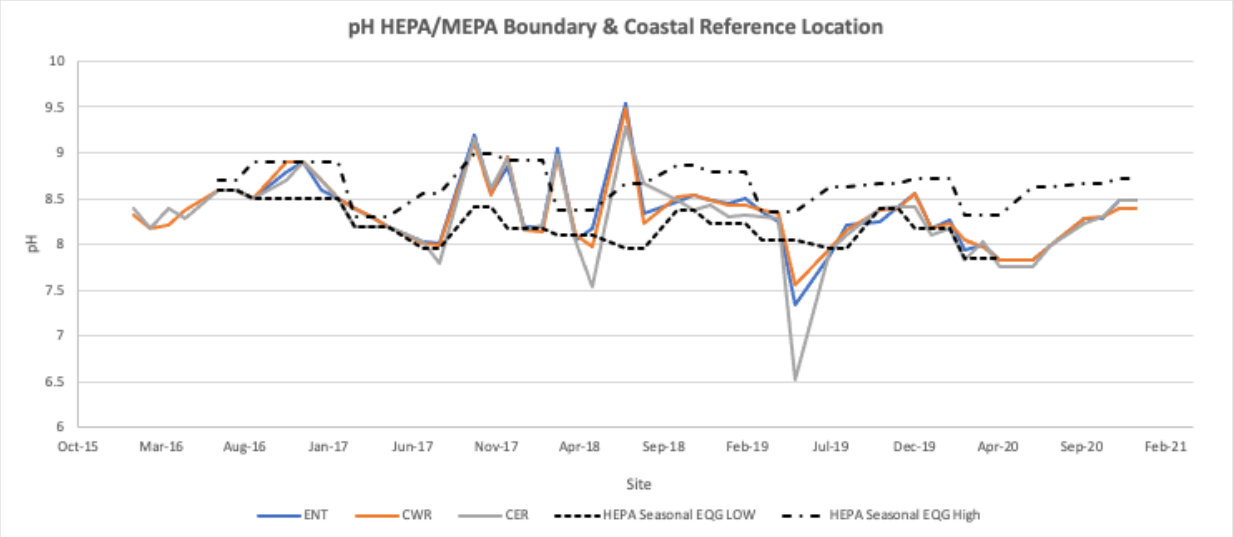




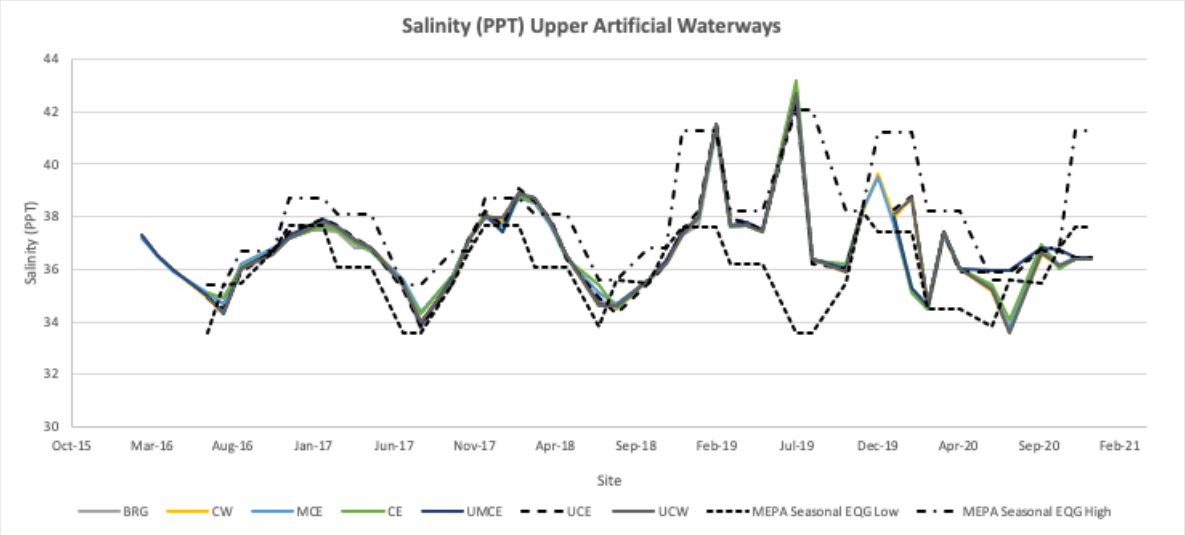
Appendix C pH Results (2016 - 2021)

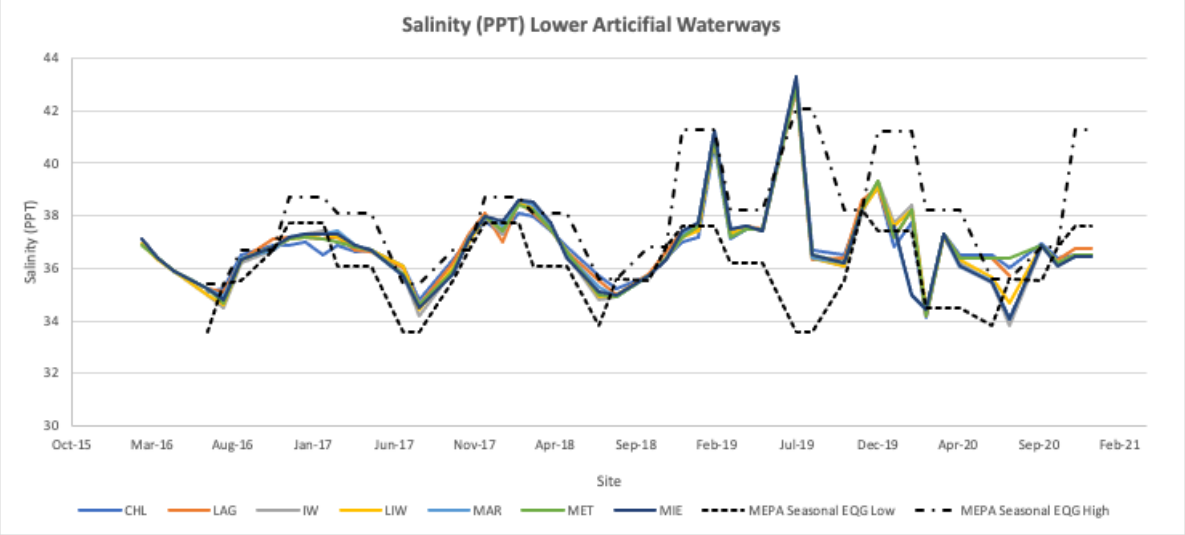


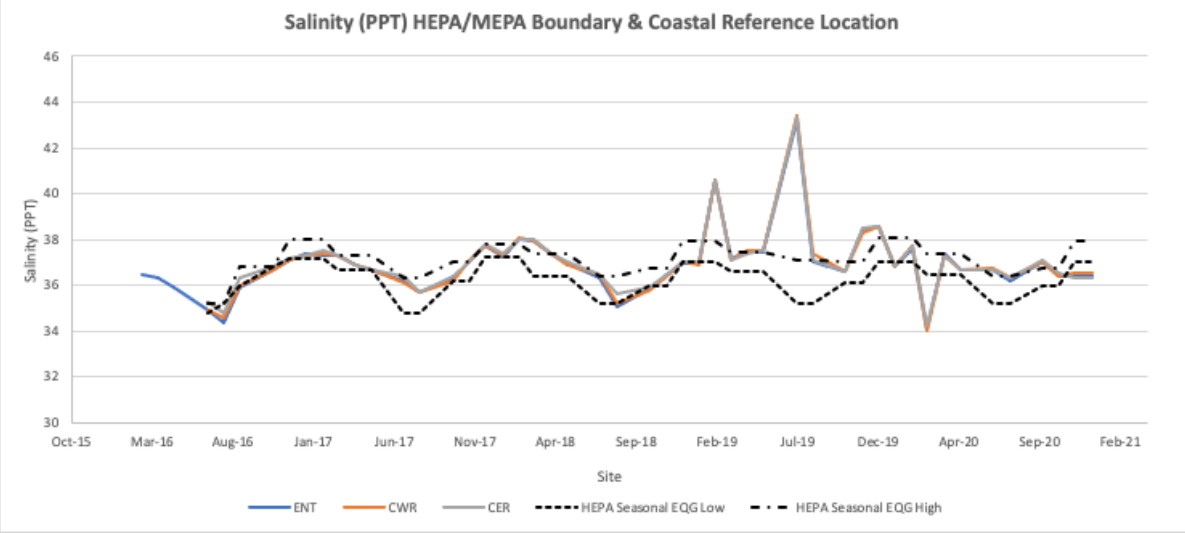




Appendix D Salinity Results (2016 - 2021)







Appendix E Microbiology (2016 – 2021)