APPENDIX 5

REVIEW OF CURRENT AND FUTURE IMPACTS TO MARMION MARINE PARK

Groundwater Replenishment Scheme

Review of current and future impacts

to Marmion Marine Park

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Background

The Water Corporation has owned and operated the Beenyup Wastewater Treatment Plant (BWWTP), located at Lot 8278 on Plan 30778, Ocean Reef Road, Craigie WA 6025 since 1972. Secondary treated wastewater (TWW) flows by gravity to the Indian Ocean in Marmion Marine Park, and is discharged in 10 metres of water via two outlets (known as the Ocean Reef Outlet) , one at 1850 metres, the other at 1650 metres offshore, where it is rapidly diluted and dispersed. The original ocean outfall was commissioned in 1978 and a second outfall was commissioned in 1989.

The operation of the BWWTP is regulated by two Ministerial Statements under Part IV of the *Environmental Protection Act 1986* (the Act) and a Licence for a Prescribed Premises under Part V of the Act, being:

- Statement 382 of 13 March 1995 (the principal statement);
- Ministerial Statement 569 of 10 July 2001 which amended Condition 2-1 of Statement 382 relating to Target Loads for Nitrogen and Phosphorus; and
- Licence Number L7882/1992/14, expiry date 31 October 2016

The BWWTP also accommodates a trial Advanced Water Recycling Plant (AWRP) whereby secondary TWW (source water) undergoes advanced treatment via ultra-filtration, reverse osmosis and disinfection to produce water which meets Australian guidelines for drinking water prior to being recharged to an aquifer for later use as a drinking water source. This is known as the Groundwater Replenishment Trial (GWRT). The advanced water treatment process also produces a wastewater stream which returns the concentrated contaminants in the TWW source water to the waste stream from from the BWWTP and the combined waste is discharged to the ocean via the Ocean Reef Ocean Outlet.

"The results of the GWRT has been provided to stakeholders and endorsed, thus the Water Corporation is proposing to move to the Groundwater Replenishment Scheme (GWRS) to be developed in a staged manner.

The proposed Perth GWRS is designed to produce between 28 and 35 Gigalitres (GL) per year based on current inflows of 120 megalitres (ML) per day of secondary treated wastewater at BWWTP.

It is proposed that the Perth GWRS stages, with timing dependant on water demand during a time of climate uncertainty will be as follows;

- Stage 1 - 7 GL recycled water for recharge, BWWTP flow 120ML/day
- Stage 2 - 14 GL recycled water for recharge, BWWTP flow 120ML/day
- Stage 3 - 28 to 35 GL recycled water for recharge, BWWTP flow 120ML/day

This report considers the discharge of secondary treated wastewater produced by the BWWTP combined with wastewater produced by the Beenyup AWRP required for Stages 1 and 2 (up to 14 GL/yr) of the Perth Groundwater Replenishment Scheme.

Monitoring of Ocean Outlets

The monitoring of discharges to the ocean through ocean outlets operated by the Water Corporation is mandated to a greater or lesser degree through requirements applied by Part IV Ministerial and Part V Licence Conditions. Beenyup WWTP combined with the AWRP is no exception, with obligations to implement a monitoring program, to the requirements of the Department of Environmental Protection, in consultation with the Department of Conservation and Land management and the Fisheries Department, and it sets target loads for nitrogen and phosphorus.

Contemporary conditions (those applied to Alkimos WWTP, Woodman Point WWTP and East Rockingham WWTP through the Sepia Depression Ocean Outlet etc) usually specify the requirement for a Monitoring and Management Plan dealing with a range of monitoring and reporting requirements consistent with the Environmental Quality Management Framework (EQMF) approach , performance criteria to be met and management responses required.

The evolution of monitoring commenced in 1992 with the development of the Perth's Coastal Water Studies (PCWS), which in turn led to the present day Perth Long Term Ocean Outlet Monitoring (PLOOM) program. The PCWS was initiated in 1992 to meet an EPA requirement for information in support of the duplication of the TWW outlets at Ocean Reef. A suite of studies was undertaken from 1992 to 1994 under the PCWS. This research led to a recommendation for Water Corporation to continue a program of environmental monitoring to further investigate and monitor the influence of TWW on Perth's coastal waters. These recommendations resulted in the development, in consultation with the Department of Environment and Conservation (DEC), of the PLOOM program, which commenced formally in 1996.

The Ministerial Conditions applied to Beenyup WWTP predate the contemporary (EQMF) approach. However, the Water Corporation has, since 1996, voluntarily implemented the PLOOM program, which was in 2003 revised in consultation with the regulators, to make it consistent with the emerging EQMF approach of that time.

The Ministerial and Licence Conditions are presently the only regulations stipulating marine monitoring as part of Water Corporation's Licence to operate the Beenyup WWTP. These include requirements to undertake the following:

- Measures of TWW flows and associated contaminant loads to ensure maximum nutrient loads are not exceeded;
- An annual summer survey of ocean and beach water quality (nutrients, primary productivity and bacteria indicators) in the vicinity of the ocean outlets, and
- A three yearly survey of metals and pesticides in marine biota.

The Condition to undertake an annual summer survey and the three yearly metals and pesticides survey is fulfilled via the PLOOM program. All other components of the PLOOM program (i.e. Compliance Monitoring, WET Testing, and Comprehensive TWW Characterisation) are conducted over and above regulatory conditions.

The application of the PLOOM program to the Ocean Reef Outlet ensures voluntary monitoring and reporting of performance of the Beenyup WWTP/GWRS to the highest standards consistent with that required of other WWTPs discharging to the ocean.

Table 1 compares the monitoring requirements applied to the Water Corporation's Alkimos WWTP and Sepia Depression Ocean Outlet through their respective mandated Monitoring and Management Plans, with the voluntarily applied PLOOM program at the Ocean Reef Outlet.

Table 1 Mandatory Monitoring at Alkimos and Sepia Depression versus the PLOOM Program at Ocean Reef

Parameter Monitored	Mandatory Ocean Outfall Monitoring and Management Plans as applied to Sepia Depression, Alkimos WWTP	Voluntary Ocean Outlet Monitoring (PLOOM) as applied to Ocean Reef Outlet
Treated wastewater characterisation An annual comprehensive characterisation of the treated wastewater discharged from the Wastewater Treatment Plant provides an indication of contaminant loads.	**YES** Concentrations of bio-accumulating toxicants in the wastewater are assessed against their ANZECC/ARMCANZ (2000) 80% species protection guidelines (prior to initial dilution).	**YES** Concentrations of bio-accumulating toxicants in the wastewater are assessed against their ANZECC/ARMCANZ (2000) 80% species protection guidelines (prior to initial dilution).
Initial dilution modeling Initial dilution modeling estimates the dilution and dispersal of the wastewater plume by seawater. The initial (or near-field) dilution zone begins at the point of discharge on the seafloor, and extends to the point of maximum elevation (e.g. the point at which the plume first reaches the surface). Estimates of the contaminant concentrations after initial dilution (calculated from the waste water characterisation and the model output)	**YES** Contaminants are assessed against their ANZECC/ARMCANZ (2000) 99% species protection guidelines (or 95% for cobalt).	**YES** Contaminants are assessed against their ANZECC/ARMCANZ (2000) 99% species protection guidelines (or 95% for cobalt).
Whole of Effluent Toxicity (WET) Tests WET tests subject marine invertebrates (and occasionally fish) to different concentrations of treated wastewater to test for a biological response of organisms to the wastewater. WET testing is conducted on a quarterly basis using the 1-hour sea urchin fertilisation test.	**YES** The 1-hour urchin test is rapid (allowing for a rapid management response) and sensitive to soaps & detergents (a key contaminant in domestic wastewater). The test determines the success of sea urchin fertilisation over a 1-hour period using gametes of the sea urchin *Heliocidaris tuberculata* that have been exposed to dilute wastewater for a 1-hour period.	**YES** The 1-hour urchin test is rapid (allowing for a rapid management response) and sensitive to soaps & detergents (a key contaminant in domestic wastewater). The test determines the success of sea urchin fertilisation over a 1-hour period using gametes of the sea urchin *Heliocidaris tuberculata* that have been exposed to dilute wastewater for a 1-hour period.

Parameter Monitored	Mandatory Ocean Outfall Monitoring and Management Plans as applied to Sepia Depression, Alkimos WWTP	Voluntary Ocean Outlet Monitoring (PLOOM) as applied to Ocean Reef Outlet
Annual Summer Water Quality Monitoring Survey Assesses the environmental impacts of the treated wastewater discharge through regular and intensive water quality monitoring in an Environmental Quality Management Framework. Each summer, eight sampling trips are conduced fortnightly commencing in early December. Some sampling is conducted at a series of fixed monitoring and reference sites. Consists of : • Compliance Monitoring and • Plume Monitoring	**YES** On each sampling occasion, a surface drogue is also deployed over the centre of the operational ocean outlet diffuser and retrieved approximately 30 minutes later. The information is used to provide a directional vector which determines the location of further sites for water quality sampling relative to the outlet.	**YES** The operation of Beenyup WWTP, and the discharge of treated wastewater to the marine environment is conducted under License Conditions set by the DEC. The License Conditions for the Beenyup WWTP includes a requirement to undertake annual summer surveys of ocean water quality to examine the effects of discharged treated wastewater on the marine environment. The Survey undertaken at Ocean Reef is consistent with similar summer water quality surveys in the marine environment at other ocean outlets
Compliance monitoring Aims to maintain a healthy and diverse ecosystem. Compliance monitoring is conducted at five fixed sites north of the outlet and four reference sites around 4 km south of the outlet s	**YES** DO, salinity and temperature profiles Light attenuation coefficient Water samples from just below the surface of the water and immediately above the top of the reef at each site. Water samples analysed for chlorophyll-a, ammonia, nitrate+nitrite and ortho-phosphate A depth integrated water sample representative of the top half of the water column collected at each site Depth integrated samples preserved in lugols for phytoplankton analysis Initial phytoplankton analysis conducted on one monitoring and one reference sample	**YES** DO, salinity and temperature profiles Light attenuation coefficient Water samples from just below the surface of the water and immediately above the top of the reef at each site. Water samples analysed for chlorophyll-a, ammonia, nitrate+nitrite and ortho-phosphate A depth integrated water sample representative of the top half of the water column collected at each site Depth integrated samples preserved in lugols for phytoplankton analysis Initial phytoplankton analysis conducted on one monitoring and one reference sample

<table>
<tr><th>Parameter Monitored</th><th>Mandatory Ocean Outfall Monitoring and Management Plans as applied to Sepia Depression, Alkimos WWTP</th><th>Voluntary Ocean Outlet Monitoring (PLOOM) as applied to Ocean Reef Outlet</th></tr>
<tr><td>Plume monitoring

Aims to maintain a healthy and diverse ecosystem.</td><td>YES

Plume monitoring in undertaken at five sites down-current of the outlet and at four reference sites

DO, salinity and temperature profiles collected at each site

Light attenuation coefficient calculated for each site

A depth-integrated water sample representative of the top half of the water column collected at each site

Depth integrated water samples analysed for chlorophyll-a, ammonia, nitrate+nitrite and ortho-phosphate</td><td>YES

Plume monitoring in undertaken at five sites down-current of the outlet and at four reference sites

DO, salinity and temperature profiles collected at each site

Light attenuation coefficient calculated for each site

A depth-integrated water sample representative of the top half of the water column collected at each site

Depth integrated water samples analysed for chlorophyll-a, ammonia, nitrate+nitrite and ortho-phosphate</td></tr>
<tr><td>Algal community monitoring

Conducted annually in mid to late summer.</td><td>YES

One location immediately north of the ocean outlet; and three reference locations, situated ~3.5 km south of the outlet and ~16 km and 19 km) north of the outlet..

Algal biochemical composition will be characterised by percent nitrogen content (%N), ratio of the stable carbon isotopes, carbon-13 to carbon-12 ($\delta^{13}C$) and ratio of stable nitrogen isotopes, nitrogen-15 to nitrogen-14 ($\delta^{15}N$) in Ulva sp., Ecklonia radiata and Plocamium preissianum.</td><td>NO</td></tr>
</table>

Parameter Monitored	Mandatory Ocean Outfall Monitoring and Management Plans as applied to Sepia Depression, Alkimos WWTP	Voluntary Ocean Outlet Monitoring (PLOOM) as applied to Ocean Reef Outlet
Aquatic life safe for human consumption Aims to support social uses such as fishing.	**YES** Thermo-tolerant coliforms are sampled near the bottom at two sites on the eastern boundary of zone S2 (i.e. the boundary closest to the shoreline). In recognition that shellfish live attached to substrate, water samples are collected at the bottom of the water column immediately above the reef matrix.	**YES** Thermo-tolerant coliforms are sampled near the bottom at five sites on the down-current boundary of the observed zone of influence (OZI) for aquatic life safe for human consumption. Phytoplankton (for Algal Bio toxins)are sampled via depth integrated water samples representative of the top half of the water column at five sites on the down-current boundary of observed zone of influence and the four reference sites.
Primary and secondary contact recreation Aims to support social uses such as swimming and boating.	**YES** Surface samples for *Enterococci* spp. are collected from five sites. Selection of sampling points is determined prior to commencement of sampling based on the trajectory of the drogue.	**YES** Enterococci spp. are sampled from depth integrated water samples representative of the top half of the water column at five sites down-current. Phytoplankton (for Algal Bio toxins) are sampled via depth integrated water samples representative of the top half of the water column at five sites on the down-current boundary of observed zone of influence and the four reference sites.
Sentinel Mussels To test the accumulation of a wide range of toxicants in their tissues, including microbiological pathogens (thermo-tolerant coliforms).	**YES** Sentinel mussel monitoring carried out at five-yearly intervals.	**NO**

Parameter Monitored	Mandatory Ocean Outfall Monitoring and Management Plans as applied to Sepia Depression, Alkimos WWTP	Voluntary Ocean Outlet Monitoring (PLOOM) as applied to Ocean Reef Outlet
Sediment Quality Collected every five years (summer).	**YES** Concentrations of potential contaminants in sediments can provide a useful time-integrated measurement of the distribution and accumulation of contaminants from marine wastewater outlets.	**NO**
Environmental Quality Management Framework (EQMF) The results of monitoring are assessed against two levels of Environmental Quality Criteria: • Environmental Quality Guidelines (EQG); and • Environmental Quality Standards (EQS).	**YES** EQGs are a threshold numerical value or narrative statement that, if met, indicate there is a high degree of certainty that the associated environmental quality objective (EQO) has been achieved. If the guideline is not met, there is uncertainty as to whether the associated EQOe has been achieved and a more detailed assessment against an EQS is triggered. EQSs are threshold values or narrative statements that indicate a level beyond which there is a significant risk that the associated EQO has been not been achieved. If an EQS is exceeded, investigation of the cause is needed and an adaptive management response is triggered if the exceedance continues.	**YES** EQGs are a threshold numerical value or narrative statement that, if met, indicate there is a high degree of certainty that the associated environmental quality objective (EQO) has been achieved. If the guideline is not met, there is uncertainty as to whether the associated EQOe has been achieved and a more detailed assessment against an EQS is triggered. EQSs are threshold values or narrative statements that indicate a level beyond which there is a significant risk that the associated EQO has been not been achieved. If an EQS is exceeded, investigation of the cause is needed and an adaptive management response is triggered if the exceedance continues.

Therefore the Ocean Reef Outlet is comprehensively monitored through the voluntary PLOOM Program.

Current performance in Marmion Marine Park

Results of 2009/2010 Summer Trial Compliance Monitoring (TCM), Whole of Effluent Toxicity Testing (WET) and Comprehensive Treated Wastewater Characterisation (CTWWC) monitoring programs, have demonstrated that the EQC for Ecosystem Integrity and Primary Contact Recreation were met in the vicinity of the Ocean Reef ocean outlets. These results indicate that the disposal of TWW to the ocean 1.5 km west of Ocean Reef is having no detectable adverse effects on marine water quality, or to marine flora and fauna. Exceedances of the EQC for Seafood Safe for Human Consumption were restricted to within 250 m of the diffuser. As there is no aquaculture within 250 m of the diffuser and no known harvesting of shellfish 1-2 km from the shoreline, the exceedances in this instance were not considered to represent a significant risk to human health. It was therefore considered that the EQO for Seafood Safe for Human Consumption was met". (*Appendix 1*)

From the 2012 Summer Water Quality Survey (*Appendix 2*) at Ocean Reef it was reported that "in surface waters close to the diffusers (<250 m), the median concentration of ammonia and total nitrogen were below the ANZECC/ARMCANZ (2000) guidelines, whereas concentrations of nitrate + nitrite, ortho-phosphate and total phosphate were above the guidelines. The same pattern of nutrient concentration exceedances occurred in bottom waters close to the diffusers (<250 m), with the exception that total phosphate was below the guideline. At greater distances from the outlet (>250 m), the median concentrations of all nutrients in surface and bottom waters, except for nitrate + nitrite in surface waters, were below the ANZECC/ARMCANZ (2000) guidelines".

The median concentrations of nutrients were also compared against the 80th percentile of reference values. At all sites, the median concentrations of all nutrient parameters in surface and bottom waters were below the 80th percentile of reference values.

The median chlorophyll *a* concentrations for surface and bottom sites <250 m and >250 m from the diffuser, and shoreline sites, were below the ANZECC/ARMCANZ (2000) guideline. Median chlorophyll *a* concentrations were above the 80th percentile of reference values at all locations except for bottom waters <250 m from the diffuser.

The guideline for the maintenance of seafood safe for human consumption was met for thermo-tolerant coliforms at surface and bottom sites >250 m from the diffuser. Thermo-tolerant coliform counts exceeded the guideline in surface and bottom waters at sites <250 m from the diffuser. Median counts of *Enterococci* spp. were below primary contact recreation criteria in all cases at Ocean Reef.

Shoreline sites at Ocean Reef met environmental quality criteria for the maintenance of seafood safe for human consumption for thermo-tolerant coliforms and met the primary contact recreation criteria for *Enterococci* spp.

Microbiological indicators are not expected to meet criteria inside the mixing zone. It is noted that despite exceeding the guideline for seafood safe for human consumption at Ocean Reef at sites <250 m from the diffuser, there are presently few, if any, suitable habitats for filter feeding shellfish in the vicinity of the ocean outlets. The risk to humans is therefore considered very low.

In the absence of the definition and establishment (through a formal Monitoring and Management Plan) of low and high (LEPA/HEPA) ecological protection zones for ecosystem integrity (EQO 1), maintenance of aquatic life for human consumption (EQO2), maintenance of primary contact recreation values (EQO3) and maintenance of secondary contact recreation values (EQO4), the reporting is descriptive and shows impacts consistent with those expected within LEPA/HEPA's at other plants where they are applied .

Modelling of Proposed Discharges

The advanced water recycling plant (AWRP) for the proposed GWRs comprises ultrafiltration (UF) reverse osmosis (RO) and ultraviolet (UV) disinfection, and at this stage it is anticipated that this will be the treatment train for any expansion. The UF and RO treatments together produce a reject stream which comprises about 30% of total influent flows and 95 to 100% of most contaminants.

The Water Corporation engaged Oceanica Pty Ltd to undertake modelling of the impacts of the Water Corporation's proposal for a staged expansion of GWRT to a full scheme (GWRS). The following is the executive summary of their findings from the 2011 report (*Appendix 3*) Water Corporation of Western Australia: Beenyup Advanced Water Recycling Plant, Impact Assessment of Water Recycling Reject Stream Discharge:

> "The resultant ocean discharge will be a combination of the AWRP reject stream and any portion of the Beenyup secondary treated wastewater which has not been introduced to the AWRP".
>
> The modelling examines the potential effects on the marine environment of increasing the amount of treated wastewater passed through the AWRP up to 100% of the current 120 ML/d of treated wastewater produced by the Beenyup WWTP.
>
> The Water Corporation is planning to proceed with up to a 14 GLpa scheme as the initial stage of a long-term water resource strategy (Stage 1 and 2); examining three stages against the base case of there being no AWRP.
>
> - **Stage 1** (7 GLpa recycled): Of the 120 ML/d coming out of the Beenyup WWTP; 30 ML/d is directed to the AWRP of which 20 ML/d is recycled and 10 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 100 ML/d.
> - **Stage 2** (14 GLpa recycled): Of the 120 ML/d coming out of the Beenyup WWTP, 60 ML/d is directed to the AWRP, of which 41 ML/d is recycled and 19 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 79 ML/d.
> - **Stage 3** (28 GLpa recycled): All of the 120 ML/d coming out of the Beenyup WWTP is directed to the AWRP, of which 81 ML/d is recycled and 39 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 39 ML/d.
>
> The following discussion is a précis of the findings of the assessment of the impacts of the AWRP on the marine environment as it relates to Stages 1 and 2.
>
> ***Effect on initial dilution***
>
> Under all current conditions, for both Outlet A and B, the initial dilution is predicted to increase with increasing ratio of reject flow to pre-recycling flow. Comparing Stage 3 with the pre-recycling case, the increase in dilution may be more than 200% due to lower flows.

The effect of introducing a slightly higher salinity stream was found to be inconsequential on mixing and dispersion as the plume is still significantly more buoyant than seawater and it was the overall reduction in flows that dominated the effect of the AWRP on initial dilution.

Environmental considerations

Potential environmental implications of the proposed AWRP include the increased concentration of nutrients and toxicants being discharged to the marine environment (by a factor of up to 3.16-fold if 100% of these contaminants are removed to the reject stream).

However, as the concentration factor increases, the flow decreases and the dilution increases, therefore the higher contaminant concentrations of the post-recycling discharge are largely offset.

Toxicants

The toxicant of primary concern is copper as it is closest to the environmental quality guideline under any conditions (this is a due to the extensive use of copper piping in domestic plumbing). Under conditions of the currents typical of the region, the EPA (2005) High Protection guideline (99% species protection) is met for the 95th percentile concentrations of contaminants of concern (ammonium, copper and zinc) under both pre-recycling discharge and post-recycling discharge stages.

Pathogens

Chloramination is required in order to maintain the effectiveness of the AWRP RO membranes, according to data supplied by the Water Corporation the ARWP process significantly reduces pathogen counts in ocean discharge. As such, the AWRP has a net benefit with regard to pathogen concentrations after discharge to the ocean compared to the existing discharge.

Nutrients

With respect to nutrient-related effects, there are presently no guidelines for assessing these at Ocean Reef. However, the AWRP will not alter the total nutrient loads discharged to Ocean Reef and therefore will not require any amendment to the existing Ministerial Conditions or Licence Conditions. Further, nutrient concentrations after initial dilution will not change under typical conditions and it is considered highly unlikely that there will be any change in nutrient-related effects due to wastewater discharge under the AWRP.

Maintenance and Clean in Place chemicals

It will be necessary to establish a schedule of cleaning for the ultra filtration membrane and reverse osmosis filters with batches of 'Maintenance Wash' (MW) and 'Clean in Place' (CIP) chemicals. The CIP chemicals do not contain material quantities of the contaminants of concern and are introduced at extremely low volumes proportional to the total flow, the combination of their high degree of dilution in the reject stream followed by the dilution after discharge means that they pose negligible risk."

Conclusions

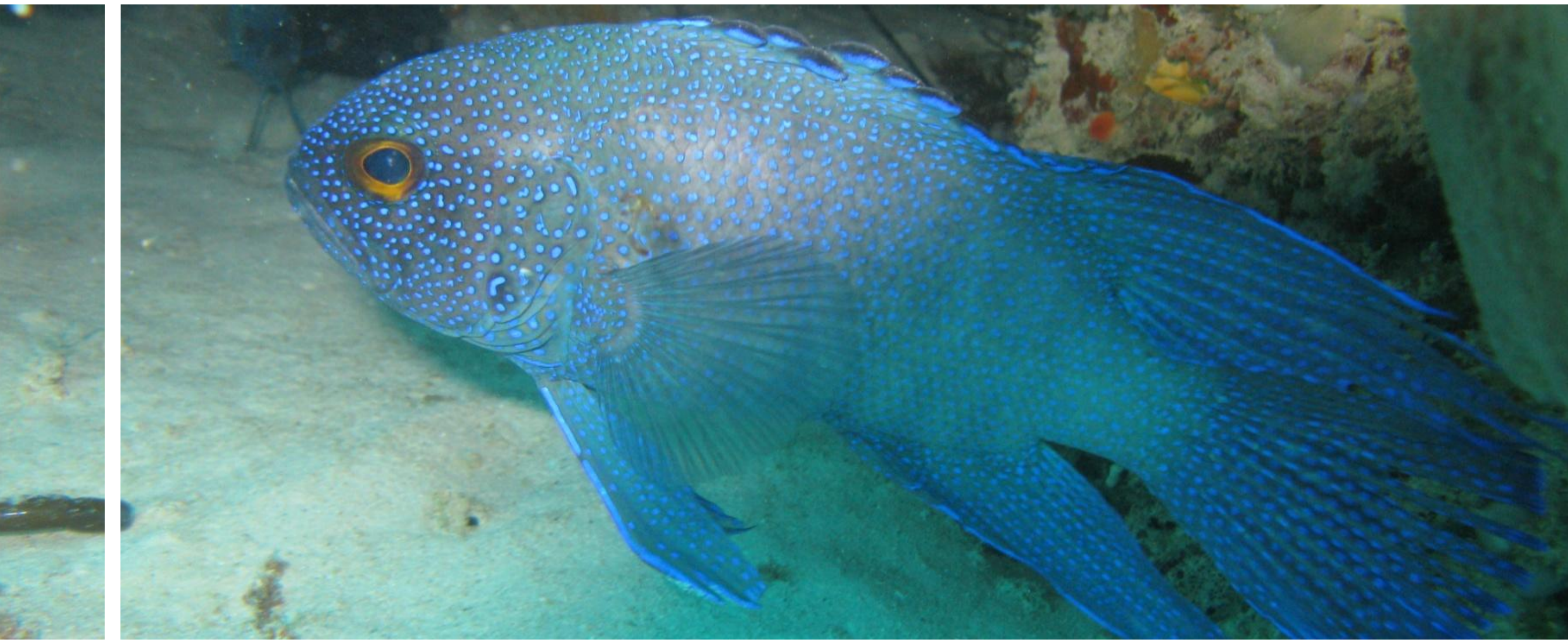
- Ocean Reef Outlet is comprehensively monitored through the voluntary PLOOM Program.
- Results of the PLOOM monitoring demonstrated that the EQC for Ecosystem Integrity and Primary Contact Recreation were met in the vicinity of the Ocean Reef ocean outlets. These results indicate that the disposal of TWW to the ocean 1.5 km west of Ocean Reef is having no detectable adverse effects on marine water quality, or to marine flora and fauna. Furthermore, exceedances of the EQC for Seafood Safe for Human Consumption were restricted to within 250 m of the diffuser. As there is no aquaculture within 250 m of the diffuser and no known harvesting of shellfish 1-2 km from the shoreline, the exceedances in this instance were not considered to represent a significant risk to human health. It was therefore considered that the EQO for Seafood Safe for Human Consumption was met.
- The Water Corporation proposes a staged development of the GWRS, the first stage being up to 14 GLpa.
- Modelling of combined BWWTP and AWRP waste streams for the three stages against the base case of there being no AWRP has concluded that:
    - the higher contaminant concentrations of the post-recycling discharge are largely offset due to decrease in flow resulting in increasing dilution;
    - the EPA (2005) High Protection guideline (99% species protection) is met for the 95th percentile concentrations of contaminants of concern (ammonium, copper and zinc) under both pre-recycling discharge and post-recycling discharge stages;
    - the ARWP process significantly reduces pathogen counts in the ocean discharge having a net benefit with regard to pathogen concentrations after discharge to the ocean compared to the existing discharge; and
    - the AWRP will not alter the total nutrient loads discharged to Ocean Reef and nutrient concentrations after initial dilution will not change under typical conditions.
- The Water Corporation commits to referring the GWRS for this proposal for an AWRP up to 14 GLpa to the EPA, and believes that the proposal will not cause a significant change to the current operation of and impacts from the Ocean Reef Outlet in the marine environment, hence possibly not requiring formal assessment.
- However, the Water Corporation recognises that development a 28 – 35 GLpa recycled water scheme will require the establishment of LEPA/HEPA boundaries and a formally mandated Monitoring and Management Plan. Any future proposal beyond 14GLpa will be referred to the EPA and the Water Corporation commits to undertake the studies necessary to inform the delineation of the ecological protection zones and Monitoring and Management Plans for the ultimate capacity at that time.

Appendices

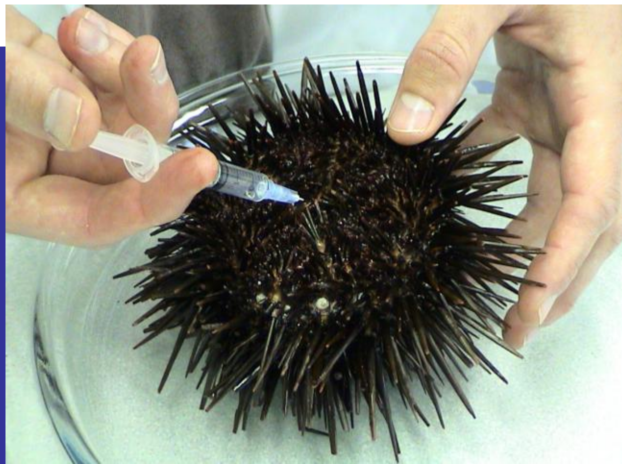
Appendix 1: Perth Long Term Ocean Outlet Monitoring Program (PLOOM) 6.0 2009/2010 Annual Report: Ocean Reef

oceanica

marine & coastal specialists

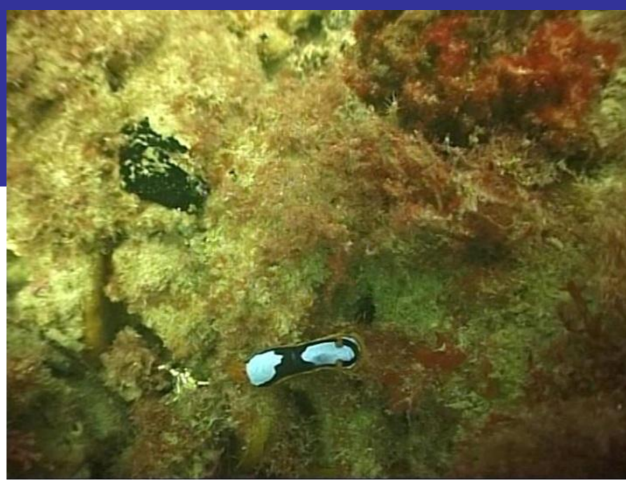


Perth Long Term Ocean Outlet Monitoring Program (PLOOM) 6.0



2009/2010 Annual Report: Ocean Reef

November 2010



Perth Long Term Ocean Outlet Monitoring Program (PLOOM) 6.0

2009/2010 Annual Report: Ocean Reef

Prepared for

Water Corporation of Western Australia

Prepared by

Oceanica Consulting Pty Ltd

November 2010

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Client: Water Corporation of Western Australia

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B	A Bevilaqua	M Bailey	1 x word doc	13/07/2010	M Bailey	22/07/2010
C	A Bevilaqua G Shiell	M Nener	1 x PDF	1/10/2010		
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Status
This report is "Draft" until the author and director have signed it off for final release. A "Draft" report should not be used for any purpose other than to be reviewed with the intention of generating a "Final" version.

Approved for final release:



Authors: Adelaide Bevilaqua   Dr Glenn Shiell   Director: Mark Bailey

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Cover
Main image: The western blue devil fish (Oceanica Consulting);
Minor images: Sea urchin fertilisation tests (Ecotox Services); Nudibranch on the Ocean Reef outlet diffuser (Oceanica Consulting).

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Executive Summary

The objective of this report is to document the findings of ocean monitoring conducted in the vicinity of the Ocean Reef ocean outlets. Specifically, this document outlines the results of monitoring and scientific investigations conducted in addition to the Licence Condition to undertake the Annual Summer Water Quality Survey [ASWQS] (reported separately in Oceanica 2010a). This follows Water Corporation's moral and social commitment to ensure the discharge of treated wastewater (TWW) to the marine environment is sustainable and managed to ensure protection of ecosystem and social values. The following data are presented in the Sections 3.1, 3.2 and 3.3 of the report:

- Summer Trial Compliance Monitoring;
- WET testing (1 hour sea urchin fertilisation); and,
- Comprehensive TWW characterisation.

Results of summer TCM, WET testing and the comprehensive TWW characterisation components supplement the information collected during the ASWQS, and demonstrate the Water Corporation's commitment to 'continual improvement of environmental performance' in accordance with the Corporate EMS (pursuant to ISO14001:2004 Standard).

Background

The Water Corporation of Western Australia (Water Corporation) operates three major wastewater treatment plants (WWTP) in metropolitan Perth, located at Beenyup, Subiaco and Woodman Point. The Beenyup WWTP services Perth's northern suburbs, and discharges approximately 116 ML/day of secondary TWW to the sea through two outlets at Ocean Reef. The operation of the Beenyup WWTP and the discharge of TWW to the marine environment are conducted under Licence and Ministerial Conditions. Licence and Ministerial Conditions include requirements to undertake a one-day snapshot survey of water quality in the vicinity of the outlets (annual requirement) and surveys of metals and pesticides in biota (3 yearly requirement). These Conditions are presently the only regulations stipulating marine monitoring as part of Water Corporation's Licence to operate the Beenyup WWTP. All other environmental monitoring components (i.e. Trial Compliance Monitoring, WET testing and comprehensive TWW characterisation) are conducted over and above the Licence conditions. This report outlines the results of these additional monitoring components conducted as part of the Perth Long Term Ocean Outlet Monitoring (PLOOM) program.

Trial Compliance Monitoring

The objective of the TCM is to assess water quality in the vicinity of the outlets over the 3-month summer period and assess whether the Environmental Quality Objectives (EQO) (as defined by the EPA) have been met. The extent to which the EQO were met is assessed against the environmental quality criteria (EQC). Samples are collected at fixed distances downstream of the outlet along the vector indicated by the drogue. The method is useful in that it provides water quality information from directly within the plume. The TCM includes analyses of the following parameters: nutrients (total nitrogen, ammonium, nitrate + nitrite, total phosphorus and ortho-phosphate), primary production (chlorophyll-*a* as a measure of phytoplankton biomass), physical-chemistry (water temperature, salinity, dissolved oxygen and light attenuation) and microbiological indicators (thermo-tolerant coliforms and *Enterococci*). Each of the measures are used to assess the level of compliance against a suite of EQC related to the following EQO: Ecosystem Integrity; Primary and Secondary Contact Recreation and Seafood Safe for Human Consumption.

Data collected over the summer TCM period indicated that the EQC for Maintenance of Ecosystem Integrity and Primary and Secondary Contact Recreation were met. Contrasting results were obtained in the case of the EQO for Seafood Safe for Human Consumption. The EQC relevant to this EQO are the same as those reported in the Annual Summer Water Quality Survey (reported separately in Oceanica 2010a). As reported in Oceanica (2010a), the EQG and EQS for thermo tolerant coliforms were exceeded within <250 m of the diffuser, but not at distances >250 m. The EQO Seafood Safe for Human Consumption is primarily concerned with the harvesting and consumption of raw shellfish (meaning filter feeding bivalve molluscs e.g. oysters, mussels, clams, pipis, scallops, cockles, and razor clams), and not other forms of seafood e.g. fin fish, abalone, crayfish etc. Human health concerns relating to seafood are not an issue at Ocean Reef as there is no aquaculture within 250 m of the diffuser and no known harvesting of shellfish in the waters 1–2 km offshore. In addition, any exceedance of the EQC for TTC is to be viewed conservatively, as the Department of Health (DoH) discourages the public from taking wild shellfish, recommending instead that shellfish are only consumed if harvested commercially and under strict monitoring programs. The Department of Health has further indicated that "*It is impossible to guarantee the safety of eating wild shellfish without having a comprehensive monitoring program that tests the waterway concerned for harmful microorganisms and toxins*" and has formally advised DEC that, in the absence of a full monitoring program, the application of the TTC criteria (EPA 2005) is insufficient to protect those who wish to collect and eat wild shellfish.

Whole of effluent toxicity tests

The WET testing (or direct toxicity assessment) program is also relevant to the EQO for Ecosystem Integrity. The 1-hour sea urchin fertilisation test is particularly effective in determining the combined effect of toxicants present in the TWW effluent, as it is a direct method for assessing the toxicity of TWW to local marine biota under ambient conditions. Wastewater samples are collected on a quarterly basis from the Beenyup WWTP for WET testing. WET testing determines the potential toxicity of the TWW using the 1-hour sea urchin (*Heliocidaris tuberculata*) fertilisation test. WET tests assess the number of dilutions required to reduce the toxicity of effluent to non-significant levels (where the number of successful fertilisation events between a control and effluent sample is statistically equal). Non-significant toxicity is referred to as the no-effects-concentration (NOEC). WET tests undertaken in January, April, July and October observed NOECs between 100% and 50%, equivalent to 0- and 1-fold dilutions of TWW respectively. All of the NOECs were greater than the 1.0% trigger for further investigation involving the full suite of WET tests involving multiple species. As the diffusers were shown to be achieving a minimum average initial dilution of 1:98 and 1:112, it was reasonably concluded that the risk to marine flora and fauna as a result of the combined TWW effluent was negligible.

TWW characterisation

The TWW Characterisation program is relevant to the EQO for Ecosystem Integrity. Levels of toxicants and contaminants in the TWW are measured before and after the initial dilution process and compared to relevant guidelines for ecosystem protection. The TWW Characterisation component indicated that the contaminants of concern (ammonia, copper, zinc) remained similar to concentrations recorded in previous years. The average initial dilution of the TWW plume, calculated using the VPLUMES UM3 numerical model set-up to match the conditions at the time of sampling, was 1:112 for Outlet A and 1:98 for Outlet B. Near field dilution calculations suggest that the 1:98-fold dilution ('worst-case' dilution from Outlet B) will adequately mix contaminants within the TWW at the initial stage of dilution to meet the ANZECC/ARMCANZ (2000) *Guidelines* for the protection of 99% of species.

Conclusions

Results of summer TCM, WET testing and Comprehensive TWW Analyses monitoring programs, have demonstrated that the EQC for Ecosystem Integrity and Primary Contact Recreation were met in the vicinity of the Ocean Reef ocean outlets. These results indicate that the disposal of TWW to the ocean 1.5 km west of Ocean Reef is having no detectable adverse effects on marine water quality, or to marine flora and fauna. Exceedances of the EQC for Seafood Safe for Human Consumption were restricted to within 250 m of the diffuser. As there is no aquaculture within 250 m of the diffuser and no known harvesting of shellfish 1-2 km from the shoreline, the exceedances in this instance were not considered to represent a significant risk to human health. It was therefore considered that the EQO for Seafood Safe for Human Consumption was met.

1. Introduction

1.1. Ocean disposal of TWW

The Water Corporation of Western Australia (Water Corporation) operates three major wastewater treatment plants in metropolitan Perth, located at Beenyup, Subiaco and Woodman Point. The Beenyup Wastewater Treatment Plant (WWTP) services Perth's northern suburbs, receiving predominantly domestic wastewater (from bathroom, toilet and laundry use) and less than 2% light industrial wastewater. The plant produces secondary TWW using an activated sludge process with advanced nitrification and denitrification stages used for nutrient removal. The Beenyup WWTP (and the Ocean Reef Ocean Outlet) does not receive significant volumes of industrial wastewater and therefore is unlikely to contain contaminants introduced through industrial processes.

The Beenyup WWTP discharges approximately 116 ML/day of secondary TWW to the sea through the two outlets at Ocean Reef. The outlets are 1.65 km (Outlet A) and 1.85 km (Outlet B) in length and located in approximately 10 m of water. The majority of TWW discharged via Outlet B and a minimal flow through Outlet A. Outlet A commenced discharge in 1978 and Outlet B in 1992. The discharge of TWW to the marine environment is characterised by a number of physical and chemical processes. Because TWW is primarily fresh, it is also lighter and lower in density relative to salty seawater. As a result, the TWW acts like a buoyant plume – rising and mixing through the water column as it ascends (Figure 1.1).

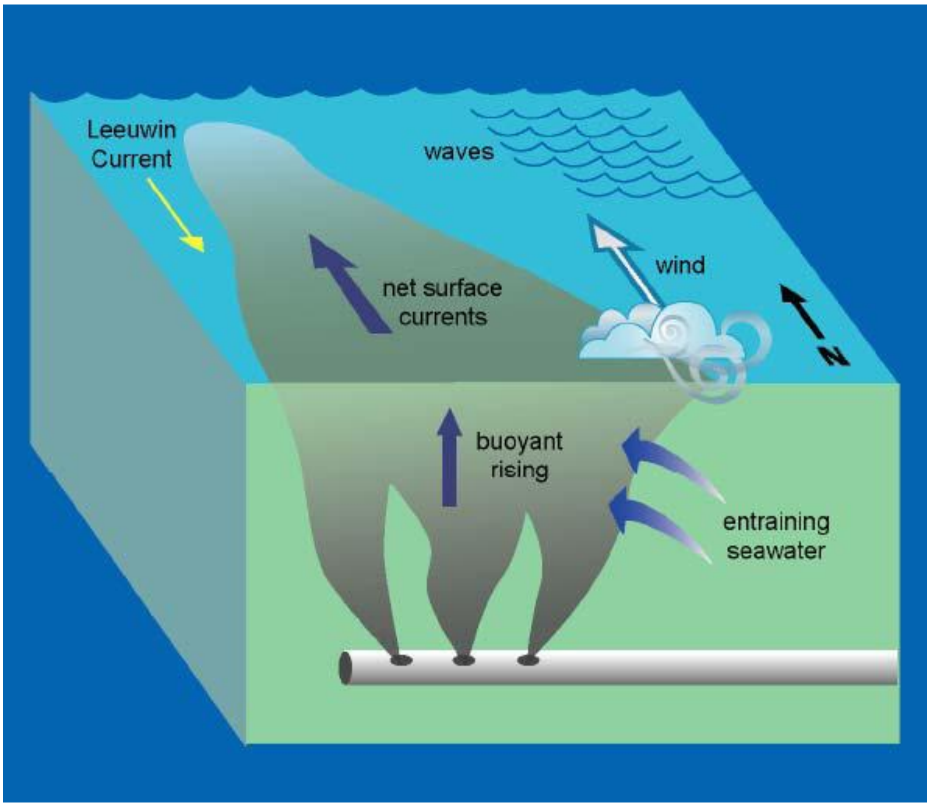

Figure 1.1 Schematic showing TWW plume dilution processes. Dilution occurs both as the wastewater rises from the seafloor to the surface (initial dilution) and as the plume is dispersed at the surface (far-field dilution).

The Water Corporation is responsible for ensuring that the discharge of TWW is environmentally sustainable and managed to ensure the protection of ecosystem and social values in the marine environment. Although scientific investigation and ongoing monitoring have resolved that discharge of TWW by the Water Corporation has little detectable impact on the marine environment (PLOOM 10 Years of Protecting Perth's Coastal Waters, Oceanica 2007), ongoing monitoring of key environmental parameters is undertaken as a means of detecting impacts, should they arise in the future. Sampling is centred around the notion that environmental degradation may result from the following possible pathways:

- Nutrients causing increased growth of marine plants (e.g. phytoplankton, macroalgae);
- Pathogens causing human health issues (e.g. faecal bacteria, shellfish poisoning); and,
- Metals and organic contaminants (e.g. pesticides, hydrocarbons) resulting in bioaccumulation or direct toxic effects on the marine environment.

The benthic (seafloor) habitat around the outlet is predominantly sand, with areas of seagrass and low relief limestone reef. Over time, the wastewater outlet itself has become encrusted with an array of marine life, including ascidians, sponges and complex macro-algae communities. In turn, these communities attract and support an array of marine life comprising demersal fin-fish, molluscs, crustaceans and echinoderms.

1.2. Regulatory framework

The operation of the Beenyup Wastewater Treatment Plant (WWTP) and the discharge of TWW to the marine environment are conducted under Licence and Ministerial Conditions. These conditions are presently the only regulations stipulating marine monitoring as part of Water Corporation's Licence to operate the Beenyup WWTP. These include requirements to undertake the following:

- Measures of TWW flows and associated contaminant loads to ensure maximum nutrient loads are not exceeded;
- An annual summer survey of ocean and beach water quality (nutrients, primary productivity and bacteria indicators) in the vicinity of the ocean outlets, and
- A three yearly survey of metals and pesticides in marine biota.

The Condition to undertake an annual summer survey and the three yearly metals and pesticides survey is fulfilled via the PLOOM ASWQS (Oceanica 2010a) and the PLOOM Metals and Pesticides Survey (Oceanica 2010b), respectively. These reports are available on the Water Corporation website: http://www.watercorporation.com.au/P/ploom.cfm. All other components of the PLOOM program (i.e. Trial Compliance Monitoring, WET Testing, and Comprehensive TWW Characterisation) are conducted over and above regulatory Conditions.

1.3. History of ocean outlet monitoring

The Water Corporation has monitored the environmental effects of TWW discharge into Perth's coastal waters since the construction of the ocean outlets at Swanbourne in 1963, Sepia Depression in 1984 and Ocean Reef in 1978 (Outlet A) and 1992 (Outlet B). Over this time, increasing awareness of the importance of environmental sustainability has led to the development of more rigorous environmental monitoring programs. The evolution of monitoring commenced in 1992 with the development of the Perth's Coastal Water Studies (PCWS), which in turn led to the present day PLOOM program.

The PCWS was initiated in 1992 to meet an EPA requirement for information in support of the duplication of the TWW outlets at Ocean Reef. A suite of studies was undertaken from 1992–1994 under the PCWS, including:

- Measurement of coastal circulation patterns, water and sediment quality, and plant and animal community structure close to and distant from the ocean outlets;
- Development of an integrated ecological model to represent the dominant physical, chemical and ecological processes of local coastal waters and the effects of increased nutrient loads on these; and
- Experiments to investigate the effects of existing discharges on selected ecological processes.

This research led to a recommendation for Water Corporation to continue a program of environmental monitoring to further investigate and monitor the influence of TWW on Perth's coastal waters. These recommendations resulted in the development of the PLOOM program, which commenced formally in 1996.

In 2003 the PLOOM program was revised pending the development of a formal Environmental Quality Management Framework. In view of the pending regulatory developments, it was considered appropriate to implement a shift in emphasis from investigative studies to a program of 'Trial Compliance Monitoring (TCM)'. The key direction changes were:

- The implementation of a program of intensive summer water quality monitoring at each of the ocean outlets, targeting nutrient and bacteriological impacts at site in the vicinity of the outlet (now referred to as Trial Compliance Monitoring);
- A reduction in water quality monitoring frequency from monthly to quarterly during the non-summer period; and
- Undertake ecotoxicological analysis of the TWW discharged to the marine environments at each of the ocean outlets.

The TCM program is now in its fifth year of operation and continues to provide excellent data on the extent and characteristics of the TWW plumes, and its effect on the surrounding environment.

1.4. Purpose of this report

The objective of the present report is to document the findings of monitoring conducted in addition to regulatory requirements. This follows Water Corporation's requirement to ensure the discharge of TWW to the marine environment is sustainable and managed to ensure protection of ecosystem and social values. The following data are presented in the Sections 3.1, 3.2 and 3.3 of the report:

- Summer Trial Compliance Monitoring;
- WET testing (1 hour sea urchin fertilisation); and,
- Comprehensive TWW characterisation.

Results of summer TCM, WET testing and the comprehensive TWW characterisation components supplement the information collected during the Annual Summer Water Quality Monitoring Program, and demonstrate the Water Corporation's commitment to 'continual improvement of environmental performance' in accordance with the Corporate EMS (pursuant to ISO14001:2004 Standard).

2. Criteria for assessing environmental health

2.1. Trial compliance monitoring

The objective of the trial compliance monitoring (TCM) is to assess water quality in the vicinity of the outlets over the 3-month summer period and assess ecosystem health using a number of EQC (refer to Section 2.1.4). The program uses objective criteria to determine whether the Environmental Values (EV) and Environmental Quality Objectives (EQO) (as published in EPA 2000) for Perth's Coastal Waters have been maintained.

2.1.1. Sampling frequency

Fortnightly water quality monitoring is conducted over the 3-month summer period (December-March) in the vicinity of the Ocean Reef ocean outlets and at appropriate reference sites (site coordinates listed in Appendix B). The dates of the 2009/2010 TCM are listed in Table 2.1.

Table 2.1 Timing of monitoring conducted at the Ocean Reef between December 2009 and March 2010 (summer)

Day	Summer
1	03/12/2009
2	17/12/2009
3	07/01/2010
4	20/01/2010
5	10/02/2010
6	24/02/2010
7	10/03/2010
8	24/03/2010

2.1.2. Sampling Protocol

Sample sites are determined at the beginning of each sampling occasion by deploying a surface-drogue. Samples are collected at fixed distances downstream of the outlet along the vector indicated by the drogue (Figure 2.1). On day one of the program, micro-biological samples are collected at four reference sites and eight compliance sites (located at intervals of 0 m, 50 m, 100 m, 200 m, 350 m, 500 m, 1000 m and 1500 m downstream of the outlet). On days 1-8, water quality samples are collected at four reference sites and five compliance sites (located at distance intervals 0 m, 50 m, 350 m, 1000 m and 1500 m downstream of the outlet) (Figure 2.1). A summary of the sampling regime is provided in Table 2.2. The compliance site 1500 m downstream of the outlet was added in 2009. The addition of this fifth site provides greater resolution to the monitoring program, including the ability to estimate the distance (downstream of the outlets) at which plume nutrient concentration reach background levels.

Table 2.2 Sampling intervals for microbiological (•) and water quality samples (•). Distances represent the straight line distance between the sampling point and the centre of outlet diffuser.

	Distance of transect sites from centre of outlet diffuser							
	T-0m	**T-50m**	**T-100m**	**T-200m**	**T-350m**	**T-500m**	**T-1000m**	**T-1500m**
Day 1	•	•	•	•	•	•	•	•
Days 1-8	•		•		•		•	•

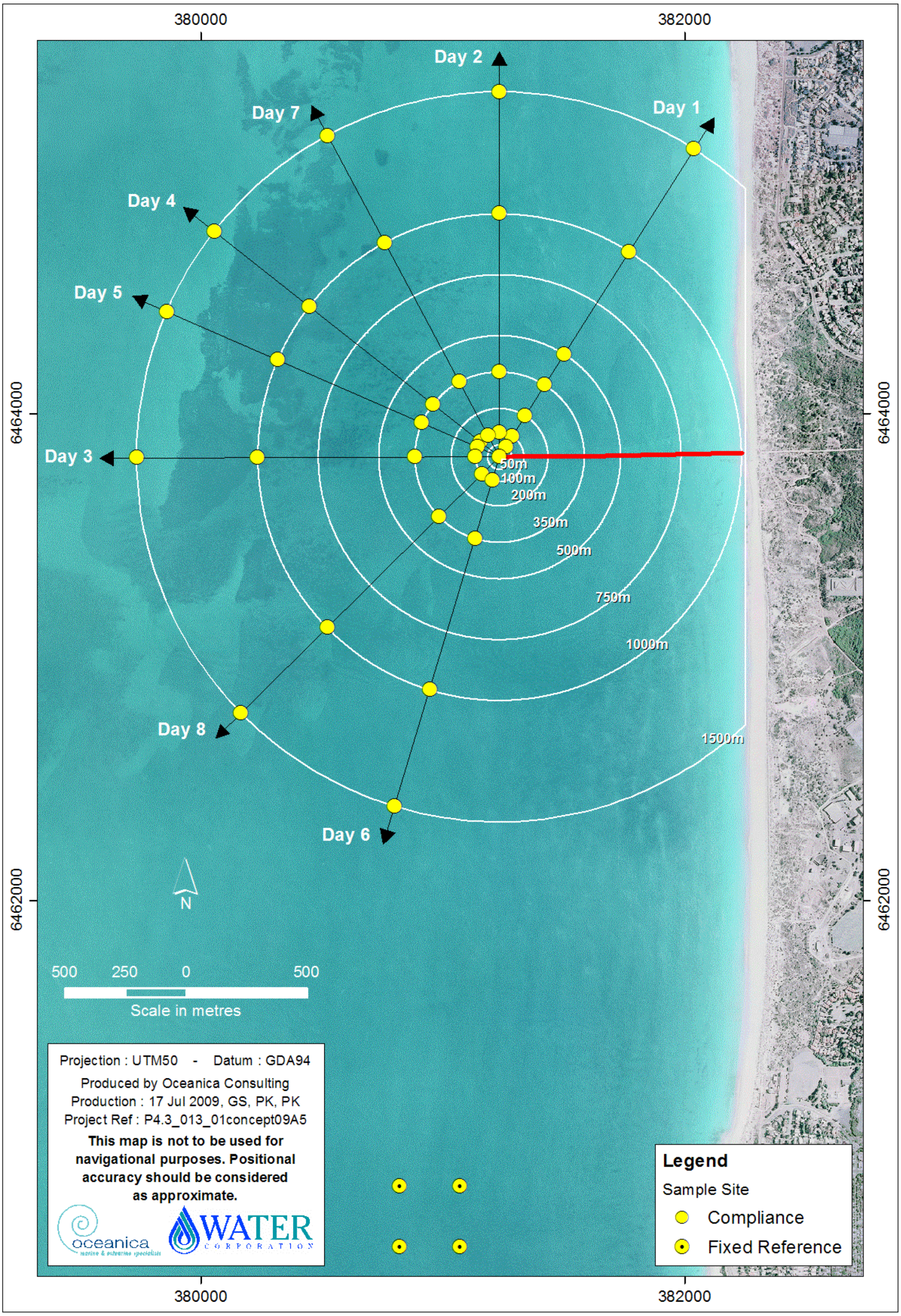

Figure 2.1 **Conceptual diagram of the TCM program showing hypothetical compliance sites and their relative distances from the outlet diffuser. Note the higher number of sites (n=8) on day one of the sampling program to accommodate the microbiological monitoring component.**

Table 2.3 indicates the number and type of samples required under the two sampling regimes (days 1 & 2-8). Samples are collected as depth integrated samples from the top half of the water column.

Table 2.3 **Number and type of samples collected as part of the TCM program. Numbers in parenthesis represent the total number of samples including those required from reference sites.**

Sample	Day 1	Days 2-8
Thermo-Tolerant Coliforms (TTC)	8(12)	None
Enterococci	8(12)	None
Physical-chemistry (Light attenuation, Temperature, Conductivity, DO%, DO mg/L)	5(9)	5(9)
Chlorophyll-a	5(9)	5(9)
Total Nitrogen	5(9)	5(9)
Total Phosphorus	5(9)	5(9)
Nitrate & Nitrite	5(9)	5(9)
Orthophosphate	5(9)	5(9)
Ammonium	5(9)	5(9)
Phytoplankton[(1)]	5(9)	5(9)

Notes:
1. As per previous TCM programs, one reference and one transect site to be analysed initially. Subsequent samples will be analysed only if transect point samples contain phytoplankton counts greater than the WASQAP trigger value.

2.1.3. Water quality monitoring

Field sampling

All field sampling is conducted by the Murdoch University Marine and Freshwater Research Laboratory (MAFRL) in accordance with the Environmental Protection Authority's (2005b) the Manual of Standard Operating Procedures. On each of the sampling occasions, a surface drogue is deployed over the centre of the operational ocean outlet diffuser, and retrieved approximately 30 minutes later. The time and location of the drogue at deployment and retrieval is recorded using an on-board global positioning system (GPS). The information is used to provide a directional vector along which sampling is undertaken. These data are also used to provide an accurate estimate of surface current speed at the time of sampling. At each of the sites (both monitoring and reference) the following physical chemical parameters are measured:

- Light attenuation coefficient
- Salinity depth profile
- Temperature depth profile
- Dissolved oxygen (DO) depth profile

To correct for ambient conditions, light attenuation measurements is conducted simultaneously at two locations (LiCor Model LI-1000) - with one sensor positioned 1 m below the surface and the second, 7 m below the surface. The light attenuation coefficient is calculated as the difference between the $\log_{10}$ of irradiance values at each depth according to the equation:

$$\text{Light Attenuation Coefficient (LAC)} = \frac{\log_{10} I_1 - \log_{10} I_7}{6}$$

Depth integrated salinity, temperature and DO measurements are conducted *in situ* using a YSI 6600/YSI 600XL water quality sensor.

Nutrient and public health

Depth-integrated samples are collected from each of the compliance and reference sites. Samples are collected using a submersible pump and hose which is flushed with seawater for 30 seconds prior to collection of the sample. From each sample the following aliquots are taken:

- One 250 mL sample in a pre-sterilised bottle for thermo-tolerant coliforms and faecal streptococci (as *Enterococci*). Samples are chilled to 4°C and placed in the dark;
- Two 10 mL filtered (on-site through a 45 µm filter) samples in polypropylene tubes for ortho-phosphate, ammonia and nitrate + nitrite analysis; and,
- One 4–10 L filtered (on-site through a Grade GF/C filter) sample for chlorophyll-a (and phaeophytin) analysis.

Nutrient and public health samples are obtained *in situ* and analysed at the MAFRL and Pathwest Laboratories, respectively. Standard laboratory analytical procedures are employed throughout, and all sampling and analyses are undertaken according to NATA-accredited methods (Refer Appendix A). Table 2.4 present the standard NATA-accredited laboratory analytical procedures are employed throughout. MAFRL undertake the nutrient and primary productivity analyses and Pathwest the microbiological analyses.

Table 2.4 Analytical methods and reporting limits for each of the measured water quality parameters

Parameter	Analytical Method$^{(1)}$	Reporting Limit	Unit
Ortho-phosphate	Lachat-Automated Flow Injection Analyser (4100)	$2^{(2)}$	µg P L^{-1}
Ammonia	Lachat-Automated Flow Injection Analyser (2000)	$3^{(2)}$	µg N L^{-1}
Nitrate + Nitrite	Lachat-Automated Flow Injection Analyser (2100)	$2^{(2)}$	µg N L^{-1}
Primary Production			
Chlorophyll-a	Acetone extraction (3000)	$0.1^{(2)}$	µg/L
Phaeophytin	Acetone extraction (3000)	$0.1^{(2)}$	µg/L
Microbiological Indicators			
Thermo-tolerant Coliforms	Membrane filtration	Dilution dependent$^{(3)}$	CFU/100mL
Faecal streptococci (as *Enterococci*)	Membrane filtration	Dilution dependent$^{(3)}$	MPN/100mL

Notes:
1. Numbers in brackets refer to the MAFRL analysis method number.
2. Method detection limit determined from 3.2×standard deviation of 10 standard samples.
3. The upper and lower detection limits for thermo-tolerant coliforms and faecal streptococci are dependent on the dilution of the original sample.

Phytoplankton

Depth-integrated water samples are collected from each of the compliance and reference sites. Samples are subsequently preserved in Lugol's iodine solution and transported to the Dalcon Environmental laboratories for phytoplankton identification and enumeration. Phytoplankton samples are analysed by Dalcon Environmental using the Utermöhl method. Phytoplankton are identified to the lowest taxonomic level possible using a range of international taxonomic references. Of the samples collected, initial analysis is undertaken on one transect site (ORT-1000m) and one reference site (ORR1). The remaining samples are archived. In the event that densities of toxic phytoplankton species (those known to concentrate in shellfish) are present in the transect site sample only (which may be indicative of a potential effect associated with the discharge of TWW) and at concentrations that exceeded the recommended WASQAP (Department of Health and Department of Fisheries 2007) guideline trigger concentrations, the remaining phytoplankton samples collected on that sampling occasion will be analysed (Table 2.5) (refer to Appendix D for further detail).

Table 2.5 Protocols for analysis of archived phytoplankton samples

Outcome of Initial Analysis	Further Action
No exceedance of WASQAP guideline concentrations	No analysis of archived samples
Exceedance of WASQAP guideline concentrations at both the reference site and the trial compliance monitoring site	No analysis of archived samples
Exceedance of WASQAP guideline concentrations at the reference site, but not at the trial compliance monitoring site	No analysis of archived samples
Exceedance of WASQAP guideline concentrations at the trial compliance monitoring site but not at the reference site.	Additional samples analysed

2.1.4. Environmental Quality Management Framework

In 2000, the Environmental Protection Authority (EPA 2000) advised that the management of Perth's metropolitan ocean outlets was to be underpinned by an Environmental Quality Management Framework (EQMF) including development of appropriate EQC. There are two levels of EQC; Environmental Quality Guidelines (EQG) and Environmental Quality Standards (EQS).

- Environmental Quality Guidelines (EQGs): EQGs are a threshold numerical value or narrative statement, that if met, indicate there is a high degree of certainty that the associated environmental quality objective has been achieved. If the guideline is not met, there is uncertainty as to whether the associated environmental quality objective has been achieved and a more detailed assessment against an EQS is triggered.
- Environmental Quality Standards (EQSs): EQSs are threshold values or narrative statements that indicate a level beyond which there is a significant risk that the associated environmental quality objective has been not been achieved. EQSs involve a risk-based approach that considers multiple lines of evidence and integrates more refined measures of the surrogate indicators with more direct measures of the Environment Quality Objective (Environmental Protection Authority 2005a). If an EQS is exceeded, it is considered that there is a significant risk that the associated Environmental Quality Objective has not been achieved, investigation of the cause is needed and an adaptive management response is triggered if the exceedance continues. Pending the introduction of the EQMF, Water Corporation in conjunction with Oceanica, developed the Trial Compliance Monitoring Program. The objective of the program, first introduced in 2003, was to meet the future requirement to develop an appropriate environmental monitoring program capable of measuring environmental quality against the Environmental Quality Objectives.

EPA have developed EQC for four levels of ecological protection: Total, High, Moderate and Low. Although notional boundaries for Moderate and High Ecological Protection have been developed for Perth's ocean outlets (see Appendix C of EPA 2000), these are yet to be formalised as the proposed Schedule to the MOU is still in preparation (refer to MOU 2003). In anticipation of the development of a formal EQMF, including the advent of spatially defined EQOs and standard protocols for monitoring, Water Corporation have developed a suite of 'trial' EQC for implementation in the vicinity of the ocean outlets (Table 2.6, Table 2.7, Table 2.8 and Table 2.9). The trial EQC developed for use in Perth's coastal waters are outlined below:

Maintenance of ecosystem integrity (Nutrients): Table 1a of EPA (2005a) refers to nutrients (nitrogen and phosphorus) as chemical stressors. Three sets of EQC relevant to Nutrients are provided: (i) nutrient enrichment, (ii) algal growth potential and (iii) phytoplankton biomass. Trial EQC specific for the high energy environment of Perth's coastal waters were developed for the TCM program (Table 2.6). For nutrient enrichment and phytoplankton biomass, the 80th percentile of reference site data for chlorophyll *a* and light attenuation is calculated according to strict protocols. The intent of the protocols is to guard against the EQC being triggered because of regional-scale events (e.g. unusually favourable natural conditions for phytoplankton growth), and to also ensure that the recalculated percentiles are not biased by unusually high or low values associated. The protocols are as follows:

- That the median of the reference site data from the year being assessed is compared against the 80th percentile and the 20th percentile of the historical reference site data.
- If the median lies between the 80th and 20th percentiles of the historical data, then the new data can be added to the historical reference data set. The new median and 80th percentile can be calculated and the Trial EQC updated.
- If the median of the current year reference site data is greater that the 80th percentile, or lower than the 20th percentile of the historical reference data set, then it is considered that the reference sites have shifted outside their 'normal' bounds and these data cannot be used to recalculate an updated set of percentile-based EQC. In addition, the comparison of the test site data against the reference sites data cannot be conducted for that year, as this finding is taken to indicate that there is a significant risk that the water quality is responding to regional forcings.

For algal growth potential, previous monitoring used periphyton growth on a trial basis. However, the periphyton monitoring program was discontinued in 2008, following a review of its efficacy. The findings suggested that periphyton growth can be linked to factors other than those associated with TWW i.e. light intensity and water temperature. Presently no 'algal growth potential' indicators are defined by the regulators, nor are they likely to be defined in the future [verbal advice from OEPA 6/5/2009]. Oceanica is presently trialling algal community indicators for use as algal growth potential indicators as part of the development of the Environmental Management Plan for the new Alkimos WWTP.

<u>Maintenance of ecosystem integrity (Physical and Chemical stressors)</u>: Table 1a of EPA (2005a) includes the following additional physical and chemical stressors: dissolved oxygen, salinity, pH and water temperature. The PLOOM TCM program includes draft EQC for DO, and salinity. The extent to which the EQG for salinity has been met is assessed against the median salinities (derived by pooling the measures obtained over the duration of the monitoring program) of individual compliance sites situated within the <u>notional</u>[1] High Ecological Protection Area (HEPA): OR-100; OR-350; OR-1000 and OR-1500. OR-0 (the outlet site) is not included in the assessment as it is situated directly above the outlet and located at the centre of the notional Low Ecological Protection Area (LEPA). The EQG for DO is assessed against measures of DO (as percentage saturation) in bottom waters immediately surrounding the ocean outlet.

<u>Seafood safe for human consumption</u>: The EPA (2005a) EQC for Seafood Safe for Human Consumption for Cockburn Sound are listed in Table 2.7. The EQG are a measure of the potential threat to human health. The EQS are intended to "confidently predict whether there is a significant risk to the health of human consumers" (EPA 2005). It is important to note that these criteria were developed for the marine waters of Cockburn Sound where aquaculture or commercial and amateur harvesting of wild seafood species occurs. They are not intended to be used as the basis for establishing conditions for the discharge of TWWs to Perth's coastal waters. The extent to which the EQC have been met is assessed against the results of samples collected on a single day each summer. Samples are collected as part of the Annual Summer Water Quality Monitoring Survey, conducted annually as part of the Licence Conditions. Results are therefore treated as a 'snap-shot' indication of thermo-tolerant coliforms counts, and not an indication of general patterns.

<u>*Enterococci* Primary and Secondary contact recreation</u>: The EQC for Primary and Secondary Contact are listed in Table 2.8. The extent to which the EQC have been met is assessed against the results of samples collected on a single day each summer. Samples are collected as part of the Annual Summer Water Quality Monitoring Survey, conducted annually as part of the Licence Conditions. Results are therefore treated as a 'snap-shot' indication of *Enterococci* counts, and not an indication of general patterns. In this report, median counts of *Enterococci* were calculated for sites located within 250 m of the diffuser and greater than 250 m from the diffuser.

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[1] Notional High and Low Ecological Protection areas were established in recognition of the fact that future EQC will be established for differing levels of Ecological Protection. As it is also recognised that High Ecological Protection criteria are not always expected to be met within the initial mixing zone (~within 100 m of the diffuser), EQC for salinity are calculated using pooled data from the notional HEPA (incorporating sites >100 m from the diffuser). It is anticipated that the boundaries of High, Moderate and Low Ecological Protection Areas will be formalised in the future in consultation with the OEPA.

It is noted that the trial EQS for Primary and Secondary contact recreation is assessed against the findings of beach surveys undertaken by the Department of Health (DoH), Government of Western Australia. The results of the assessment can be found at http://www.healthyswimming.health.wa.gov.au/sites/. If the status of the beaches is graded as 'fair' or 'very good', then the EQS is deemed to have been met. If the status of the beaches is graded as 'poor', and the decrease in quality can be attributed to the ocean outlets, then the EQS is deemed to have been exceeded. Details of the EQC for contact recreation (both primary and secondary) are outlined in Table 2.8.

Table 2.6 Trial Environmental Quality Criteria for protecting the Marine Ecosystem from the effects of physical and chemical stressors in High Ecological Protection Areas – based on the *Environmental Quality Criteria Reference Document for Cockburn Sound (2003-2004)* (Environmental Protection Authority 2005a).

Environmental Quality Indicator	Trial Environmental Quality Guideline	The Environmental Quality Standard
Nutrient Enrichment	Ambient value(1) of defined area(2) during non river-flow period(3) not to exceed: *Chlorophyll-a:* 80%ile of reference site data *Light attenuation:* 80%ile of reference site data	Not applicable
Algal Growth Potential – not yet defined by the Environmental Protection Authority (2005a)	None developed (see text under Trial Environmental Quality Criteria above)	None developed
Phytoplankton Biomass(4)	(i) Ambient value for phytoplankton biomass measured as chlorophyll-a not to exceed 3 times median chlorophyll-a concentration of reference sites, on any occasion during non river-flow period (ii) Phytoplankton biomass measured as chlorophyll-a at any site does not exceed 3 times median chlorophyll-a concentration of reference sites, on 25% or more occasions during the non river-flow period	(i) Ambient value for phytoplankton biomass measured as chlorophyll-a not to exceed 3 times median chlorophyll-a concentration of reference sites, on more than one occasion during non river-flow period and in two consecutive years (ii) Phytoplankton biomass measured as chlorophyll-a at any site does not exceed 3 times median chlorophyll-a concentration of reference sites, on 25% or more occasions during non river-flow period and in two consecutive years
Dissolved Oxygen Concentration	Ambient value for dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) greater than 90% saturation at any site for a defined period of not more than six weeks	(i) Ambient value for dissolved oxygen in bottom waters (0–0.5 m above the sediment surface) greater than 60% saturation at any site for a defined period of not more than six weeks (ii) No deaths of marine organisms resulting from deoxygenation
Salinity	Median salinity (0.5 m below the water surface) at an individual site over any period not to deviate beyond the 20th and 80th percentile of natural salinity range over the same period	(iii) No deaths of marine organisms resulting from anthropogenically sourced salinity stress

Notes:
1. Ambient Value = median value of individual sample data for a defined area.
2. Defined Area = area to be characterised for environmental quality against pre-determined Environmental Quality Objectives and levels of ecological protection.
3. Non River-flow Period = period December–March inclusive, when river and estuarine flows are weak.
4. Where there is more than one Environmental Quality Criteria for an indicator designated by (i) and (ii), each one is to be considered individually. If any one of these is exceeded then the guideline or standard for that indicator has not been met.

Table 2.7 **Trial Environmental Quality Criteria for the maintenance of seafood for human consumption – based on the *Environmental Quality Criteria Reference Document for Cockburn Sound (2003-2004)* (Environmental Protection Authority 2005a).**

Environmental Quality Indicator	Trial Environmental Quality Guideline	The Environmental Quality Standard
Thermo-tolerant Coliforms in Water	Median thermo-tolerant coliform counts not to exceed 14 CFU/100mL, with no more than 10% of the samples exceeding 21 CFU/100mL measured using the membrane filtration method	Median thermo-tolerant coliform counts not to exceed 70 CFU/100mL, with no more than 10% of the samples exceeding 85 CFU/100mL measured using the membrane filtration method
Algal Biotoxins	Concentrations of potentially toxic algae not to exceed the WASQAP[1] trigger concentrations	Toxin concentrations in seafood not to exceed environmental quality standards in any sample

Notes:
1. Western Australian Shellfish Quality Assurance Program (Department of Health and Department of Fisheries 2007).

Table 2.8 **Trial Environmental Quality Criteria for the maintenance of primary contact recreation – based on the *Environmental Quality Criteria Reference Document for Cockburn Sound (2003-2004)* (Environmental Protection Authority 2005a).**

Environmental Quality Indicator	Trial Environmental Quality Guideline	The Environmental Quality Standard
Faecal Pathogens	Median value of *Enterococci* taken over the bathing season not to exceed 35 MPN/100 mL (as per the ANZECC/ARMCANZ (2000) microbiological guidelines)	The EQS is assessed annually against the results of the annual DoH survey, and particularly, whether the beaches in the vicinity of the ocean outlets were classified as safe and, if not, whether the decrease in safety can be attributed to the TWW outlets. If the status of the beaches is graded as 'fair' or 'very good', then the EQS is deemed to have been met. If the status of the beaches is graded as 'poor', and the decrease in quality can be attributed to the ocean outlets, then the EQS is deemed to have been exceeded.
Algal Biotoxins	Median total phytoplankton cell count for the area of concern (either from one sampling run or from a single site over agreed period of time) should not exceed 15,000 cells/mL [1] OR There should be no reports of skin or eye irritation or potential algal poisoning in swimmers considered by a medical practitioner as potentially resulting from toxic algae when less than 15,000 cells/mL is present in the water column	There should be no confirmed incidences (by the Health Department of WA) of skin or eye irritation caused by toxic algae, or of algal poisoning in recreational users

Notes:
1. The numerical Environmental Quality Guideline for toxic algae was largely developed for inland waters and is to be used as an indicative guideline only, until sufficient marine data have been gathered for its revision (Environmental Protection Authority 2005a).

Table 2.9 Trial Environmental Quality Criteria for the maintenance of secondary contact recreation.

Environmental Quality Indicator	Trial Environmental Quality Guideline	The Environmental Quality Standard
Faecal Pathogens	Median value of *Enterococci* taken over the bathing season not to exceed 230 MPN/100 mL (as per the ANZECC/ARMCANZ (2000) microbiological guidelines)	The EQS is assessed annually against the results of the annual DoH survey, and particularly, whether the beaches in the vicinity of the ocean outlets were classified as safe and, if not, whether the decrease in safety can be attributed to the TWW outlets. If the status of the beaches is graded as 'fair' or 'very good', then the EQS is deemed to have been met. If the status of the beaches is graded as 'poor', and the decrease in quality can be attributed to the ocean outlets, then the EQS is deemed to have been exceeded.
Algal Biotoxins	Median total phytoplankton cell count for the area of concern (either from one sampling run or from a single site over agreed period of time) should not exceed 15,000 cells/mL (1) OR There should be no reports of skin or eye irritation or potential algal poisoning in swimmers considered by a medical practitioner as potentially resulting from toxic algae when less than 15,000 cells/mL is present in the water column	There should be no confirmed incidences (by the Health Department of WA) of skin or eye irritation caused by toxic algae, or of algal poisoning in recreational users

Notes:
1. The numerical Environmental Quality Guideline for toxic algae was largely developed for inland waters and is to be used as an indicative guideline only, until sufficient marine data have been gathered for its revision (Environmental Protection Authority 2005a).

2.2. Whole of effluent toxicity tests

2.2.1. 1-hour sea urchin fertilisation tests

Wastewater sample collection is undertaken in collaboration with the Water Corporation. Twenty-four hour flow-weighted composite samples are collected on a quarterly basis from the end of the Ocean Reef pipelines at Beenyup WWTP and analysed for toxicity using the 1-hour sea urchin (*Heliocidaris tuberculata*) EC50 fertilisation test. This test has been chosen for its fast analytical turn-around time (providing rapid feed-back on potential toxicity) and its established sensitivity to organic contaminants, particularly surfactants.

The 1-hour sea urchin fertilisation test is carried out by NATA accredited Ecotox Services Australasia Pty Ltd ('Ecotox'), Sydney, New South Wales. Wastewater samples are collected in HDPE containers supplied by Ecotox. The test determines the success of sea urchin fertilisation over a 1-hour period using the gametes of the sea urchin *Heliocidaris tuberculata*. The sperm of the sea urchin are exposed to dilute wastewater for a 1-hour period and then added to an egg suspension. The fertilised eggs are counted and the percent fertilisation calculated. These results are used to calculate the NOEC (no observed effects concentration), LOEC (lowest observed effects concentration) and EC50 (the concentration at which 50% fertilisation is achieved).

The dilutions of wastewater used are 1%, 1.56%, 3.125%, 6.25%, 12.5%, 25%, 50% and 100%. All test dilutions for wastewater are salt-adjusted (using artificial sea salts) to achieve marine salinities, so that only the toxicity due to the presence of contaminants is examined, not the toxic effect of freshwater on the marine organism. Testing is also undertaken on a seawater 'control', and an artificial sea salt (brine) control.

2.2.2. Trigger for further WET testing

In some circumstances, the results of the sea urchin WET tests may act as a 'trigger' for the full suite of WET testing; that is, an additional series of WET tests incorporating a suite of marine organisms from a variety of trophic levels. To trigger the full suite of WET tests, the NOEC must be ≤1% (equivalent to more than a 100-fold dilution).

2.3. TWW characterisation

On-going monitoring of the TWW provides information on the type and concentration of contaminants discharged from the Beenyup WWTP. The comprehensive wastewater characterisation complements the regular sampling of TWW undertaken by the Water Corporation.

There are a number of contaminants that have the potential to cause toxicity effects in the marine environment. The objectives of the TWW characterisation are to identify potential contaminants of concern from treated municipal wastewaters through literature reviews and expert advice. The final effluent discharged from the Beenyup WWTP via the Ocean Reef outlet are analysed for potential contaminants of concern. ANZECC/ARMCANZ (2000) 99% Species Protection Guidelines are used to evaluate whether the contaminants meet the appropriate guidelines following initial dilution.

2.3.1. Sample collection

A 24–hour flow weighted composite sample is obtained from the Beenyup WWTP on the same date as the Annual Summer Water Quality Survey (see Section 2.1). This sample represents an average of the final treated effluent discharged from the Beenyup WWTP for the 24–hour period prior to and during the sample collection. A separate grab sample for microbiological parameters is taken, as 24–hour composite samples are not suitable for microbiological parameters. The bulk sample is homogenised (agitated), split into separate sample containers for the various analyte groups and handled according to the NATA-accredited laboratory requirements for those analytes. Samples for bioavailable metals are filtered through a 0.45 µm filter prior to analysis, in accordance with Environmental Protection Authority prescribed methods (EPA 2000b).

2.3.2. Analysis

TWW (final effluent) from the Beenyup WWTP is analysed for a suite of parameters comprising the major contaminants of concern for the Ocean Reef Ocean Outlets, including:

- Nutrients (total nitrogen, ammonia, nitrate + nitrite, total phosphorus, ortho-phosphate);
- Microbial contaminants;
- Bio-available fractions of metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc);
- Pesticides and herbicides (organophosphate pesticides, organochlorine pesticides, triazine herbicides);
- Poly-aromatic hydrocarbons (PAHs);
- Phthalates;
- PCBs;
- BTEX;
- Petroleum hydrocarbons;
- Surfactants (MBAS); and,
- Dissolved organic carbon.

These parameters have been selected for analysis through ongoing internal (Oceanica) review of the current Australian and international "contaminants of concern" in treated municipal wastewaters in the context of the wastewater supply and operating conditions of the Beenyup WWTP. The selected microbiological, nutrient, heavy metal, organic and physical parameters are undertaken by laboratories with NATA-accredited methods (refer Appendix A). The information on the characteristics of the TWW samples collected and analysed from the Beenyup WWTP is used in the calculation of the minimum initial dilutions for each of the measured water quality parameters.

2.3.3. Dilution calculations

Where the toxicants measured in the TWW do not meet the ANZECC/ARMCANZ (2000) 99% species protection guidelines, the number of dilutions required to meet these levels are calculated. The formula used to estimate the minimum dilution requirements for any particular toxicant and level of species protection is:

$$\text{Dilution required} = \frac{[\text{Max Filtered}] - [\text{Background}]}{[\text{Trigger Value}] - [\text{Background}]}$$

Note that where there are no established trigger levels for toxicants in marine waters, an estimate of the required number of dilutions cannot be calculated. Where the measured concentrations are below the analytical limit of reporting, for the purpose of calculating dilution requirements, it is assumed that the concentrations were equal to the analytical limit of reporting.

2.3.4. Total toxicity of the mixture

The total toxicity calculation is an additional (albeit, simplistic) interpretative tool used for estimating the potential toxicity of TWW. The potential for toxicity of TWW to marine biota after initial mixing at the Ocean Reef outlet (i.e. after initial dilution of the wastewater with seawater) is assessed as per the ANZECC/ARMCANZ (2000) Guidelines, based on the effects of ammonia, copper and zinc; the three contaminants identified as most likely to cause toxicity effects. It is important to note, however, that the formula is only meant to be used for simple mixtures where the interactions are simple and predictable (i.e. usually 2–3 components but up to 5 components if toxicity is additive; ANZEC/ARMCANZ 2000, Section 8.3.5.18). The approach does not account for synergistic and or antagonistic effects, or complex mixtures. If the mixture is complex (i.e. >5 components and/or has uncertain mixture effects), ANZECC/ARMCANZ (2000) recommends proceeding to direct toxicity assessment.

$$\text{Total Toxicity of Mixture} = \frac{[\text{ammonia}]}{[\text{Trigger Value}]} + \frac{[\text{copper}]}{[\text{Trigger Value}]} + \frac{[\text{zinc}]}{[\text{Trigger Value}]}$$

The total toxicity of the mixture needs to be less than 1 in order to meet the total toxicity criteria, in accordance with ANZECC/ARMCANZ (2000) *Guidelines*. The initial mixing zone dilution calculated in the Annual Summer Water Quality Survey is applied.

2.3.5. Initial dilution modelling

Numerical modelling has been used in the PLOOM program as a tool to help understand how discharged TWW is diluted by seawater, and how it is dispersed in the marine environment under the action of winds and currents. This modelling has enabled predictions of how the TWW discharged from the ocean outlets may affect coastal water quality. While numerical modelling programs cannot provide definitive predictions of what will happen in the environment, a robust model provides a good approximation of what is likely to happen under a given set of environmental conditions.

As TWW is primarily freshwater it has a greater buoyancy than the surrounding sea water. Once discharged through the ocean outlet diffuser, the TWW mixes with the surrounding sea water as it ascends. The initial dilution zone begins at the point of discharge on the seafloor, and extends to the point of maximum elevation (e.g. the point at which the plume first reaches the surface). At Ocean Reef, this process is sufficient to achieve an 'initial dilution' in the range 120-178 times[2]. Initial dilution occurs between the outlet diffuser (located at ~10 m depth) and the surface of the water column. Further dilution, known as 'far field' dilution takes place between the point at which the plume first makes contact with the surface and distances downstream of the outlet.

[2] *Based on modeling conducted between 2002 and 2009*

The CORMIX (Cornell Mixing Zone Expert System) and VPLUMES (Visual Plumes) programs are initial dilution models accepted for use by the United States Environmental Protection Agency (http://www.epa.gov/). These numerical models are designed to model the nearfield behaviour of plumes—that is, the behaviour in the region where the plume first jets into the surrounding waters and then (in the case of positively buoyant plumes) rises and mixes with the surrounding waters. These initial dilution models capture simple features about the discharge characteristics and the local environment such as depth at point of discharge, local current and wind speed. However, because the models do not take into account the broader scale bathymetry and hydrodynamics, these models generally do not accurately predict the far-field behaviour—that is, the behaviour of the plume once it has reached the surface.

The objective of the near-field dilution modelling is to utilise information from the TWW quality in conjunction with the modelled initial dilution rates and mixing zones for the Ocean Reef Ocean Outlets to establish whether the appropriate ANZECC/ARMCANZ (2000) *Guidelines* are met. Initial dilution modelling is particularly useful where concentrations of a contaminant of concern are below the practical limit of reporting (below the ability of established analytical techniques to detect it) in the marine environment adjacent to the ocean outlets.

Model set-up

The UM3 initial dilution model, which is part of the Visual Plumes (VPLUMES) suite of dilution models, is applied to the discharge from the Ocean Reef diffuser for the ambient conditions and wastewater flows at the time of the Annual Summer Water Quality Survey.

The model set-up parameters selected to represent the conditions at the Ocean Reef Ocean Outlets at the time of the Annual Summer Water Quality Survey include:

- Diffuser Characteristics: port diameter, number of open ports, port spacing, diffuser pipe diameter, port orientation and water depth;
- Ambient conditions at time of sampling: temperature, salinity and current speed and direction; and
- Discharge characteristics: flow rate, temperature and salinity.

At the time of the Annual Summer Water Quality Survey (Oceanica 2010a), information is collected on ambient conditions for the initial dilution modelling. During each survey, a surface drogue is released above the outlet diffusers and the location of the drogue is recorded at intervals throughout the survey using an on-board GPS. Surface drogue tracking provides an accurate estimate of mean surface current speed. The mean direction[3] of the surface current is also estimated from the surface drogue tracking locations. These mean surface currents are used to synthesise a vertical velocity profile based on the findings of Pattiaratchi et al. (1995), who installed current meters at 3 m and 7 m above the seabed at the Ocean Reef Ocean Outlets. The difference between the mean currents at these depths is used as an indication of a likely linear decrease in current speeds from the surface to the seabed[4]. At Ocean Reef it is estimated that the current speed drops by approximately 1.2% per meter depth.

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[3] For modeling, the current direction is assumed to remain constant throughout the water column.
[4] Two sets of ambient conditions are set in the model, one at the surface (0 m) and one at approximately one metre above the seabed. The current speed is set to linearly decrease to zero from this depth to the seabed.

3. Results

3.1. Trial Compliance Monitoring

Results of the 2009/2010 summer TCM program for Ocean Reef are presented below. Results are partitioned into the following sections:

- Surface drogue deployments;
- Physical chemistry;
- Nutrients; and
- Public health.

Each section outlines the results of the eight week summer monitoring program and, where applicable, assesses the results against the EQC. Note that for reporting purposes, results are assessed typically against the relevant EQG; further assessment against the EQS is required only upon exceedance of an EQG.

3.1.1. Surface drogue deployments

The velocity and direction of the surface drogue released over the centre of the Ocean Reef outlet diffuser at fortnightly intervals between December 2008 and March 2009 is detailed in Table 3.1. Surface drogue data provides valuable information on the direction of surface currents on the day of sampling, and therefore, the likely trajectory of the TWW plume. Wind directions over the 2009/2010 summer period were largely S-SW, with the exception of the 3 December, 24 February and 10 March, when winds were ESE, E and NE respectively. Wind speeds were light to moderate ranging between 6–12 knots. The average velocity of the drogue ranged from 0.03–0.15 m/s. Drogue direction was typically N-NW.

Table 3.1 Field observations and surface drogue deployments measures at fortnightly intervals over the period December 2009 – March 2010.

Date	Field Observations	Distance	Interval (min)	Velocity (m/s)	Bearing	Direction
03/12/2009	ESE 8-10kts; 0% cloud cover	274.45	54	0.09	299.59	NW
17/12/2009	S 14-16kts; 0% cloud cover	342.02	48	0.12	323.80	NW
07/01/2010	SW 12-14kts; 30% cloud cover	560.22	61	0.15	356.21	N
20/01/2010	SW 6-8kts; 70% cloud cover	115.39	101	0.02	205.68	SW
10/02/2010	SW 12-14kts; 100% cloud cover	431.61	80	0.09	3.05	N
24/02/2010	E 8-10kts; 0% cloud cover	320.25	95	0.06	297.53	NW
10/03/2010	NE 6-8kts; 30% cloud cover	300.72	160	0.03	208.61	SW
24/03/2010	SW 6-8kts; 20% cloud cover	271.33	55	0.08	341.97	NW

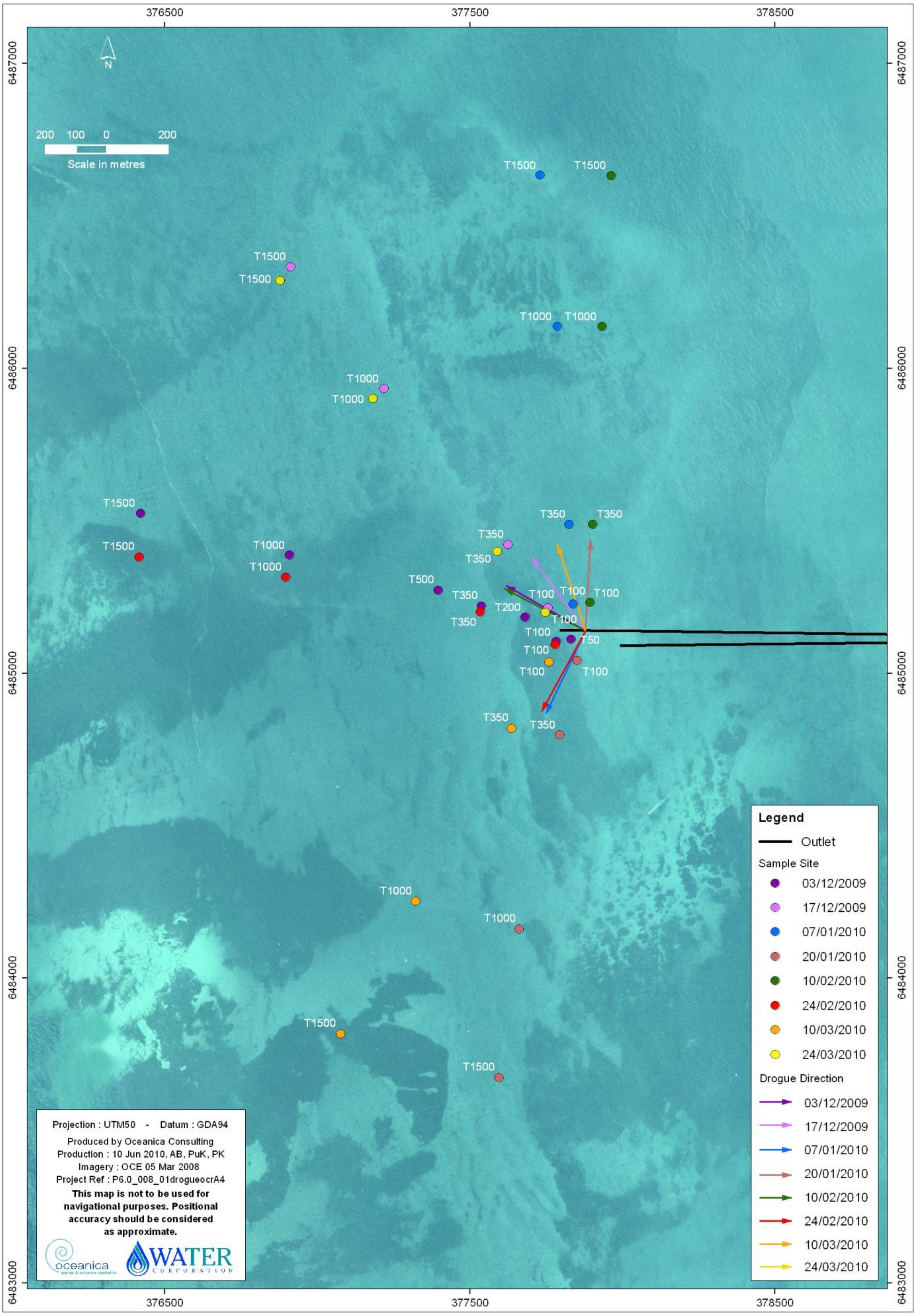

Figure 3.1 **Direction of the surface currents (as indicated by the drogue), together with the position of the Ocean Reef TCM sites.**

3.1.2. Physical chemistry

As per the requirements of the EQC Reference Document for Cockburn Sound (2005a), dissolved oxygen (DO) data are presented for the bottom strata of the water column (i.e. 0.5 m above the sediment surface) (Table 3.2). Results indicate no instances of compliance site DO concentrations falling below the EPA's (2005a) EQG trigger of 90% saturation (Table 3.2). These results also satisfy the Trial Environmental Quality Criteria developed specifically for the TCM monitoring program. Based on these results, the EQC for dissolved oxygen were met (Table 3.4).

Table 3.2 Results of summer TCM dissolved oxygen (as %saturation) monitoring program – Results are presented for bottom waters (0.5m above benthos).

Day	Outlet Site	Compliance Sites				Reference Sites			
	OR-0	OR-100	OR-350	OR-1000	OR-1500	ORR1	ORR2	ORR3	ORR4
03/12/2009	103.1	107.0	100.2	101.0	*	94.6	96.4	92.1	93.9
17/12/2009	107.4	106.7	104.1	103.7	103.9	96.0	95.9	99.7	97.3
07/01/2010	101.5	103.1	102.3	107.7	107.7	92.7	89.6	97.3	93.1
20/01/2010	101.6	98.7	101.0	101.6	101.4	95.0	98.8	93.0	96.7
10/02/2010	98.3	98.8	99.2	101.9	101.3	97.5	101.0	94.6	100.1
24/02/2010	100.7	100.5	98.2	94.8	95.7	86.7	94.7	85.4	87.5
10/03/2010	102.2	101.9	100.4	98.2	100.9	100.4	100.2	96.9	98.9
24/03/2010	100.0	99.3	89.8	95.9	96.1	89.6	94.3	84.9	88.9
Median (03/12-07/01)	103.1	106.7	102.3	103.7	105.8				
Median (07/01-10/02)	101.5	98.8	101.0	101.9	101.4				
Median (10/02-24/03)	100.3	99.9	98.7	97.1	98.5				

Notes:

1. * - No data recorded due to instrument malfunction

Results of the surface water salinity monitoring program are presented in Table 3.3 and Figure 3.2. Figure 3.2 clearly shows the dilution of low salinity TWW as it moves downstream from the outlet. The volume of low salinity TWW is sufficient to reduce surface water salinities to levels below the 20th percentile of background at the point of the outlet site. The median salinity value downstream of the outlet is within the range (between the 20th and 80th percentile of background) expected under natural conditions (but note the potential for salinity fluctuations as indicated by the 95% confidence interval bars in Figure 3.2.

The extent to which the EQG for salinity has been met is assessed against the median salinities (derived by pooling the measures obtained over the duration of the monitoring program) of individual compliance sites situated within the High Ecological Protection Area (HEPA): OR-100; OR-350; OR-1000 and OR-1500. The outlet site (OR-0) is not included in the assessment as it is situated directly above the outlet and located at the centre of the Low Ecological Protection Area (LEPA). Based on these criteria, the EQG was met (Table 3.4).

Table 3.3 **Results of summer TCM surface salinity (ppt) monitoring program – Results presented for surface waters (0.5 m below the surface).**

Day	Outlet Site	Compliance Sites				Reference Sites			
	OR-0	OR-100	OR-350	OR-1000	OR-1500	ORR1	ORR2	ORR3	ORR4
03/12/2009	35.7	35.8	36.0	36.0	*	36.0	36.1	36.1	36.1
17/12/2009	36.1	36.2	36.3	36.5	36.6	36.6	36.6	36.6	36.6
07/01/2010	37.1	37.0	37.0	37.0	37.1	37.0	37.1	37.1	37.1
20/01/2010	37.0	37.0	37.0	37.2	37.2	37.2	37.2	37.1	37.2
10/02/2010	36.3	36.4	36.5	36.7	36.7	36.8	36.8	36.8	36.8
24/02/2010	36.1	36.1	36.3	36.3	36.1	36.5	36.5	36.5	36.5
10/03/2010	35.8	36.2	36.2	36.1	36.2	36.4	36.4	36.4	36.4
24/03/2010	35.5	35.7	35.7	35.8	35.7	36.0	36.0	36.0	36.1
Median	36.1	36.2	36.3	36.4	36.6	36.6	36.6	36.5	36.5
20th percentile of reference data					36.1				
80th percentile of reference data					37.1				

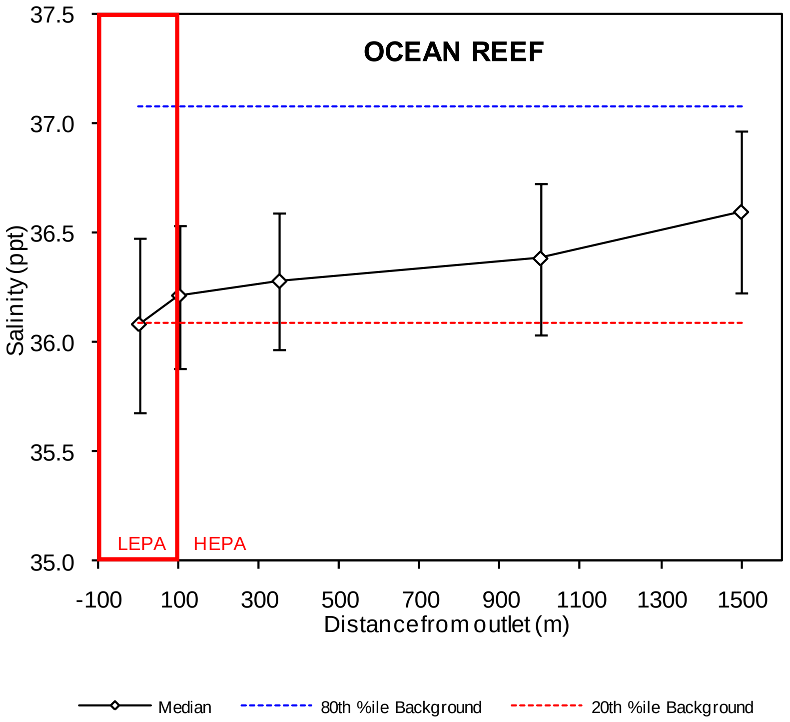

Figure 3.2 **Median salinity concentrations ± 95% confidence intervals obtained at fixed distances downstream of the Ocean Reef outlets. Blue (--) and red (--) broken lines represent historical 80th and 20th percentiles of reference site concentrations.**

Table 3.4 Comparison of ambient salinity and dissolved oxygen values obtained at fixed distances downstream of the Ocean Reef outlets against the Trial Environmental Quality Guidelines. The Green (■) and Amber (■) indicators represent whether the EQGs were met or not met, respectively.

Environmental Value	Trial Environmental Quality Guideline	Trial Environmental Quality Guideline	Ambient Value	EQG
Protection of Marine Ecosystem from the effects of Physical and Chemical Stressors	Salinity	Median salinity (0.5m below the water surface) at an individual site over any period not to deviate beyond the 20th and 80th %ile of the natural salinity range over the same period	**Ambient Values:** OR-0: 36.1 OR-100: 36.2 OR-350:36.3 OR-1000: 36.4 OR-1500: 36.6 **Percentiles:** 20th %ile: 36.1 80th %ile: 37.1	■
	Dissolved Oxygen Concentration	Ambient value for dissolved oxygen in bottom waters (0-0.5m above the sediment surface) greater than 90% saturation at any site for a defined period of not more than six weeks	**SB-0** (03/12-07/01): 103.1 (07/01-10/02): 101.5 (10/02-24/03): 100.3	■
			SB-100 ((03/12-07/01): 106.7 (07/01-10/02): 98.8 (10/02-24/03):99.9	■
			SB-350 (03/12-07/01): 102.3 (07/01-10/02): 101 (10/02-24/03): 98.7	■
			SB-1000 (03/12-07/01): 103.7 (07/01-10/02): 101.9 (10/02-24/03): 97.1	■
			SB-1500 (03/12-07/01): 105.8 (07/01-10/02): 101.4 (10/02-24/03): 98.5	■

3.1.3. Nutrients

Nutrient gradients

Nutrient and chlorophyll *a* concentrations were measured on eight separate occasions between 3 December 2009 and the 23 March 2010. On each occasion, nutrients were measured at five distances along a straight-line vector as indicated by a surface drogue[5]: directly over the outlet (0 m); 100 m from the outlet; 350 m from the outlet; 1000 m from the outlet; and 1500 m from the outlet. Median nutrient and chlorophyll *a* concentrations (± 95% confidence intervals) at five distances downstream of the outlet are presented in Figure 3.3. Strong concentration gradients were detected between the outlet and the 1500 m mark for total nitrogen (TN), filterable reactive phosphorus (FRP), total phosphorus (TP) and nitrate & nitrite (NO_x). The steepest concentration gradients (and therefore the greatest dilution gradients) were detected between the outlet and the 100 m mark. Concentration gradients then appeared to 'level off' between the 100 m and 350 m marks, before decreasing further (albeit at more gradual rate) between the 350 m and the 1500 m marks (Figure 3.3).

The tracking and characterisation of nutrient gradients in the vicinity of Perth's ocean outlets is a useful management tool. This component of PLOOM (introduced in 2007) enables managers to detect the extent of influence of the plume including the distance downstream of the outlets at which concentrations reach background. Background in this case is represented by the range of concentrations between the 80^{th} and 20^{th} percentiles of historical reference site data compiled between 2003 and 2010 (blue and green broken lines, respectively) (Figure 3.3). From the data it is clear that, despite the rapid dilution of nutrients, the TWW plume must travel a distance of approximately 1500 m downstream of the outlet before nutrient concentrations reach background levels. TN and NOx are the only possible exceptions to this observation, having the potential to meet the 80^{th} percentile of background at the 1000 m mark (as indicated by the overlap of the 95% confidence interval bars with the 80^{th} percentile values at this distance).

The results for chlorophyll *a* concentrations show an increase between the 350 m and 1500 m mark. This concentration gradient is indicative of the 'lag' effect; where the uptake of nutrients and the eventual growth of marine algae results typically in a 'reverse gradient' between the outlet and distances downstream of the outlet. Elevated chlorophyll-a concentrations in the vicinity of outlets are typically recorded during periods of low wind, when the lower dispersion of nutrients and lower surface currents allows marine algae to multiply in the vicinity of the outlet. There is a potential for chlorophyll *a* concentrations to exceed the 80^{th} percentile of historical as indicated by the 95% confidence interval bars. We note however that median chlorophyll *a* concentrations remain within background levels irrespective of the slightly elevated results. All measurements of NH_3 were below the limit of analytical detection (LOR).

[5] *The surface drogue was used to determine the direction of the surface current and therefore the likely dispersal direction of the plume.*

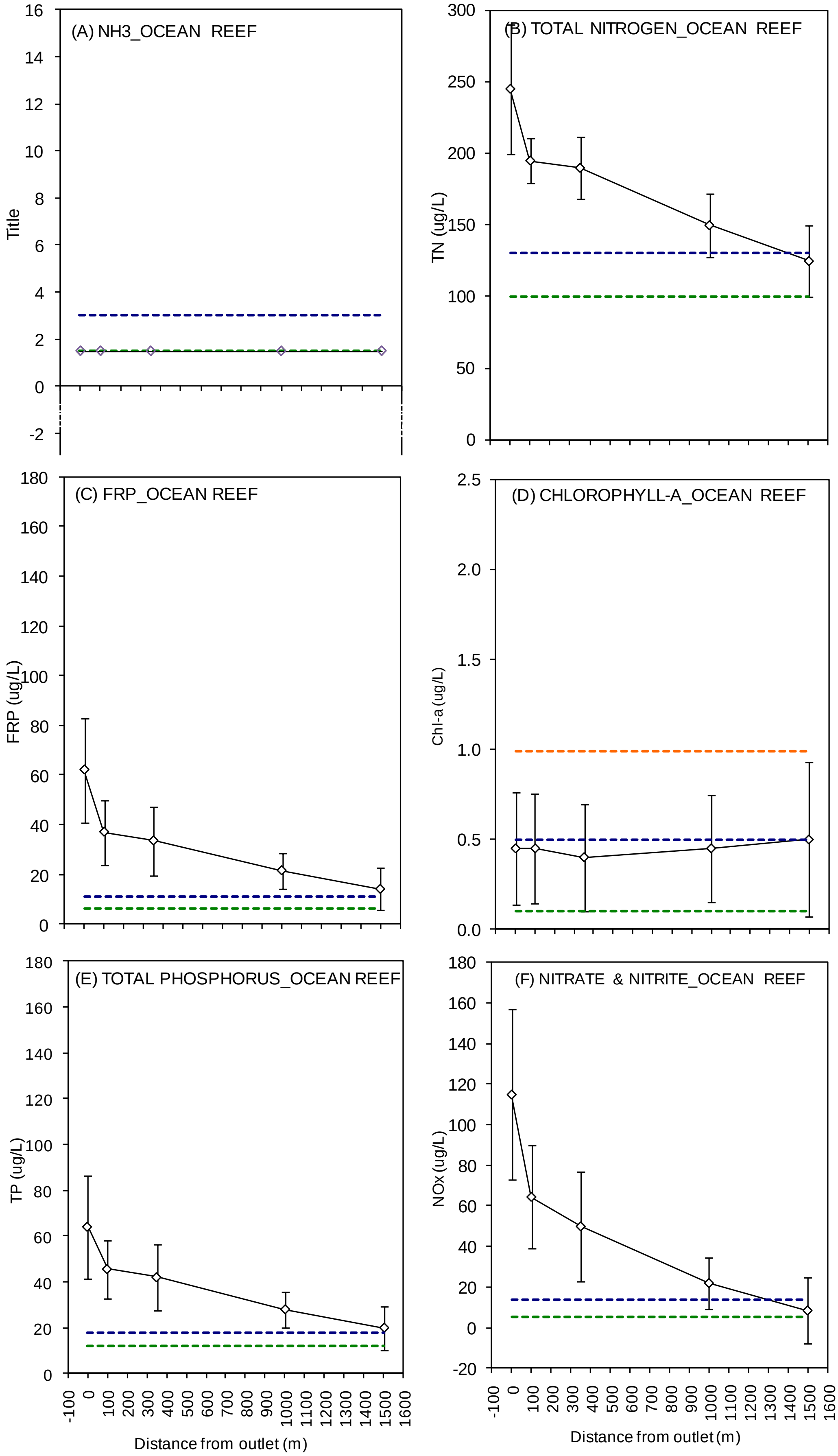

Figure 3.3 **Median nutrient and chlorophyll-a concentrations ± 95% confidence intervals obtained at a fix distance downstream of the Ocean Reef outlets. Blue (--), green (--) and orange (--) broken lines represent historical 80th and 20th percentile concentrations and 3 × median of 2009-2010 reference data, respectively.**

Nutrient enrichment

One of the objectives of the TCM program is to monitor for the effects of physical and chemical stressors that may affect the integrity of the Marine Ecosystem. Measures of light attenuation and chlorophyll *a* were conducted on eight separate occasions between the 3 December 2009 and the 24 March 2010. Results of this program, together with the relevant assessments of compliance for these indicators are provided in Table 3.5, Table 3.6 and Table 3.7.

Table 3.5 Results of summer TCM light attenuation ($log^{10}m^{-1}$) monitoring program. Note that the ambient medians were calculated using data from the High Ecological Protection Area (HEPA) (sites T-100 to T-1500).

Day	Outlet Site	Compliance Sites				Reference Sites			
	OR-0	OR-100	OR-350	OR-1000	OR-1500	ORR1	ORR2	ORR3	ORR4
03/12/2009	*	*	*	*	*	*	*	*	*
17/12/2009	0.079	0.076	0.081	0.080	0.069	0.071	0.071	0.069	0.071
07/01/2010	0.092	0.087	0.092	0.079	0.085	0.084	0.083	0.084	0.085
20/01/2010	0.103	0.094	0.082	0.065	0.066	0.069	0.067	0.068	0.074
10/02/2010	0.082	0.078	0.072	0.068	0.072	0.069	0.072	0.074	0.073
24/02/2010	0.076	0.070	0.068	0.061	0.066	0.064	0.066	0.072	0.069
10/03/2010	0.077	0.068	0.066	0.064	0.067	0.068	0.076	0.078	0.075
24/03/2010	0.082	0.085	0.082	0.074	0.069	0.064	0.059	0.065	0.075
Median	0.079	0.076	0.081	0.080	0.069	0.071	0.071	0.069	0.071
Ambient median value of defined area: 0.073						80^{th} %ile of reference data (2009-2010): 0.081			
						80^{th} %ile of reference data (2003-2010): 0.074			

Notes:
1. * - No data due to instrument malfunction

Table 3.6 Results of summer TCM chlorophyll-a (µg/L) monitoring program. Note that the median was calculated using data from the High Ecological Protection Area (HEPA) (sites OR-100 to OR-1500).

Day	Outlet Site	Compliance Sites				Reference Sites			
	OR-0	OR-100	OR-350	OR-1000	OR-1500	ORR1	ORR2	ORR3	ORR4
03/12/2009	0.40	0.30	0.40	0.40	0.60	0.05	0.10	0.05	0.05
17/12/2009	0.30	0.30	0.30	0.20	0.20	0.10	0.20	0.30	0.40
07/01/2010	0.90	1.00	1.20	1.20	1.70	0.30	0.40	0.40	0.50
20/01/2010	0.30	0.30	0.30	0.20	0.20	0.20	0.20	0.10	0.10
10/02/2010	0.50	0.50	0.60	0.50	0.50	0.60	0.30	0.80	0.50
24/02/2010	0.30	0.40	0.40	0.30	0.30	0.20	0.20	0.20	0.20
10/03/2010	0.60	0.50	0.40	0.50	0.50	0.80	0.70	0.70	0.60
24/03/2010	1.30	1.20	1.00	0.80	0.80	0.30	0.40	0.20	0.40
Median	0.45	0.45	0.40	0.45	0.50	0.25	0.25	0.25	0.40
Ambient Median	0.45					80^{th} percentile of reference data: 0.50			
3×Ambient Median	1.35								

Over the course of the summer monitoring period, measures of light attenuation ranged between 0.061-0.094 $\log^{10}$ m^{-1} and 0.059-0.085 $\log^{10}$ m^{-1} for the compliance and reference sites, respectively. For comparative purposes, median light attenuation values are plotted against the long term 80th and 20th percentiles of reference site data (Figure 3.4). From the results, it is clear that median light attenuation values exceed the long term 80th percentile at distances 0 m (directly above the outlet), 100 m and 350 m downstream of the outlets, but not at distances 1000 m or 1500 m downstream of the outlets. The relevant EQG for light attenuation stipulates that the ambient median (including the combined data from sites 100 m, 350 m, 1000 m and 1500 m downstream of the outlet) is not to exceed the 80th percentile of the reference distribution. Following this protocol, the ambient median of 0.0725 $\log^{10}m^{-1}$ does not exceed the 80th percentile of 0.760 $\log^{10}$ m^{-1}, thus meeting the EQG for this indicator (Table 3.7).

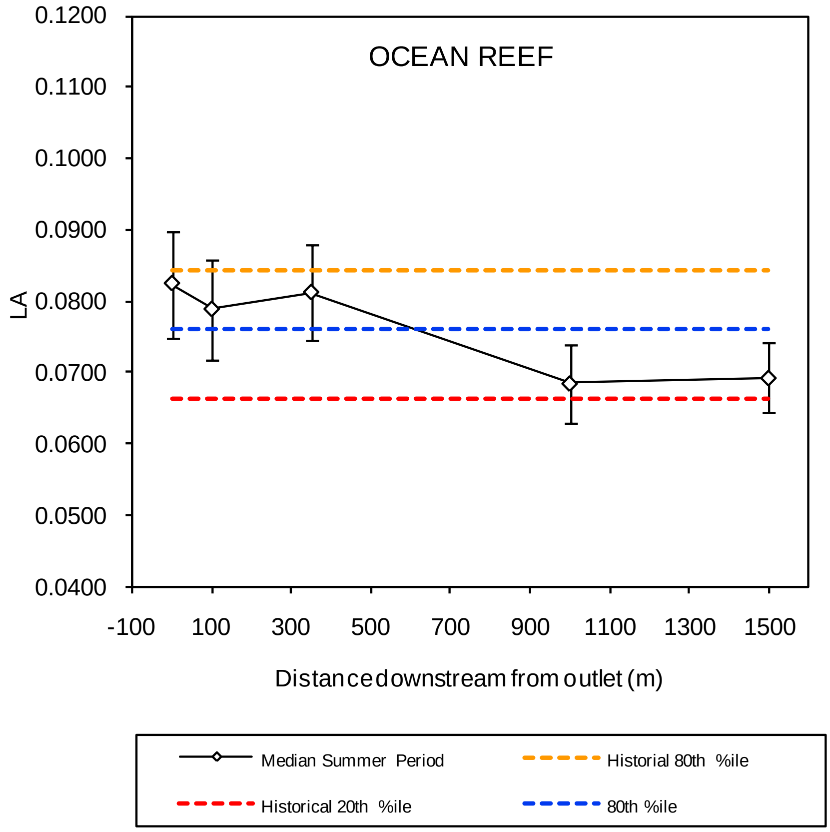

Figure 3.4 **Median light attenuation values ± 95% confidence intervals obtained at fixed distances downstream of the Ocean Reef outlets. Orange (--) and red (--) broken lines represent historical 80th and 20th percentiles of reference site light attenuation values, and the blue (--) broken line the 80th percentile of reference site data from 2009-2010 monitoring program.**

According to the EQC Reference Document for Cockburn Sound (EPA 2005a), the EQG for Nutrient Enrichment and Phytoplankton Biomass are both assessed against measures of chlorophyll *a*. For example, in the case of Nutrient Enrichment, the median concentration of Chlorophyll *a* (from a defined area) is not to exceed the 80th percentile of the long term reference data; and for Phytoplankton Biomass, the ambient value is not to exceed 3 x median of reference sites and/or 3 x median of reference sites on 25% or more occasions during non river-flow period. Results obtained between the 3 December 2009 and 24 March 2010 indicated the EQG for both indicators was met.

Table 3.7 Comparison of ambient values obtained at fixed distances downstream of the Ocean Reef outlets with Trial Environmental Quality Guidelines. The Green (■) and Amber (■) indicators represent whether the EQGs were met or not met, respectively. Note the ambient medians were calculated using data from the High Ecological Protection Area (HEPA) (sites T-100 to T-1500).

Environmental Objective	Trial environmental Quality Indicator	Trial Environmental Quality Guideline	Ambient Value	EQG
Protection of Marine Ecosystem from the effects of Physical and Chemical Stressors	Nutrient Enrichment	*Light attenuation:* Ambient value[1] of defined area[2] during non river-flow period[3] not to exceed 80%ile of reference sites data: 0.074 $\log^{10} m^{-1}$	0.073 $\log^{10} m^{-1}$	■
		Chlorophyll-a: Ambient value[1] of defined area[2] during non river-flow period[3] not to exceed 80%ile of reference sites data: 0.50 µg/L	0.45 µg/L	■
	Phytoplankton Biomass	(i) Ambient value of defined area during non river-flow period not to exceed 3×median of reference sites: 1.35 µg/L	Day1: 0.40 µg/L Day2: 0.25 µg/L Day3: 1.20 µg/L Day4: 0.25 µg/L Day5: 0.50 µg/L Day6: 0.35 µg/L Day7: 0.50 µg/L Day8: 0.90 µg/L	■
		(ii) Phytoplankton biomass at any site does not exceed 3×median of reference sites on 25% or more occasions during non river-flow period	No trial compliance site >1.35 µg/L on 25% or more occasions	■

Notes:
1. Ambient value = median value of individual sample data for a defined area
2. Defined Area = area to be characterised for environmental quality against pre-determined Environmental Quality Objectives and levels of ecological protection.
3. Non river-flow Period = period December-March inclusive, when river and estuarine flows are weak.
4. Value is 80th percentile of chlorophyll-a concentration at reference sites during the 2003-2010 non-river flow periods, following the approach proposed by the EPA.

3.1.4. Public health

Unlike other data collected as part of the summer TCM program, the microbiological data were not collected over the period 3 December 2009 to 24 March 2010, but were collected as part of a more intensive program on the 2 December 2009. On this day, eight samples were collected from fixed distances along the predicted trajectory of the plume (as indicated by a surface drogue). The more intensive sampling program was designed to provide fine scale information about the extent of microbiological dilution (or 'die off') downstream of the ocean outlets. Results of this program are presented in Table 3.8 and Figure 3.5.

Table 3.8 Results of summer TCM microbiological monitoring program. Results are presented for faecal streptococci (as *Enterococci*) and thermo-tolerant coliforms (TTC). Units for *Enterococci* and TTC are MPN/100mL and CFU/100 mL, respectively. Note that for median and 95th percentile calculations, less than (<) values are halved and greater than (>) values are doubled.

Compliance				Reference Sites		
Ecological Protection Area	**Site**	***Enterococci***	**TTC**	**Site**	***Enterococci***	**TTC**
LEPA	T-0	10	70	ORR1	<10	<10
	T-50	20	150	ORR2	<10	<10
HEPA	T-100	10	10	ORR3	<10	<10
	T-200	10	5	ORR4	<10	<10
	T-350	5	5			
	T-500	5	10			
	T-1000	<10	<10			
	T-1500	<10	<10			
	Median HEPA	5	5			
	95th percentile	16.5	122			

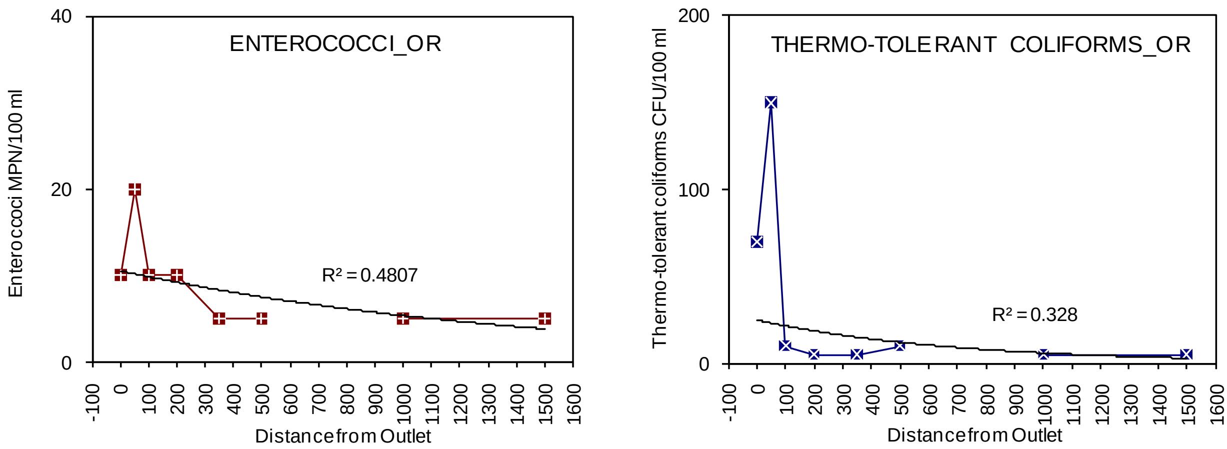

Figure 3.5 Results of microbiological monitoring conducted on the 2 December 2009 at fixed sites downstream of the Ocean Reef wastewater outlets. Exponential trend lines are added along with relevant R^2 values.

Sampling conducted on the 2 December 2009 indicated higher numbers of *Enterococci* and thermo-tolerant coliforms in the vicinity of the outlet and lower number with increasing distance downstream of the outlet (Figure 3.5). Numbers for *Enterococci* and thermo-tolerant coliforms peaked at the 100 m mark before diminishing rapidly to circum background concentrations at a distance of approximately 350 m downstream of the outlet. The peak at 100 m is indicative of the effect of surface currents on the TWW plume. As the buoyant plume ascends through the water column, surface currents force the TWW plume away from the outlet, meaning the majority of microbial organisms are first detected at the surface a short distance (50 m – 100 m) downstream of the outlet.

The public health component of the summer TCM program assesses the results of the microbiological and phytoplankton monitoring program against the EQC relevant to the following environmental objectives: Seafood Safe for Human Consumption and Primary/Secondary Contact Recreation. The EQC for microbiological indicators are based those included in the ASWQS (Oceanica 2010a). The assessment against the EQC as reported in the ASWQS is included in Table 3.9 and Table 3.10.

Table 3.9 Assessment of compliance against Trial EQG for microbiological indicators, thermo-tolerant coliforms and faecal streptococci (as *Enterococci*). The green (■) and amber (■) indicators represent the EQGs were met or not met, respectively.

Environmental Objective	Trial Environmental Quality Guideline	Ambient Value	EQG
Seafood Safe for Human Consumption (shellfish)	Median thermo-tolerant coliform counts not to exceed 14 CFU/100mLusing the membrane filtration method	Median thermo-tolerant coliform value calculated from 28 sites during annual summer water quality survey = 5 CFU/100mL	Inside 250 m Greater than 250 m
Primary Contact Recreation	Median value of *Enterococci* taken over the bathing season not to exceed 35 MPN/100 mL (as per the ANZECC/ARMCANZ (2000) microbiological guidelines)	Median counts of *Enterococci* obtained at sites located within 250 m of the diffuser and greater than 250 m from the diffuser	Inside 250 m Greater than 250 m
Secondary Contact Recreation	Median value of *Enterococci* taken over the bathing season not to exceed 230 MPN/100 mL (as per the ANZECC/ARMCANZ (2000) microbiological guidelines)	Median counts of *Enterococci* obtained at sites located within 250 m of the diffuser and greater than 250 m from the diffuser	Inside 250 m Greater than 250 m

Table 3.10 Assessment of compliance against Trial EQS for microbiological indicators, thermo-tolerant coliforms and faecal streptococci (as *Enterococci*). The green (■) and red (■) indicators represent whether the EQSs were met or not met, respectively.

Environmental Objective	Trial Environmental Quality Standards	Ambient Value	EQS
Seafood Safe for Human Consumption (shellfish)	Median thermo-tolerant coliform counts not to exceed 70 CFU/100mL using the membrane filtration method	Median thermo-tolerant coliform value calculated from 28 sites during annual summer water quality survey = 5 CFU/100mL	Inside 250 m Greater than 250 m
Primary Contact Recreation	The EQS is assessed annually against the results of the annual DoH survey, and particularly, whether the beaches in the vicinity of the ocean outlets were classified as safe and, if not, whether the decrease in safety can be attributed to the TWW outlets. If the status of the beaches is graded 'very good', then the EQS is deemed to have been met. If the status of the beaches is graded as 'poor', and the decrease in quality can be attributed to the ocean outlets, then the EQS is deemed to have been exceeded.	Beaches in the vicinity of outlet classified as safe for swimming	
Secondary Contact Recreation		Beaches in the vicinity of outlet classified as safe for swimming	

The median of thermo-tolerant coliform counts for surface sites <250 m from the diffuser exceeded the EQG and the EQS for the maintenance of seafood safe for human consumption. (Table 3.9, Table 3.10); however, there were no exceedances of the EQG or EQS at surface sites >250 m from the diffuser. Human health concerns relating to seafood are not considered to be an issue at Ocean Reef as there is no harvesting of seafood or aquaculture undertaken within 250 m of the diffuser and no known harvesting of seafood in the waters 1–2 km offshore. *Enterococci* counts met the guidelines for primary contact recreation in all cases (Table 3.9, Table 3.10). Shoreline monitoring found no indication of contamination of any beaches adjacent to the outlets (Table 3.9, Table 3.10).

In addition to the microbiological component, the Public Health component of the TCM program includes a requirement to monitor potentially toxic phytoplankton species in the vicinity of the TWW ocean outlets. The objective of this program is to assess the risk of (i) toxins accumulating in seafood or (ii) toxins posing a direct threat to the public via ingestion or skin-contact. Table 3.11 lists the phytoplankton species known to produce toxins which may be concentrated in shellfish recorded at the reference site ORR1 and downstream of the Ocean Reef outlets over the 2009–2010 non river-flow period (December–March). The WASQAP (Department of Health and Department of Fisheries 2007) guideline trigger concentrations for phytoplankton toxins are also listed. No potentially toxic phytoplankton were recorded during the 2009-2010 summer monitoring period. Hence, the EQGs for potentially toxic phytoplankton species for the environmental objectives: Seafood Safe for Human Consumption; Primary and Secondary Contact Recreation - were met (Table 3.12).

Although presently, the taxa *Nitzschia* spp. and *Rhizosolenia* spp. are not included in the list of causative agents of toxic shellfish poisonings, and there are no defined trigger levels for action in the WASQAP Operations Manual (Department of Fisheries 2007), there is a requirement for the occurrence of these taxa to be reported. The total cell densities and relative cell densities recorded for these Genera are reported in Table 3.11.

Table 3.11 Estimated cell densities (cells/L) of phytoplankton species known to produce toxins which may be concentrated in shellfish, in samples collected downstream of the Ocean Reef outlets (ORT-1000) and the reference site (ORR1) between the 4 December 2009 and 24 March 2010.

Date	Site	Species	Estimated Density (cell/L)	WASQAP Guideline Trigger Concentrations (cells/L)[1]	Exceedance
04/12/2009	ORR1	*Nitzschia longissima*	549	n.d.	N/A
		Nitzschia sp. 038	183	n.d.	N/A
	ORT-1000	*Nitzschia longissima*	183	n.d.	N/A
17/12/2009	ORR1	*Nitzschia longissima*	366	n.d.	N/A
	ORT-1000	No toxic species recorded			
07/01/2010	ORR1	No toxic species recorded			
	ORT-1000	*Nitzschia hungarica*	183	n.d.	N/A
20/01/2010	ORR1	No toxic species recorded			
	ORT-1000	No toxic species recorded			
10/02/2010	ORR1	*Pseudo-nitzschia turgidula*	366	250,000	**No**
	ORT-1000	*Rhizosolenia imbricata var. shrubsolei*	366	n.d.	N/A
	ORR1	*Rhizosolenia* sp. 021	366	n.d.	N/A
	ORT-1000	*Pseudo-nitzschia turgidula*	366	250,000	**No**
09/03/2010	ORR1	*Nitzschia sp. 008*	183	n.d.	N/A
		Pseudo-nitzschia turgidula	732	250,000	**No**
	ORT-1000	No toxic species recorded			
24/03/2010	ORR1	*Pseudo-nitzschia heimii*	7,686	250,000	**No**
		Pseudo-nitzschia turgidula	8,418	250,000	**No**
	ORT-1000	*Pseudo-nitzschia turgidula*	184,464	250,000	**No**
		Rhizosolenia setigera	366	n.d.	N/A

Notes:
1. n.d. = no available data or threshold limit to trigger testing of flesh.

Table 3.12 Assessment of compliance for the bio-indicator Algal Bio-toxins. The green (■) and the amber (■) indicators represent whether the EQGs were met or not met, respectively.

Environmental Objective	Trial Environmental Quality Guideline	Ambient Value	EQG
Seafood Safe for Human Consumption	Concentrations of potentially toxic algae not to exceed the WASQAP[(1)] trigger concentrations: *Alexandrium* spp. (100 cells/L) *Gymnodinium* spp. (1000 cells/L) *Karenia* spp. (1000 cells/L) *Dinophysis* spp. (500 cells/L) *Dinophysis acuminta* (3000 cells/L) *Prorocentrum* spp. (500 cells/L) *Psuedo-nitzschia* spp. (25000 cells/L) *Gonyaulax cf spinifera* (100 cells/L) Protoceratium reticulatum (*Gonyaulax grindleyi*) (500 cells cells/L)	All incidences of potentially toxic species recorded cell densities below the prescribed WASQAP trigger concentrations	■
	Median total phytoplankton cell count for the area of concern (either from one sampling run or from a single site over agreed period of time) should not exceed 15,000 cells/mL [(1)]	Median total phytoplankton cell count at the trial compliance monitoring site SBT-1000 over the non-river flow period: 0.366 cells/mL	■
	OR There should be no reports of skin or eye irritation or potential algal poisoning in swimmers considered by a medical practitioner as potentially resulting from toxic algae when less than 15,000 cells/mL is present in the water column	There were no reports of skin or eye irritation or potential algal poisoning in swimmers	■
Primary Contact Recreation	Median total phytoplankton cell count for the area of concern (either from one sampling run or from a single site over agreed period of time) should not exceed 15,000 cells/mL [(2)]	Median total phytoplankton cell count at the trial compliance monitoring site SBT-1000 over the non-river flow period: 0.366 cells/mL	■
	OR There should be no reports of skin or eye irritation or potential algal poisoning in swimmers considered by a medical practitioner as potentially resulting from toxic algae when less than 15,000 cells/mL is present in the water column	There were no reports of skin or eye irritation or potential algal poisoning in swimmers.	■
Secondary Contact Recreation	Median total phytoplankton cell count for the area of concern (either from one sampling run or from a single site over agreed period of time) should not exceed 15,000 cells/mL [(2)]	Median total phytoplankton cell count at the trial compliance monitoring site SBT-1000 over the non-river flow period: 0.366 cells/mL	■

Environmental Objective	Trial Environmental Quality Guideline	Ambient Value	EQG
	OR There should be no reports of skin or eye irritation or potential algal poisoning in swimmers considered by a medical practitioner as potentially resulting from toxic algae when less than 15,000 cells/mL is present in the water column	There were no reports of skin or eye irritation or potential algal poisoning in swimmers	

Notes:

1. Western Australian Shellfish Assurance Program (Department of Health and Department of Fisheries 2007).
2. The numerical Environmental Quality Guideline for toxic algae was largely developed for inland water and is to be used as an indicative guideline only, until sufficient marine data have been gathered for its revision (Environmental Protection Authority 2005a).

3.2. Whole of effluent toxicity tests

3.2.1. 1-hour sea urchin fertilisation test

Table 3.13 presents the results of the quarterly 1-hour sea urchin (*Heliocidaris tuberculata*) fertilisation tests. With the exception of July 2009, relative to the seawater control (in which fertilisation was achieved in approximately 91.3 - 98.5% of cases) no concentrations of TWW acted to significantly reduce the success of sea urchin fertilisation. In July 2009 the lowest dilution of the TWW sample to achieve a similar rate of fertilisation to the seawater control was 50% (equivalent to 2-fold dilution).

3.2.2. Triggers for further action

To 'trigger' for the full suite of WET testing (incorporating marine organisms from a variety of trophic levels) the NOEC must be less than 1.0% (equivalent to more than 100-fold dilution). The concentration to which the NOEC was demonstrated occurred at 50% (equivalent to 2-fold dilution) in July 2009; and 100% (equivalent to 1-fold dilution) in October 2009, January 2010 and April 2010 (Table 3.13) indicating that the disposal of wastewater from the Ocean Reef outlets is not adversely affecting the surrounding marine environment with respect to toxicity. As the 1-hour sea urchin NOEC was <1.0% in each of the quarterly tests, there was no requirement for further investigation using the full suite of WET tests.

Table 3.13 Results of 1-hour sea urchin fertilisation tests. NOEC concentrations are shown in bold text.

Test Date	Seawater Control	Artificial Seawater (Brine) Control	1.0% TWW	1.6% TWW	3.1% TWW	6.25% TWW	12.5% TWW	25% TWW	50% TWW	100% TWW
July 2009	91.3 ± 2.2	90.5 ± 3.9	87.5 ± 2.1	91.0 ± 3.2	88.8 ± 6.7	89.5 ± 4.5	86.8 ± 5.0	89.8 ± 3.3	82.5 ± 2.4	**75.8 ± 9.3**(1)
Oct 2009	98.5 ± 1.9	76.8 ± 4.1	98.3 ± 1.5	98.5 ± 1.3	99.3 ± 1.5	98.5 ± 0.6	98.8 ± 1.0	98.8 ± 1.0	96.3 ± 2.1	79.8 ± 8.5
Jan 2010	92.5 ± 2.1	86.8 ± 1.7 (2)	95.8 ± 2.2	92.5 ± 2.1	94.0 ± 2.9	92.8 ± 3.9	93.8 ± 3.3	94.8 ± 3.9	95.3 ± 3.6	96.3 ± 1.5
April 2010	98.0 ± 2.5	95.5 ± 4.1	98.8 ± 1.0	99.8 ± 0.5	99.0 ± 1.4	98.5 ± 1.0	99.3 ± 1.5	98.3 ± 2.1	99.0 ± 1.4	98.5 ± 1.7

Notes:

1. Significantly lower % fertilised eggs compared with the artificial seawater control treatment (Dunnett's Test, 1 tailed, P=0.05, df= July 2009: missing; October 2009; 8, 27; January 2010: 8, 27; and April 2010: 8, 27)
2. Significantly lower percentage of fertilised eggs in artificial seawater (brine) control compared with the seawater control (Paired *t*-test, 1-tailed, P=0.05)

3.3. TWW characterisation

3.3.1. Contaminant concentrations

The TWW characterisation data obtained from the Ocean Reef WWTP on 23 February 2010 are presented in Table 3.14. The table includes values in bold that indicate contaminant concentrations that were confirmed to exceed the ANZECC/ARMCANZ (2000) guideline trigger values for marine waters prior to dilution with ambient seawater. Note that for some parameters, the analytical limits of reporting were not low enough to compare against guidelines and/or the Low Reliability Values.

Low Reliability Values (LRVs) were derived for contaminants having insufficient data to derive reliable national guidelines, thus, LRVs were formulated using conservative assessment factors. The EPA position is that LRVs should only be used as indicative working levels, not guidelines, until reliable guidelines have been published. The laboratory analytical sheets for the TWW characterisation are provided in Appendix A.

Table 3.14 Concentrations of contaminants present in the Beenyup TWW **sample prior to initial dilution. Values in bold are above the ANZECC/ARMCANZ (2000) guidelines for high ecological protection**[1]**.**

Parameter	Beenyup TWW	ANZECC/ARMCANZ (2000) Guideline				
		Level of Protection				Low Reliability Value (LRV)
		99%	95%	90%	80%	
Microbiological						
Confirmed *Enterococci*[2]	**2550 (MPN/100ml)**	n/a[3]	n/a	n/a	n/a	n/a
Presumptive Thermo-tolerant Coliforms (TTC)[4]	Est. >200 (CFU/100ml)	n/a	n/a	n/a	n/a	n/a
Confirmed Thermo-tolerant Coliforms (TTC)[4]	n/a	n/a	n/a	n/a	n/a	n/a
Escherichia coli	n/a	n/a	n/a	n/a	n/a	n/a
Nutrients (µg/L)						
Ammonia-N	280	500	910	1,200	1,700	-
Nitrate-N+Nitrite-N	17,000	ID[5]	ID	ID	ID	13,000
Nitrogen-Total N	20,000	n/a	n/a	n/a	n/a	n/a
Phosphate-Ortho as P	2,500	n/a	n/a	n/a	n/a	n/a
Phosphorous-Total P	8,900	n/a	n/a	n/a	n/a	n/a
"Dissolved" Metals (0.45 µm filtered) (µg/L)						
Arsenic (As)	<1.0	ID	ID	ID	ID	2.3 (As III) 4.5 (AsV)

Parameter	Beenyup TWW	ANZECC/ARMCANZ (2000) Guideline				
		Level of Protection				Low Reliability Value (LRV)
		99%	95%	90%	80%	
Cadmium (Cd)	<0.1	0.7	5.5	14	36	-
Chromium (Cr)	<1.0	7.7 (Cr III) 0.14 (Cr VI)	27.4 (Cr III) 4.4 (Cr VI)	48.6 (Cr III) 20 (Cr VI)	90.6 (Cr III) 85 (Cr VI)	-
Copper (Cu)	**7.3**	0.3	1.3	3	8	-
Lead (Pb)	1.5	2.2	4.4	6.6	12	-
Mercury (Hg)	<0.1	0.1	0.4	0.7	1.4	-
Nickel (Ni)	1.7	7	70	200	560	-
Selenium (Se)	<1.0	ID	ID	ID	ID	3
Silver (Ag)	<0.8	0.8	1.4	1.8	2.6	-
Zinc (Zn)	**54**	7	15	23	43	-
Total Metals (Acid extractable; unfiltered) (µg/L)						
Arsenic (As)	<1	ID	ID	ID	ID	2.3 (As III) 4.5 (AsV)
Cadmium (Cd)	<0.1	0.7	5.5	14	36	-
Chromium (Cr)[6]	<1.0	7.7 (Cr III) 0.14 (Cr VI)	27.4 (Cr III) 4.4 (Cr VI)	48.6 (Cr III) 20 (Cr VI)	90.6 (Cr III) 85 (Cr VI)	-
Copper (Cu)	**11**	0.3	1.3	3	8	-
Lead (Pb)	1.5	2.2	4.4	6.6	12	-
Mercury (Hg)	<0.1	0.1	0.4	0.7	1.4	-
Nickel (Ni)	1.8	7	70	200	560	-
Selenium (Se)	<1.0	ID	ID	ID	ID	3
Silver (Ag)	<0.8	0.8	1.4	1.8	2.6	-
Zinc (Zn)	**56**	7	15	23	43	-
Triazine Herbicides (µg/L)						
Atrazine	<0.1	ID	ID	ID	ID	13
Hexazinone	<0.1	ID	ID	ID	ID	75
Metribuzine	<0.1	n/a	n/a	n/a	n/a	n/a
Prometryne	<0.1	n/a	n/a	n/a	n/a	n/a
Simazine	<0.1	ID	ID	ID	ID	3.2
Phenoxy Acid Herbicides (µg/L)						
Dicamba[6]	<1.0	n/a	n/a	n/a	n/a	n/a
MCPA	<1.0	ID	ID	ID	ID	1.4
Dichlorprop	<1.0	n/a	n/a	n/a	n/a	n/a
2,4-D	<1.0	ID	ID	ID	ID	280
2,4,5-T	<1.0	n/a	n/a	n/a	n/a	n/a
2,4,5-TP	<1.0	n/a	n/a	n/a	n/a	n/a
2,4-DB	<1.0	n/a	n/a	n/a	n/a	n/a
MCPP	<1.0	n/a	n/a	n/a	n/a	n/a
Triclopyr[7]	<1.0	n/a	n/a	n/a	n/a	n/a
Organophosohate Pesticides (µg/L)						
Azinphos-Methyl	<0.1	ID	ID	ID	ID	0.01
Azinphos-Ethyl	<0.1	n/a	n/a	n/a	n/a	n/a
Chlorpyrifos	<0.1	0.0005	0.009	0.04	0.3	-
Chlorpyrifous Methyl	<0.1	n/a	n/a	n/a	n/a	n/a
Chlorfenvinphos (E)	<0.1	n/a	n/a	n/a	n/a	n/a
Chlorfenvinphos (Z)	<0.1	n/a	n/a	n/a	n/a	n/a
Demeton-S-Methyl	<0.1	ID	ID	ID	ID	4
Dichlorvous	<0.1	n/a	n/a	n/a	n/a	n/a
Diazinon	<0.1	ID	ID	ID	ID	0.01

[6] *Dissolved chromium (Cr) in TWW is predominantly Cr III, not Cr VI*

Parameter	Beenyup TWW	ANZECC/ARMCANZ (2000) Guideline				
		Level of Protection				Low Reliability Value (LRV)
		99%	95%	90%	80%	
Dimethoate	<0.1	ID	ID	ID	ID	0.15
Ethion	<0.1	n/a	n/a	n/a	n/a	n/a
Fenthion	<0.1	n/a	n/a	n/a	n/a	n/a
Fenitrothion	<0.1	ID	ID	ID	ID	0.001
Malathion	<0.1	ID	ID	ID	ID	0.05
Parathion (Ethyl)	<0.1	ID	ID	ID	ID	0.004
Parathion Methyl	<0.1	n/a	n/a	n/a	n/a	n/a
Pirimiphos-Ethyl[8]	<0.1	n/a	n/a	n/a	n/a	n/a
Pirimiphos-Methyl[9]	<0.1	n/a	n/a	n/a	n/a	n/a
Organochlorine Pesticides (µg/L)						
Aldrin	<0.01	ID	ID	ID	ID	0.003
Trans-Chlordane[10]	<0.01	ID	ID	ID	ID	0.001
Cis-Chlordane[10]	<0.01	ID	ID	ID	ID	0.001
Oxychlordane[10]	<0.01	ID	ID	ID	ID	0.001
gamma-BHC (Lindane)	<0.01	ID	ID	ID	ID	0.007
alpha-BHC	<0.01	n/a	n/a	n/a	n/a	n/a
beta-BHC	<0.01	n/a	n/a	n/a	n/a	n/a
delta-BHC	<0.01	n/a	n/a	n/a	n/a	n/a
p,p-DDD	<0.01	n/a	n/a	n/a	n/a	n/a
p,p-DDE	<0.01	ID	ID	ID	ID	0.0005
p,p-DDT	<0.01	ID	ID	ID	ID	0.0004
Dieldrin	<0.01	ID	ID	ID	ID	0.01
Endrin	<0.01	0.004	0.008	0.01	0.02	-
Endrin Aldehyde	<0.01	n/a	n/a	n/a	n/a	n/a
Endrin Ketone	<0.01	n/a	n/a	n/a	n/a	n/a
alpha-Endosulfan	<0.01	ID	ID	ID	ID	0.0002
Beta-Endosulfan	<0.01	ID	ID	ID	ID	0.007
Endosulfan Sulfate[11]	<0.01	0.005	0.01	0.02	0.05	-
HCB (Hexachlorobenzene)	<0.01	ID	ID	ID	ID	0.05
Heptachlor	<0.01	ID	ID	ID	ID	0.0004
Heptachlor epoxide	<0.01	n/a	n/a	n/a	n/a	n/a
Methoxychlor	<0.01	ID	ID	ID	ID	0.004
Phenol (µg/L)[(22)]						
Phenol	n/d	270	400	520	720	-
Nonylphenol	n/d	ID	ID	ID	ID	1
2-Chorophenol	n/d	ID	ID	ID	ID	340
2-Methylphenol	n/d	n/a	n/a	n/a	n/a	n/a
2,4-Dichlorophenol	n/d	ID	ID	ID	ID	120
2-Nitrophenol	n/d	n/a	n/a	n/a	n/a	n/a
4-Chloro-3-methylphenol	n/d	n/a	n/a	n/a	n/a	2
2,4,6-Trichlorophenol	n/d	ID	ID	ID	ID	34
4-Nitrophenol	n/d	ID	ID	ID	ID	2
2,4,5-Trichlorophenol	n/d	n/a	n/a	n/a	n/a	n/a
2,3,4,6-Trichlorophenol	n/d	ID	ID	ID	ID	10
Pentachlorophenol (PCP)	n/d	11	22	33	55	-
Phthalates (µg/L)						
Dimethyl phthalate	<10	ID	ID	ID	ID	3700
Diethyl phthalate	<10	ID	ID	ID	ID	900
Di-n-butyl phthalate	<10	ID	ID	ID	ID	25
Benzyl butyl phthalate	<10	n/a	n/a	n/a	n/a	n/a
Bis(2-ethylhexyl) phthalate	<20	ID	ID	ID	ID	1
PCB Aroclors (µg/L)						

Parameter	Beenyup TWW	ANZECC/ARMCANZ (2000) Guideline				
		Level of Protection				Low Reliability Value (LRV)
		99%	95%	90%	80%	
Aroclor 1016	<0.1	ID	ID	ID	ID	0.009
Aroclor 1221	<0.1	ID	ID	ID	ID	1
Aroclor 1232	<0.1	ID	ID	ID	ID	0.3
Aroclor 1242	<0.1	ID	ID	ID	ID	0.3
Aroclor 1248	<0.1	ID	ID	ID	ID	0.03
Aroclor 1254	<0.1	ID	ID	ID	ID	0.01
Aroclor 1260	<0.1	ID	ID	ID	ID	n/a
Total PCB's (as above)[12]	<0.1	ID	ID	ID	ID	n/a
Chlorinated Hydrocarbons (µg/L)[(22)]						
2-Chloronaphthalene	n/d	n/a	n/a	n/a	n/a	n/a
1,4-Dichlorobenzene	n/d	ID	ID	ID	ID	60
1,2-Dichlorobenzene	n/d	ID	ID	ID	ID	160
1,3-Dichlorobenzene	n/d	ID	ID	ID	ID	260
Hexachlorobenzene	n/d	ID	ID	ID	ID	0.05
1,2,4-Trichlorobenzene	n/d	20	80	140	240	-
Hexachloroethane	n/d	ID	ID	ID	ID	290
Hexachlorocyclopentadiene	n/d	ID	ID	ID	ID	0.05
Hexachloro-1,3-butadiene	n/d	ID	ID	ID	ID	0.03
Ethers (µg/L)						
4-Bromophenyl phenyl ether	n/d	n/a	n/a	n/a	n/a	n/a
4-Chlorophenyl phenyl ether	n/d	n/a	n/a	n/a	n/a	n/a
Bis(2-chloroethyl)ether	n/d	n/a	n/a	n/a	n/a	n/a
Bis(2-chloroethoxy)methane	n/d	n/a	n/a	n/a	n/a	n/a
Bis(2-chloroisopropyl)ether	n/d	n/a	n/a	n/a	n/a	n/a
Amines, Nitroaromatics Nitrosamines (µg/L)[(22)]						
Azobenzene	n/d	n/a	n/a	n/a	n/a	n/a
2,4-Dinitrotoluene	n/d	ID	ID	ID	ID	16
2,6-Dinitrotoluene	n/d	n/a	n/a	n/a	n/a	0.3
Nitrobenzene	n/d	ID	ID	ID	ID	550
N-Nitrosodimethylamine	n/d	n/a	n/a	n/a	n/a	n/a
N-Nitrosodiphenylamine	n/d	ID	ID	ID	ID	6
N-Nitrosodi-n-propylamine	n/d	n/a	n/a	n/a	n/a	n/a
Aniline	n/d	ID	ID	ID	ID	8
4-Chloroaniline	n/d	n/a	n/a	n/a	n/a	n/a
2-Nitroaniline	n/d	n/a	n/a	n/a	n/a	n/a
3-Nitroaniline	n/d	n/a	n/a	n/a	n/a	n/a
4-Nitroaniline	n/d	n/a	n/a	n/a	n/a	n/a
Other Organics (µg/L)[(22)]						
Dichlorobenzidine[15]	n/d	ID	ID	ID	ID	0.5
2-Methylnaphthalene	n/d	n/a	n/a	n/a	n/a	n/a
Isophorone	n/d	ID	ID	ID	ID	130
Benzyl alcohol	n/d	n/a	n/a	n/a	n/a	n/a
Carbazole	n/d	n/a	n/a	n/a	n/a	n/a
Dibenzofuran	n/d	n/a	n/a	n/a	n/a	n/a
BTEX (µg/L)						
Benzene	<1.0	500	700	900	1300	500
Toluene	<1.0	ID	ID	ID	ID	180
Ethylbenzene	<1.0	ID	ID	ID	ID	5
Xylene[16]	<2.0	ID	ID	ID	ID	75
Total BTEX[12]	<5.0	n/a	n/a	n/a	n/a	n/a

Parameter	Beenyup TWW	ANZECC/ARMCANZ (2000) Guideline				
		Level of Protection				Low Reliability Value (LRV)
		99%	95%	90%	80%	
Total Petroleum Hydrocarbons (TPH) (µg/L)						
TPH C6 - C9[17]	<25	ID	ID	ID	ID	n/a
TPH C10 - C14[17]	<25	ID	ID	ID	ID	n/a
TPH C15 - C28[17]	<100	ID	ID	ID	ID	n/a
TPH C29 - C36[17]	<100	ID	ID	ID	ID	n/a
Total TPH[17,18]	<250	ID	ID	ID	ID	n/a
Poly Aromatic Hydrocarbons (PAHs) (µg/L)						
Naphthalene	<0.10	50	70	90	120	-
Acenaphthylene	<0.10	n/a	n/a	n/a	n/a	n/a
Acenaphthene	<0.10	n/a	n/a	n/a	n/a	n/a
Fluorene	<0.10	n/a	n/a	n/a	n/a	n/a
Phenanthrene	<0.10	ID	ID	ID	ID	2
Anthracene	<0.10	ID	ID	ID	ID	0.4
Fluoranthene	<0.10	ID	ID	ID	ID	1.4
Pyrene	<0.10	n/a	n/a	n/a	n/a	n/a
Benz(a)anthracene	<0.10	n/a	n/a	n/a	n/a	n/a
Chrysene	<0.10	n/a	n/a	n/a	n/a	n/a
Benzo(b,k)fluoranthene	<0.20	n/a	n/a	n/a	n/a	n/a
Benzo(a)pyrene	<0.10	n/a	n/a	n/a	n/a	n/a
Indeno(1,2,3-cd)pyrene	<0.10	n/a	n/a	n/a	n/a	n/a
Dibenz(a,h)anthracene	<0.10	n/a	n/a	n/a	n/a	n/a
Benzo(g,h,i)perylene	<0.10	50	70	90	120	-
Surfactants (µg/L)						
Methylene Blue Active Substances (MBAS)[19]	200	n/a	n/a	n/a	n/a	n/a
Miscellaneous other (µg/L unless indicated)						
Chlorine-Free	<20	ID	ID	ID	ID	3
Chlorine-Total	<20	ID	ID	ID	ID	3
Dissolved Organic Carbon (DOC)	8,000	n/a	n/a	n/a	n/a	n/a
Total Organic Carbon (TOC)	12,000	n/a	n/a	n/a	n/a	n/a
Total Suspended Solids (TSS)[20]	7,000	n/a	n/a	n/a	n/a	n/a
Biological Oxygen Demand (BOD)	5,000	n/a	n/a	n/a	n/a	n/a
pH[21]	7.3 (pH)	n/a	n/a	n/a	n/a	n/a

Notes:

1. The trigger values for marine waters are from (Table 3.4.1 in ANZECC/ARMCANZ (2000). The EPA has provided advice that in WA waters where a high level of protection applies, that the 99% species protection levels should be used, with the exception of cobalt, where the 95% species protection levels is used.
2. Primary and secondary contact guideline for recreational marine waters 35 and 230 *Enterococci* organisms 100 mL^{-1}, respectively (ANZECC/ARMCANZ 2000).
3. n/a = ANZECC/ARMCANZ (2000) Guideline or Low Reliability Value not available for this parameter.
4. Primary and secondary contact guidelines for recreational marine waters 150 and 1,000 faecal coliforms 100 mL^{-1} (ANZECC/ARMCANZ 2000), respectively.
5. ID = insufficient data to derive a reliable national trigger value.
6. Recreational guideline for Dicamba = 300 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000).
7. Recreational guideline for Triclopyr = 20 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000).
8. Recreational guideline for Pirimiphos-ethyl = 1 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000).
9. Recreational guideline for Pirimiphos-methy = 60 µg L^{-1} (Table 5.2.4; ANZECC/ARMCANZ 2000).
10. Guideline values are for total chlordane though cis-chlordane is around 7 times more toxic than transchlordane (ANZECC/ARMCANZ 2000).
11. Values for Endosulphan, not Endosulphan sulfate (Table 3.4.1; ANZECC/ARMCANZ 2000).
12. ANZECC/ARMCANZ (2000) recommends using a formula to calculate total toxicity of the mixture if using total PCBs and BTEX (page 8.3-65; ANZECC/ARMCANZ 2000).
13. Environmental Concern Level (ECL) for Hexachloro-1,3-butadiene (not LRV) (definition of ECL on page 8.3-35; page 8.3-231; ANZECC/ARMCANZ 2000).
14. Recommended ECL for 4-Bromophenyl phenyl ether = 12 µg L^{-1} (page 8.3-232; ANZECC/ARMCANZ 2000).
15. ECL for Dichlorobenzidine (not LRV) (page 8.3-187; ANZECC/ARMCANZ 2000).

16. Guideline for o-Xylene = 350 µg/L, for m-xylene = 75 µg/L and for p-xylene = 200 µg L^{-1} (ANZECC/ARMZANC 2000).
17. Guideline values are for generic oils and petroleum hydrocarbons (Table 3.4.1; ANZECC/ARMCANZ 2000).
18. A generic estimate of 7 µg L^{-1} for a total petroleum hydrocarbon chronic value has been estimated using USEPA methods (page 8.3-297; ANZECC/ARMCANZ 2000).
19. Recreational guideline for MBAS = 200 µg L-1 (ANZECC/ARMCANZ 2000).
20. Suspended solids guidelines for the protection of saltwater aquaculture species = <10,000 µg L^{-1} (Table 4.4.2; ANZECC/ARMCANZ 2000).
21. pH guideline range for slightly disturbed inshore marine ecosystems in south-west Australia = 8.0 to 8.4 (Table 3.3.6; ANZECC/ARMCANZ 2000).
22. No data (n/d) received for this annual reporting period due to clerical error.

The majority of parameters measured in the undiluted TWW were either below the analytical limit of reporting or below the EPA guideline trigger values for high ecological protection (Table 3.14). However, it was noted that concentrations of unfiltered copper, unfiltered zinc, filtered copper and filtered zinc exceeded the EPA guidelines for high ecological protection prior to initial dilution. Following initial dilution (equivalent to 98-fold), concentrations of unfiltered copper, unfiltered zinc, filtered copper and filtered zinc were sufficiently diluted to achieve values below the EPA guideline trigger values for high ecological protection.
The potential toxicity for the few pesticides for which there are reliable guidelines (chlorpyrifos, endrin and endosulfan) could not be assessed because laboratory reporting limits were not low enough to confirm exceedance or non-exceedance of the ANZECC/ARMCANZ (2000) guidelines. The detection limits required for pesticides to enable comparison against the ANZECC/ARMCANZ (2000) guidelines are not presently attainable by commercial laboratories in Australia.

3.3.2. Total toxicity of the mixture

The potential for toxicity of TWW to marine organisms at the edge of the initial mixing zone (i.e. after dilution of the TWW with seawater) was simplistically assessed as per ANZECC/ARMCANZ (2000) based on the additive effects of copper and zinc, which are the contaminants identified as most likely to cause toxicity effects. The results are presented in Table 3.15. The calculated total toxicity of the mixture following initial dilution was below the ANZECC/ARMCANZ (2000) guideline trigger value of 1.0, meaning the combined additive effects of these contaminants is not expected to impart adverse effects of marine flora and fauna in the vicinity of the outlets.

Table 3.15 Total toxicity of TWW **for Beenyup WWTP at the edge of the initial mixing zone associated with the Ocean Reef Outlets.**

Natural background concentrations in Perth's coastal waters (µg/L)			**Initial Dilution of TWW with seawater**	**Total Toxicity of the Mixture[(3)]**
Ammonia[(1)]	**Copper[(2)]**	**Zinc[(2)]**		
3.02	0.085	0.141	98[(4)]	0.629

Notes:
1. Value from (Oceanica, unpublished data)
2. Values from Mc Alpine et al. (2005), site OS.
3. Total toxicity of mixture = [ammonia]/guideline + [copper]/guideline + [zinc]/guideline.
4. Calculated from data obtained at outlet B, representing the 'worst-case' dilution. Outlet A had a high dilution ratio of 1:112.

3.3.3. Initial dilution modelling

The results from the initial dilution calculations are shown in Table 3.16. Results indicated that the maximum dilution of contaminants required to meet the ANZECC/ARMCANZ (2000) guidelines for high ecological protection is ~1:33. The worst-case initial dilution expected to occur at Ocean Reef was 1:98, suggesting contaminants will be sufficiently mixed during the initial dilution process to meet the ANZECC/ARMCANZ (2000) guidelines for high ecological protection.

Table 3.16 Number of dilutions of TWW required to meet ANZECC/ARMCANZ (2000) *Guidelines* trigger values.

Toxicants	TWW Conc. (µg/L)	ANZECC/ARMCANZ (2000) trigger values (µg/L) Level of protection (% species)			Background (µg/L)	Dilution required to meet level of protection (% species)		
		99%	90%	80%		99%	90%	80%
Ammonia	280	500	1200	1700	3.02(2)	0.6	0.2	0.2
Copper(1)	54	0.3	3	8	0.085(3)	33.6	2.5	0.9
Zinc(1)	7.3	7	23	43	0.141(3)	7.9	2.4	1.3

Notes:
1. Measures concentrations shown are for the filtered metal samples
2. Value from (Oceanica, unpublished data)
3. Values from McAlpine et al. (2005), site TR.

4. Report synthesis

4.1. Trial Compliance Monitoring

The objective of the summer TCM is to assess water quality in the vicinity of the outlets over the 3-month summer period and assess whether the Environmental Quality Objectives (EQO) (as defined by the EPA) have been met. The extent to which the EQO were met is assessed against the environmental quality criteria (EQC). Result of the summer TCM program provide a rigorous overview of water quality parameters in the vicinity of the Ocean Reef outlet. Data collected over the 3-month summer period, between December 2009 and March 2010, show a gradual decline in the concentration of nutrients with increasing distance, with nutrients typically reaching background levels 1000 m to 1500 m downstream of the outlet. Measures of chlorophyll *a* are a proxy measure of the volume of micro-alga present in the surface layers of the water column. Results of the summer TCM indicated that chlorophyll *a* concentrations were within the 20th and 80th percentile of background chlorophyll a concentrations. These data suggest that the effect of anthropogenic nutrients on micro-algal communities in the vicinity of the outlet was negligible at the time of sampling. Results of the summer TCM program indicated that each of the trial EQC for Maintenance of Ecosystem Integrity were met.

Contrasting results were obtained in the case of the EQO for Seafood Safe for Human Consumption. The EQC relevant to this EQO are the same as those used in the Annual Summer Water Quality Survey (reported separately in Oceanica 2010a). As reported in Oceanica (2010a), the EQG and EQS for thermo tolerant coliforms were exceeded within <250 m of the diffuser, but not at distances >250 m. The EQO Seafood Safe for Human Consumption is primarily concerned with the harvesting and consumption of raw shellfish (meaning filter feeding bivalve molluscs e.g. oysters, mussels, clams, pipis, scallops, cockles, and razor clams), and not other forms of seafood e.g. fin fish, abalone, crayfish etc. Human health concerns relating to consumption of shellfish are not considered an issue at Ocean Reef as there is no aquaculture within 250 m of the diffuser and no known harvesting of shellfish in the waters 1–2 km offshore.

Although the PLOOM program includes EQC for the EQO Seafood Safe for Human Consumption, it is emphasised that these criteria apply to shellfish (meaning filter feeding bivalve molluscs [e.g. oysters, mussels, clams, pipis, scallops, cockles, and razor clams; but not, abalone, crayfish, crabs, finfish etc]). Criteria developed to protect shellfish for human consumption do not apply to any other forms of aquatic life for human consumption as Health Authorities see filter feeding bivalves as the highest risk seafood type for human poisoning because:

1. The filter feeding strategy of bivalves means that trace contaminants in the source water can become highly concentrated in the gut of the organism;
2. The organism is generally eaten whole (including gut contents);
3. The organism may be eaten raw; and
4. There are natural as well as anthropogenic causes of poisoning.

In addition, any exceedance of the draft EQC for TTC is to be viewed conservatively, as the Department of Health (DoH) discourages the public from taking wild shellfish, recommending instead that shellfish are only consumed if harvested commercially and under strict monitoring programs. The Department of Health has further indicated that "It is impossible to guarantee the safety of eating wild shellfish without having a comprehensive monitoring program that tests the waterway concerned for harmful microorganisms and toxins" and has formally advised DEC that, in the absence of a full monitoring program, the application of the TTC criteria (EPA 2005) is insufficient to protect those who wish to collect and eat wild shellfish.

4.2. Whole of effluent toxicity tests

The WET testing (or direct toxicity assessment) program is relevant to the EQO for Ecosystem Integrity. Results obtained in October 2009, January 2010 and April 2010 indicate that 0 (nil) dilutions were required to achieve the NOEC (no effects concentration) and in

July 2009 only 1-fold dilution was required to achieve the NOEC on sea urchin fertilisation. These dilutions are well below the minimum initial dilution of 98-fold dilution at Outlet B (worst-case scenario). As the diffusers were shown to be achieving a minimum average initial dilution of 1:98 and 1:112, it was reasonably concluded that the risk to marine flora and fauna as a result of the combined TWW effluent was negligible.

4.3. TWW characterisation

The Treated Wastewater Characterisation program is relevant to the EQO for Ecosystem Integrity. Levels of toxicants and contaminants in the TWW are measured before and after the initial dilution process and compared to relevant guidelines for ecosystem protection. The principle contaminants of concern (ammonia, copper, zinc) remained similar to concentrations recorded in previous years. The near-field dilution calculations indicate that the plume of TWW rapidly dissipates and outside the immediate zone of influence. Following initial dilution, the water quality conditions required for high ecosystem protection were met.

4.4. Report cards and compliance summary

The EPA advocates the use of easy to understand methods of reporting the condition of the marine environment to stakeholders and the community, particularly through the use of "report cards". The aim of the report cards is to illustrate key findings from the PLOOM program in "report card" format.

It is important to note that the report cards do not present broader trends in ecosystem quality, nor do they assess levels of environmental impact associated with wastewater discharge. Perth's coastal waters are of very high quality and experience little in the way of adverse anthropogenic impacts, particularly in comparison to coastal areas adjacent to other major cities. Thus, the report cards focus on measures of water quality relative to local background reference values (i.e. very high quality). Note that any one exceedance of a background level is not indicative of broader ecosystem effects.

Where monitoring or investigative studies are not undertaken on an annual basis (for example the metals and pesticides surveys undertaken every three years), then the most recent information available are presented. Data used to complete the report cards are based largely on data collected as part of the summer Trial Compliance Monitoring Program the Comprehensive TWW analysis and the Annual Summer Water Quality Monitoring program (see Oceanica 2010a).

Table 4.1 2009/2010 report card summarising results of recent monitoring in the vicinity of the Ocean Reef outlets

Environmental Quality Indicators		Management Response	Comments
Physical & Chemical Measures	Chlorophyll-a		Summer Trial Compliance Monitoring results indicated no exceedance of the relevant EQGs, indicating a high degree of certainty that the associated EQO has been achieved. Green categories are assigned to chlorophyll-a, light attenuation, DO and salinity. None of these parameters were outside the range expected under typical conditions.
	Light Attenuation		
	Dissolved Oxygen		
	Salinity		
Direct Biological Measures	*Phytoplankton Biomass* Chlorophyll-a		Summer Trial Compliance Monitoring results indicated no exceedance of the EQG relevant to phytoplankton biomass

Environmental Quality Indicators		Management Response	Comments
Toxicants in TWW	Metals	Monitor	Concentrations of copper and zinc exceeded ANZECC/ARMCANZ *Guidelines* in the TWW prior to initial dilution. After 98-fold dilution with seawater in the mixing zone, concentrations reduced to below the ANZECC/ARMCANZ trigger values for high ecological protection.
	Pesticides	Monitor	On the day of sampling, concentrations of pesticides and herbicides were below the level of analytical detection. Concentrations of pesticides and herbicides met the ANZECC/ARMCANZ (2000) guidelines for high ecological protection.
	Herbicides	Monitor	
	WET tests	Monitor	Results of the 1hr sea urchin fertilisation tests indicate that between 0 and 1-fold dilutions of the secondary TWW were required to achieve the NOEC (no effects concentration). Based on these results it can reasonably be inferred that the ocean disposal of secondary TWW poses a minimal risk to the marine environment.

Legend

Management Response:

Monitor: Below guideline, continue monitoring

Below Reporting Limit: Below normal laboratory reporting limit

Investigate: Above guideline, investigate

Action: Above standard, management response

Research: Additional information required

Table 4.2 **2009/2010 report card summarising the monitoring results for the EQO of Seafood Safe for Human Consumption in the vicinity of the Ocean Reef outlets.**

Environmental Quality Indicators		**Management Response**	**Comments**
Biological Contaminants	Algal biotoxins	Monitor	Potentially toxic phytoplankton species were recorded at both compliance and reference sites, indicating that the presence of these species is due to regional forcings rather than that of TWW. All incidences of potentially toxic species recorded cell densities below the prescribed WASQAP trigger concentrations.
	Thermo-tolerant coliforms in shellfish	Monitor	Median thermo-tolerant coliform counts calculated for those sites >250 m from the diffuser were below the ANZECC/ARMCANZ (2000) Guideline of 70 CFU/100mL.

Legend
Management Response:

- **Monitor:** Below guideline, continue monitoring
- **Below Reporting Limit:** Below normal laboratory reporting limit
- **Investigate:** Above guideline, investigate
- **Action:** Above standard, management response
- **Research:** Additional information required

Table 4.3 2009/2010 report card summarising the monitoring results for the EQO of Clean Waters safe for Swimming and Boating around the Ocean Reef outlets.

Environmental Quality Indicators		Management Response	Comments
Biological contaminants	Faecal pathogens (swimming)	Monitor	Beaches in the vicinity of the Ocean Reef outlet are classified as safe for swimming according to the WA Health department http://www.healthyswimming.health.wa.gov.au/sites/
	Faecal pathogens (boating)	Monitor	Note: There are no primary (whole-body) contact recreational waters in the vicinity of the outlet: the water-body is therefore unclassified (National Health and Medical Research Council *Guidelines for Managing Risks in Recreational Water* 2005)
	Toxic Algae	Monitor	All incidences of these species recorded cell densities below the prescribed WASQAP trigger concentrations.
Chemical Contaminants in Seawater	Metals	Monitor	Although concentrations of copper and zinc exceeded the ANZECC/ARMCANZ guidelines for high ecological protection in the undiluted TWW, contaminant concentrations were shown to meet the ANZECC/ARMCANZ guidelines following a 98-fold dilution of TWW in the initial mixing zone,
	Pesticides	Below Reporting Limit	No pesticides or herbicides were detected at concentrations greater than the analytical limits of reporting.
	Herbicides	Below Reporting Limit	

Legend

Management Response:

Monitor: Below guideline, continue monitoring

Below Reporting Limit: Below normal laboratory reporting limit

Investigate: Above guideline, investigate

Action: Above standard, management response

Research: Additional information required

5. Acknowledgements

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Appendices on CD ROM:

Appendix A	**Analytical laboratories**
Appendix B	**Site Co-ordinates**
Appendix C	**National Measurement Institute**
Appendix D	**Dalcon Environmental Consultants**
Appendix E	**Ecotox Australasia Results**
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Appendix G	**Marine and Freshwater Research Laboratory**

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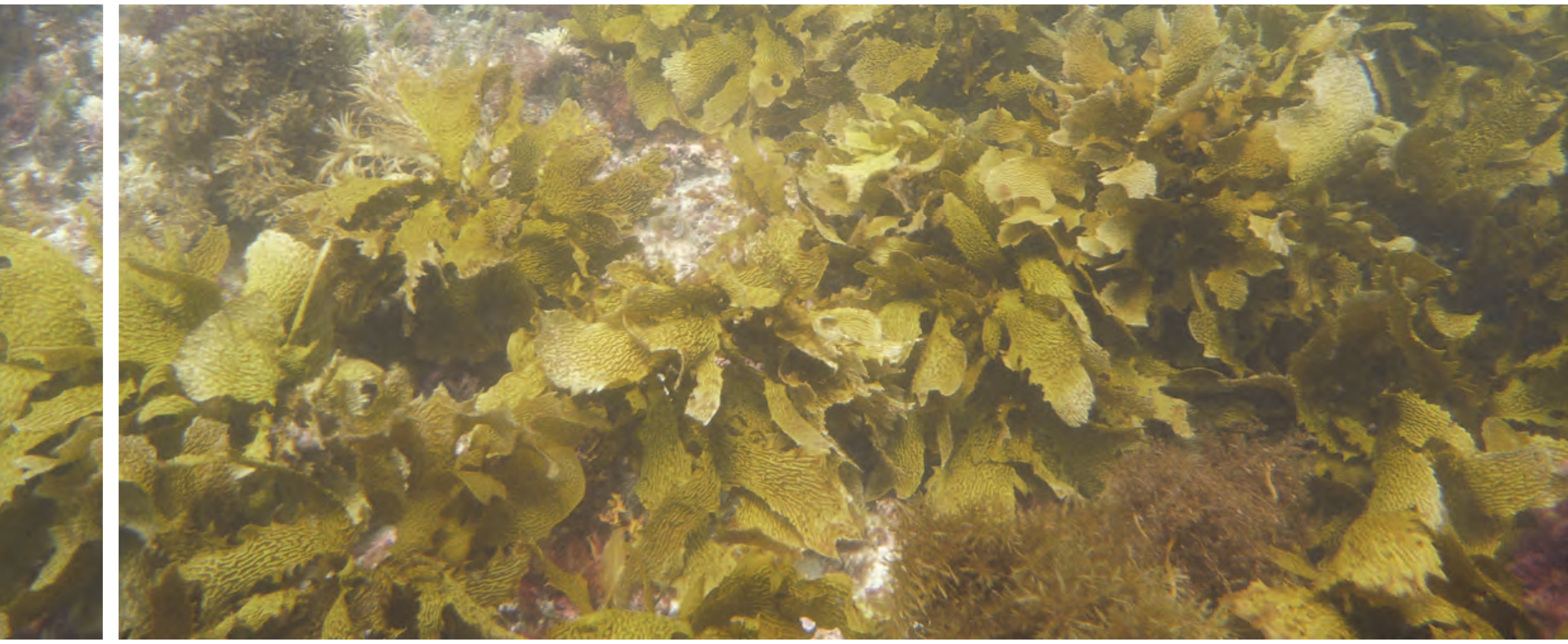
Appendix 2 PLOOM 6.2 2012 Summer Water Quality Survey



Perth Long-term Ocean Outlet Monitoring (PLOOM) Program

2012 Summer Water Quality Survey

Ocean Reef: 07 February 2012
Swanbourne: 24 January 2012
Sepia Depression: 21 February 2012

July 2012

Perth Long-term Ocean Outlet Monitoring (PLOOM) Program

2012 Summer Water Quality Survey

Ocean Reef: 07 February 2012

Swanbourne: 24 January 2012

Sepia Depression: 21 February 2012

Prepared for

Water Corporation of Western Australia

Prepared by

Oceanica Consulting Pty Ltd

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Revisions history

Revision	Author	DISTRIBUTION			REVIEW		
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A	D. Rivers	M. Lourey G. Shiell	1 x .docm	13/06/12	M. Lourey	Technical	14/06/12
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C	D. Rivers	M. Nener	1 x .pdf	26/06/12	M. Nener	Technical	05/07/12
0	D. Rivers	M. Nener Oceanica	4 x hardcopy 1 x .pdf 2 x hardcopy	12/07/12			
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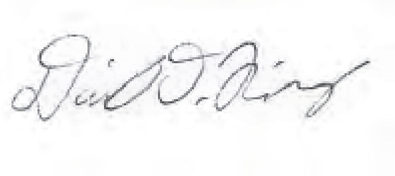

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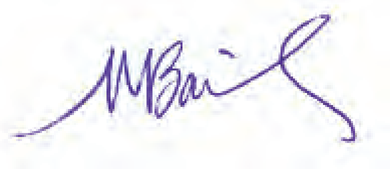

Director

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Cover

Main image: Macroalgae (*Ecklonia radiata*), Alkimos (Oceanica Consulting);

Minor images: Western rock lobster (*Panulirus cygnus*), Alkimos (Oceanica Consulting);
Nudibranch, Alkimos (Oceanica Consulting).

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Executive Summary

Background

The Water Corporation of Western Australia (Water Corporation) operates three major wastewater treatment plants (WWTP) in metropolitan Perth: Beenyup, Subiaco and Woodman Point. The bulk of the treated wastewater processed by the Beenyup, Subiaco and Woodman Point WWTPs is discharged to the sea through three ocean outlets located respectively at Ocean Reef, Swanbourne and Sepia Depression. The discharge of treated wastewater to the marine environment is undertaken according to licence conditions set by the Department of Environment and Conservation. The licence conditions include a requirement to undertake annual summer surveys of ocean water quality at Ocean Reef and Sepia Depression. For consistency, Water Corporation undertakes an identical survey at Swanbourne.

The objective of the annual water quality surveys is to measure the effects of treated wastewater on the marine environment, based on a one-day survey of water quality at each of the ocean outlets. This report presents the results of the summer water quality surveys conducted at Ocean Reef (07 February 2012), Swanbourne (24 January 2012) and Sepia Depression (21 February 2012).

Field Survey

Water samples were collected from 35 offshore sites (34 sites at Sepia Depression) within a rectangular sampling grid selected for the prevailing current conditions at each outlet on the day of the survey. At each location, samples were collected from the surface (1 m depth) and the bottom (approximately 2 m above the seafloor) of the water column. Nine shoreline sites located along the coast adjacent to each of the ocean outlets were also sampled. As per licence conditions, water samples were analysed for nutrients (total nitrogen, ammonium, nitrate+nitrite, total phosphorus and ortho-phosphate), chlorophyll *a* (as a measure of phytoplankton biomass) and microbiological indicators (thermo-tolerant coliforms and *Enterococci* spp.).

The key results from the 2012 summer water quality surveys are presented below.

Ocean Reef

The flow rate of the treated wastewater discharge on 07 February 2012 at Ocean Reef was 122.43 ML/d. The average initial dilution of the plume, calculated using the VPLUMES UM3 numerical model set-up to match the conditions at the time of sampling, was 1:77 for Outlet A and 1:64 for Outlet B. Median concentrations of surface water quality parameters within 250 m of the diffuser were: total nitrogen 140 µg/L, ammonium <3 µg/L, nitrate+nitrite 45 µg/L, total phosphorus 44 µg/L and ortho-phosphate 35 µg/L. Median concentrations in the surface waters beyond 250 m from the outlet were: total nitrogen 100 µg/L, ammonium <3 µg/L, nitrate+nitrite 6 µg/L, total phosphorus 16 µg/L and ortho-phosphate 5 µg/L. Offshore surface and bottom chlorophyll *a* concentrations ranged from <0.1 to 1.2 µg/L. The counts of microbiological indicators in surface and bottom waters showed slightly elevated counts in the immediate vicinity of the diffuser and a decline in counts away from the outlet, indicating rapid die-off of microbes.

Swanbourne

The flow rate of the treated wastewater discharge on 24 January 2012 at Swanbourne was 69.05 ML/d. The average initial dilution of the plume, calculated using the VPLUMES UM3 numerical model set-up to match the conditions at the time of sampling, was 1:67. Median concentrations of surface water quality parameters within 250 m of the diffuser were: total nitrogen 150 µg/L, ammonium <3 µg/L, nitrate+nitrite 30 µg/L, total phosphorus 36 µg/L and ortho-phosphate 23 µg/L. Median concentrations in the surface waters beyond 250 m from the outlet were: total nitrogen 120 µg/L, ammonium <3 µg/L, nitrate+nitrite <2 µg/L, total phosphorus 15 µg/L and ortho-phosphate 4 µg/L. Offshore surface and bottom chlorophyll *a* concentrations ranged from <0.1 to 0.8 µg/L. The counts of microbiological indicators in surface and bottom waters showed slightly elevated counts in the immediate vicinity of the diffuser and a decline in counts away from the outlet, indicating rapid die-off of microbes.

Sepia Depression

The rate of the treated wastewater discharge on 21 February 2012 at Sepia Depression from Woodman Point only[1] was 138.3 ML/d. The average initial dilution of the plume, calculated using the VPLUMES UM3 numerical model set-up to match the conditions at the time of sampling, was 1:139. Median concentrations of surface water quality parameters within 250 m of the diffuser were: total nitrogen 90 µg/L, ammonium <3 µg/L, nitrate+nitrite <2 µg/L, total phosphorus 9 µg/L and ortho-phosphate 2 µg/L. Median concentrations in the surface waters beyond 250 m from the outlet were: total nitrogen 130 µg/L, ammonium <3 µg/L, nitrate+nitrite 7 µg/L, total phosphorus 12 µg/L and ortho-phosphate 3 µg/L. Offshore surface and bottom chlorophyll *a* concentrations ranged from <0.1 to 0.6 µg/L. The counts of microbiological indicators in surface and bottom waters showed elevated counts in the immediate vicinity of the diffuser and a decline in counts away from the outlet, indicating rapid die-off of microbes.

Water Quality Criteria

There are presently no regulatory guidelines for the establishment of Environmental Quality Criteria appropriate for use in the vicinity of Perth's existing ocean outlets. However, to provide some context for the results, the values for each of the measured nutrient and primary production water quality parameters were compared with: (1) ANZECC/ARMCANZ (2000) default low-risk water quality guideline trigger values for southwest Australian inshore marine waters, and (2) 'reference values' calculated as the 80th percentile of values from reference sites, collected over 12 years via the PLOOM program.

Thermo-tolerant coliforms were compared with the environmental quality criteria for the maintenance of seafood safe for human consumption (based on those developed for Cockburn Sound [EPA 2005]) and *Enterococci* spp. were compared with the ANZECC/ARMCANZ (2000) water quality guideline. Results for these microbial indicators are summarised in the Report Cards below. The Report Cards compare the median counts for thermo-tolerant coliforms and *Enterococci* spp. in surface and bottom waters <250 m from the diffuser and >250 m from the diffuser, and in the case of *Enterococci* spp. at the Sepia Depression outlet, the median counts inside and outside the post-upgrade boundary, with the relevant guidelines.

<u>Ocean Reef</u>

In surface waters close to the diffusers (<250 m), the median concentration of ammonia and total nitrogen were below the ANZECC/ARMCANZ (2000) guidelines, whereas concentrations of nitrate+nitrite, ortho-phosphate and total phosphate were above the guidelines. The same pattern of nutrient concentration exceedances occurred in bottom waters close to the diffusers (<250 m), with the exception that total phosphate was below the guideline. At greater distances from the outlet (>250 m), the median concentrations of all nutrients in surface and bottom waters, except for nitrate+nitrite in surface waters, were below the ANZECC/ARMCANZ (2000) guidelines.

The median concentrations of nutrients were also compared against the 80th percentile of reference values. At all sites, the median concentrations of all nutrient parameters in surface and bottom waters were below the 80th percentile of reference values.

The median chlorophyll *a* concentrations for surface and bottom sites <250 m and >250 m from the diffuser, and shoreline sites, were below the ANZECC/ARMCANZ (2000) guideline. Median chlorophyll *a* concentrations were above the 80th percentile of reference values at all locations except for bottom waters <250 m from the diffuser.

The Report Card (Table ES.1) shows that at Ocean Reef, the guideline for the maintenance of seafood safe for human consumption was met for thermo-tolerant coliforms at surface and bottom sites >250 m from the diffuser. Thermo-tolerant coliform counts exceeded the guideline in surface and bottom waters at sites <250 m from the diffuser. Median counts of *Enterococci* spp. were below primary contact recreation criteria in all cases at Ocean Reef.

[1] *Point Peron WWTP flow not measured that day*

Shoreline sites at Ocean Reef met environmental quality criteria for the maintenance of seafood safe for human consumption for thermo-tolerant coliforms and met the primary contact recreation criteria for *Enterococci* spp..

Microbiological indicators are not expected to meet criteria inside the mixing zone. It is noted that despite exceeding the guideline for seafood safe for human consumption at Ocean Reef at sites <250 m from the diffuser, there are presently few, if any, suitable habitats for filter feeding shellfish in the vicinity of the ocean outlets. The risk to humans is therefore considered very low.

Table ES.1 Summer Water Quality Survey 2012 Report Card: Thermo-tolerant coliforms (TTC) and *Enterococci* spp

Outlet	Inside the mixing zone (Sites <250 m from diffuser)		Outside the mixing zone (Sites >250 m from diffuser)		Shoreline sites
	Surface	Bottom	Surface	Bottom	
TTC					
Enterococci spp.					

Notes: Environmental Quality Criteria:
1. Green = TTC: ≤14 coliforms/100 mL (seafood safe for human consumption)
   Enterococci spp.: ≤35 *Enterococci* spp./100 mL (1° contact recreation)
2. Red = TTC: >14 coliforms/100 mL (seafood safe for human consumption)
   Enterococci spp.: >35 *Enterococci* spp./100 mL (1° contact recreation)

Swanbourne

In surface waters close to the diffusers (<250 m), the median concentration of ammonia and total nitrogen were below the ANZECC/ARMCANZ (2000) guidelines, whereas concentrations of nitrate+nitrite, ortho-phosphate and total phosphate were above the guidelines. The same pattern of nutrient concentration exceedances occurred in bottom waters close to the diffusers (<250 m). At greater distances from the outlet (>250 m), the median concentrations of all nutrients in surface and bottom waters were below the ANZECC/ARMCANZ (2000) guidelines.

The median concentrations of nutrients were also compared against the 80th percentile of reference values. At all sites, the median concentrations of all nutrient parameters in surface and bottom waters were below the 80th percentile of reference values.

The median chlorophyll *a* concentrations for surface and bottom sites <250 m and >250 m from the diffuser were below the ANZECC/ARMCANZ (2000) guideline and the 80th percentile of reference values. The median chlorophyll *a* concentration at shoreline sites was also below the ANZECC/ARMCANZ (2000) guideline.

The Report Card (Table ES.2) shows that at Swanbourne, the guideline for the maintenance of seafood safe for human consumption was met for thermo-tolerant coliforms at surface and bottom sites >250 m from the diffuser, and at bottom sites <250 m from the diffuser. Thermo-tolerant coliform counts exceeded the guideline in surface waters at sites <250 m from the diffuser. Median counts of *Enterococci* spp. were below primary contact recreation criteria in all cases at Swanbourne.

Shoreline sites at Swanbourne met environmental quality criteria for the maintenance of seafood safe for human consumption for thermo-tolerant coliforms and met the primary contact recreation criteria for *Enterococci* spp.

Microbiological indicators are not expected to meet criteria inside the mixing zone. It is noted that despite exceeding the guideline for seafood safe for human consumption at Swanbourne at surface sites <250 m from the diffuser, there are presently few, if any, suitable habitats for filter feeding shellfish in the vicinity of the ocean outlet. The risk to humans is therefore considered very low.

Table ES.2 Summer Water Quality Survey 2010 Report Card: Thermo-tolerant coliforms (TTC) and *Enterococci* spp

Outlet	Inside the mixing zone (Sites <250 m from diffuser)		Outside the mixing zone (Sites >250 m from diffuser)		Shoreline sites
	Surface	Bottom	Surface	Bottom	
TTC					
Enterococci spp.					

Notes: Environmental Quality Criteria:
1. Green = TTC: ≤14 coliforms/100 mL (seafood safe for human consumption)
   Enterococci spp.: ≤35 *Enterococci* spp./100 mL (1° contact recreation)
2. Red = TTC: >14 coliforms/100 mL (seafood safe for human consumption)
   Enterococci spp.: >35 *Enterococci* spp./100 mL (1° contact recreation

Sepia Depression

In surface and bottom waters, close to the diffusers (<250 m) and at a distance (>250 m), the median concentrations of all nutrient parameters were below the ANZECC/ARMCANZ (2000) guidelines. The median concentrations of all nutrient parameters were also below the 80th percentile of reference values, with the exception of nitrate+nitrite in surface waters >250 m from the diffuser. These low nutrient concentrations provide evidence that the discharge plume was restricted to within approximately 250 m of the diffuser.

At Sepia Depression, the median chlorophyll *a* concentrations for surface and bottom sites <250 m and >250 m from the diffuser were below the ANZECC/ARMCANZ (2000) guideline and the 80th percentile of reference values. The shoreline median chlorophyll *a* concentration was above the guideline value.

The Report Card (Table ES.3) shows that at Sepia Depression, the guideline for the maintenance of seafood safe for human consumption was met for thermo-tolerant coliforms at surface and bottom sites >250 m from the diffuser, and at surface sites <250 m from the diffuser. Thermo-tolerant coliform counts exceeded the guideline in bottom waters at sites <250 m from the diffuser. Median counts of *Enterococci* spp. exceeded the ANZECC/ARMCANZ (2000) guideline for primary contact recreation at surface sites within the post-upgrade boundary, but were below the guideline at bottom sites inside the post-upgrade boundary and at surface and bottom sites outside the post-upgrade boundary.

Shoreline sites at Sepia Depression met environmental quality criteria for the maintenance of seafood safe for human consumption for thermo-tolerant coliforms and met the primary contact recreation criteria for *Enterococci* spp.

Microbiological indicators are not expected to meet criteria inside the mixing zone. It is noted that despite exceeding the guideline for seafood safe for human consumption at Sepia Depression at surface and bottom sites <250 m from the diffuser, there are presently few, if any, suitable habitats for filter feeding shellfish in the vicinity of the ocean outlets. The risk to humans is therefore considered very low.

Table ES.3 Summer Water Quality Survey 2010 Report Card: *Enterococci* spp

Outlet	Inside the mixing zone Sites <250 m from diffuser		Inside the mixing zone Sites >250 m from diffuser		Shoreline sites
	Surface	Bottom	Surface	Bottom	
TTC					
Enterococci spp.	Sites inside post upgrade boundary		Sites outside post upgrade boundary		Shoreline sites
	Surface	Bottom	Surface	Bottom	

Notes: Environmental Quality Criteria:
1. Green= TTC: ≤14 coliforms/100 mL (seafood safe for human consumption)
   Enterococci spp.: ≤ 35 *Enterococci* spp./100 mL (1° contact recreation)
2. Red= TTC: >14 coliforms/100 mL (seafood safe for human consumption)
   Enterococci spp.: > 35 *Enterococci* spp./100 mL (1° contact recreation)

Conclusions

The 2012 summer water quality report provides a snapshot of marine water quality conditions, on individual sampling days during summer, near three ocean outlets. Results indicated that the treated wastewater plumes dissipated away from the diffusers and that the region of influence was localised within the immediate vicinity (<250 m) of each of the outlets. The results of this report, in conjunction with other PLOOM components (i.e. trial compliance monitoring), found no evidence that the treated wastewater from any of the three outlets are having detectable adverse effects on water quality conditions in the surrounding area.

1. Introduction

1.1 Background

The Water Corporation of Western Australia (Water Corporation) operates three major wastewater treatment plants (WWTPs) within the Perth metropolitan area, located at Beenyup, Subiaco and Woodman Point (Figure 1.1). The bulk of the treated wastewater is discharged to the sea through three ocean outlets located at Ocean Reef, Swanbourne and Sepia Depression (Figure 1.1).

The Beenyup and Subiaco WWTPs employ an activated sludge treatment process with high nitrogen removal capacity. The Beenyup WWTP discharges advanced secondary treated wastewater via two outlets at Ocean Reef. The two outlets are located in approximately 10 m of water and have overall lengths of 1.6 km (outlet A) and 1.8 km (outlet B) and diffuser lengths of 195 m each. The Subiaco WWTP discharges secondary treated wastewater via an outlet at Swanbourne, which is located in approximately 11 m of water and has an overall length of 1.1 km and a diffuser length of 91 m.

From July 2007, the Sepia Depression Ocean Outlet Landline (SDOOL) has been used to discharge both treated wastewater and industrial effluent that was previously discharged to Cockburn Sound. The Woodman Point WWTP was upgraded in 2002 to a secondary treatment plant using activated sludge treatment. Although secondary treated domestic wastewater accounts for the majority of the discharge (approximately 85% of the total), a small amount of primary treated wastewater is also discharged (approximately 10% of the total discharge flow). The remainder of the flow is from industry, the Jervoise Bay Groundwater Recovery Scheme (JBGRS) and the Kwinana Wastewater Reclamation Plant (KWRP). The Sepia Depression ocean outlet is located in approximately 20 m of water and has an overall (offshore) length of 4.2 km and a diffuser length of 324 m.

The operation of each of the WWTPs in Perth's metropolitan region and the discharge of treated wastewater to the marine environment is conducted under licence conditions set by the Department of Environment and Conservation (DEC) (Appendix A). Licence conditions include a requirement to undertake annual summer surveys of ocean water quality at Ocean Reef and Sepia Depression. However, for consistency, Water Corporation undertakes an identical survey at Swanbourne. The objective of the annual water quality surveys is to measure the effects of treated wastewater on the marine environment, based on a one-day survey of water quality at each of the ocean outlets.

Water quality parameters (Table 1.1) are determined annually at 35 offshore sites (34 sites at Sepia Depression) within a rectangular sampling grid appropriate for the prevailing flow conditions on the day of the survey (Appendix B). Nine shoreline sites are located along the coast adjacent to each of the outlets.

Table 1.1 Water quality parameters for summer surveys of ocean outlets

Nutrients	Phytoplankton biomass	Microbial indicators
Total phosphorus Ortho-phosphate Total nitrogen Ammonium nitrogen Nitrate+nitrite nitrogen	Chlorophyll *a* Phaeophytin	Thermo-tolerant coliforms *Enterococci* spp.

The purpose of the annual summer water quality surveys is to:

- provide data on water quality in the vicinity of the outlets, to ensure compliance with the licence conditions;
- assess the performance of each outlet by determining the dilution and dispersion characteristics of the treated wastewater;
- examine the extent of influence of the plumes;
- allow for the ongoing assessment of the environmental impact of the wastewater discharge in relation to the marine water quality and beneficial uses of the area; and
- allow for the ongoing assessment of the level of public health risk associated with ocean disposal of treated wastewater.

The Water Corporation has conducted annual water quality surveys in the vicinity of the outlets since their construction. The annual summer water quality surveys represent one of the monitoring components of Perth's Long-term Ocean Outlet Monitoring (PLOOM) program implemented in 1996 by the Water Corporation. The PLOOM Program was developed to determine the impacts of treated wastewater discharges on the marine environment in terms of nutrients, bacteria, metals and organic contaminants, and to assess whether environmental and public health values are being maintained (DALSE 2004a).

This report presents the results of the 2012 summer water quality surveys conducted in the marine environment of the three ocean outlets: Ocean Reef (07 February 2012), Swanbourne (24 January 2012) and Sepia Depression (21 February 2012).

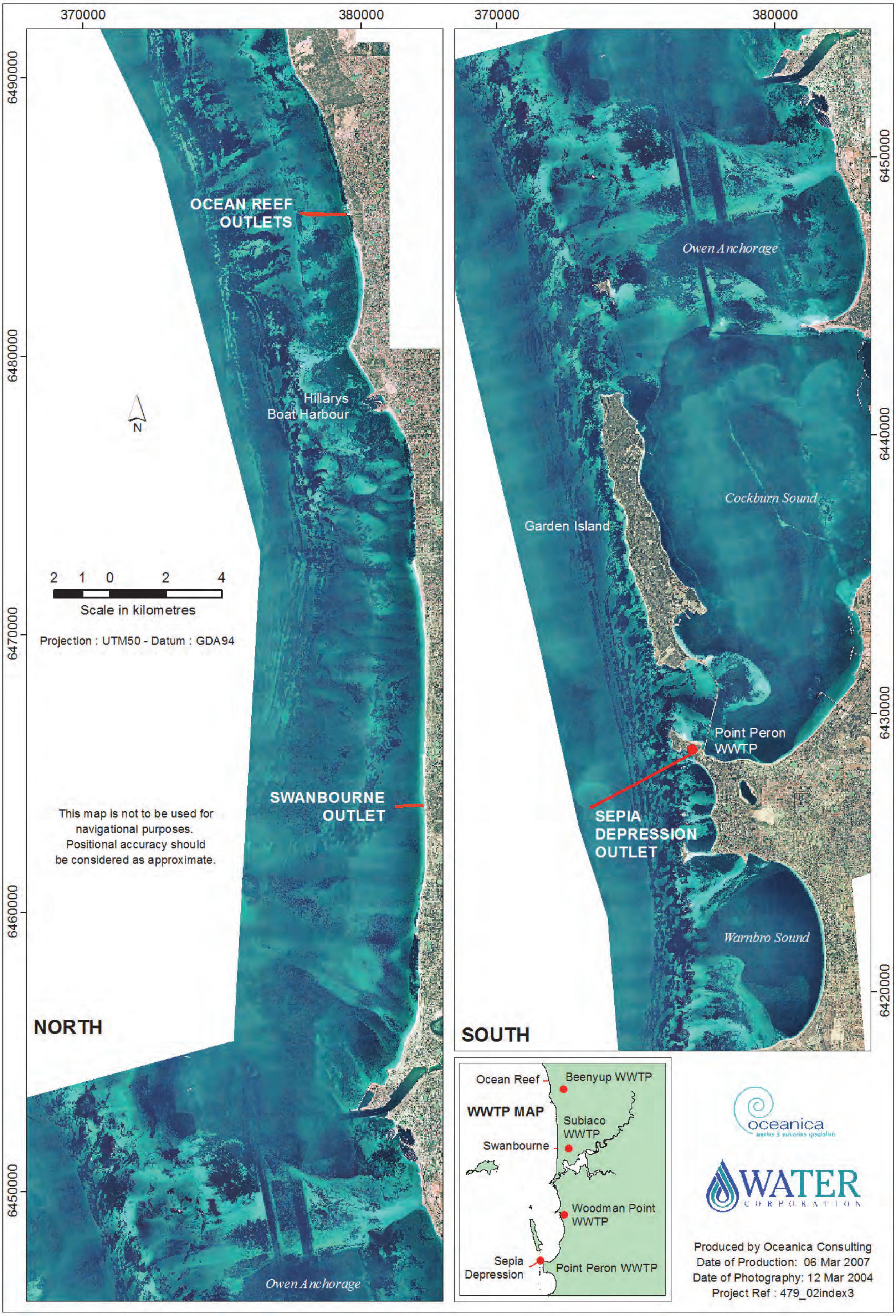

Figure 1.1 Perth coastal waters showing location of treated wastewater ocean outlets

1.2 Water quality criteria for Perth coastal waters

1.2.1 An environmental quality management framework for Perth's coastal waters

In 2000, the Environmental Protection Authority (EPA) published *Perth's Coastal Waters – Environmental Values and Objectives*, a working document aimed at establishing an Environmental Quality Management Framework (EQMF) for Perth's coastal waters. The document identified Environmental Values and Objectives relevant to Perth's coastal waters, and outlined the EPA's intentions to develop Environmental Quality Criteria (EPA 2000). Four Environmental Values were identified: Ecosystem Health (an ecological value), Fishing and Aquaculture (a social value), Recreation and Aesthetics (a social value) and Industrial Water Supply (a social value). Seven Environmental Quality Objectives (EQOs) were developed to protect these Environmental Values. The relevant EQOs are:

EQO1: Maintenance of ecosystem integrity

To maintain a healthy and diverse ecosystem. Over 99% of Perth's coastal waters have been designated as having a high level of protection (E2) with less than 1% designated as moderate (E3) or low (E4) levels of protection. The areas designated with a moderate (E3) level of protection, where moderate changes from natural variation are identified as the limit of acceptable change, include those areas around the discharge points of the Ocean Reef and Swanbourne metropolitan ocean outlets (EPA 2000). EPA (2000) includes appendices showing notional levels of ecological protection around each of the metropolitan ocean outlets (see Figure 3, Map 2, Map 3 and Map 4; EPA 2000). While this document still applies at Ocean Reef and Swanbourne, it was superseded at Sepia Depression through the publication of Ministerial Statement 665 (28 October 2004). The levels of ecological protection were updated in this document such that area within 100 m of the Sepia Depression outlet is a low protection area, while the area outside 100 m is a high protection area.

EQO2: Maintenance of seafood for human consumption, EQO3: Maintenance of aquaculture, EQO4: Maintenance of primary contact recreation values and EQO5: Maintenance of secondary contact recreation values

To support social uses such as fishing, swimming and boating. These EQOs will be enforced throughout Perth's coastal waters with the exception of small areas surrounding the three metropolitan ocean outlets. The EPA has appended maps to *Perth's Coastal Waters – Environmental Values and Objectives* to provide an indication for each of the metropolitan ocean outlets of the boundaries identified by the EPA for S2 areas where EQO2 will not apply (i.e. seafood collected from these waters may be unsafe to eat) and S3 areas where EQO4 will not apply (i.e. water quality may not be suitable for swimming) (see Figure 4, Map 2, Map 3 and Map 4; EPA 2000).

EQO6: Maintenance of aesthetic values and EQO7: Maintenance of industrial water supply values

To maintain the attractiveness of the environment and maintain industrial water supplies. These EQOs will apply throughout Perth's coastal waters.

In 2003, a Memorandum of Understanding (MOU) was developed between five relevant stakeholders, each with an interest in the management of treated wastewater discharges to the Marmion Marine Park. According to the MOU (Anon 2003), the next phase in the establishment of an EQMF was to develop a Schedule outlining the Environmental Quality Criteria (EQC)[2], their associated measurement and interpretation protocols, and the boundaries of the areas where the different EQOs will apply. On the 6 May 2009, the EPA advised that the development of the proposed Schedule in support of the MOU is no longer an action item (Office of the Environmental Protection Authority [OEPA] pers. comm.)[3]. Hence, there are presently no regulatory guidelines for establishing Environmental Quality Criteria

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[2] *Environmental Quality Criteria are benchmarks for monitoring used to guide and assess the results of monitoring programs, specifically to identify when and where Environmental Quality Objectives are being met or not met. There are two types of Environmental Quality Criteria: Environmental Quality Guidelines and Environmental Quality Standards.*

[3] *Previously known as Environmental Protection Authority Services Unit (EPASU)*

appropriate for use in the vicinity of Perth's existing ocean outlets. Nonetheless, Water Corporation in conjunction with Oceanica has developed EQC for use with Sepia Depression Ocean Outlet Landline (SDOOL) and the Alkimos Wastewater Treatment Plant Marine Environmental Management Plan. Although the SDOOL EMP has yet to receive formal approval, the Alkimos EMP was approved on 28 July 2010.

1.2.2 ANZECC/ARMCANZ guidelines for fresh and marine water quality

Physical and chemical stressors

In the absence of Environmental Quality Guidelines (EQGs) or Environmental Quality Standards (EQSs), the ANZECC/ARMCANZ (2000) Guidelines for Fresh and Marine Water Quality include default trigger values, which are low-risk water quality guidelines for physical and chemical stressors. These guidelines are applicable to southwest Australian 'inshore marine waters', which includes the coastal waters off metropolitan Perth. To provide some context for the results from the annual summer water quality surveys, it is useful to compare the values for each of the measured water quality parameters with the default water quality guidelines identified in ANZECC/ARMCANZ (2000). According to the guidelines, an exceedance of a trigger value should be regarded as an 'early warning' mechanism; trigger values are not intended as a means of assessing 'compliance'.

The default water quality guidelines for 'slightly disturbed' marine inshore waters in the southwest Australia region are shown in Table 1.2. The ANZECC/ARMCANZ (2000) guidelines define 'slightly-to-moderately disturbed systems' as those "ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity" and where the "biological communities remain in a healthy condition and ecosystem integrity is largely retained". The ANZECC/ARMCANZ (2000) guidelines identify marine ecosystems lying immediately adjacent to metropolitan areas as potential examples of slightly-to-moderately disturbed systems. Inshore waters are defined in the ANZECC/ARMCANZ (2000) guidelines as "coastal lagoons (excluding estuaries) and embayments and waters less than 20 m depth". The marine environments of the three metropolitan ocean outlets can be classed as 'inshore marine'. The Ocean Reef and Swanbourne outlets discharge to waters of approximately 10 m depth and the Sepia Depression outlet discharges into a natural channel which is approximately 20 m deep, bounded offshore by a shallower reef (approximately 15 m deep).

Table 1.2 Summary of default water quality guidelines (trigger values) applicable to southwest Australian coastal waters as defined in ANZECC/ARMCANZ (2000)

Parameter	ANZECC/ARMCANZ (2000) Inshore marine waters
Total phosphorus (µg/L)	20 (1)
Ortho-phosphate (µg/L)	5 (1)
Total nitrogen (µg/L)	230
Ammonium (µg/L)	5
Nitrate+nitrite (µg/L)	5
Chlorophyll *a* (µg/L)	0.7

Note:
1. The ANZECC/ARMCANZ (2000) guidelines shown are recommended for summer (low rainfall) periods.

Comparison of water quality data from previous summer surveys (DALSE 2002, 2003, 2004b; Oceanica 2005, 2006, 2007c, 2008, 2009, 2010, 2011) with the ANZECC/ARMCANZ (2000) default water quality guidelines has indicated that levels of some of the measured 'background' water quality parameters are naturally higher than the guidelines. For example, it has been the general trend for concentrations of ortho-phosphate, measured at sites located away from the influence of the outlets, to be above the guideline values. Conversely, in the case of the chlorophyll *a*, it is likely that the ANZECC/ARMCANZ (2000) guideline is relatively high compared to the background levels in Perth coastal waters.

The ANZECC/ARMCANZ (2000) guidelines recommend, for naturally occurring stressors, that data from appropriate local reference systems should be used to determine the low-risk trigger values for each key water quality parameter. Data collected over two years of monthly sampling are generally regarded as sufficient to indicate ecosystem variability and can be used to derive trigger values. Where few data are available (e.g. few reference sites or sampling times) the guidelines recommend that a single trigger value should be derived from the available data as an interim measure. The guidelines recommend defining trigger values for physical and chemical stressors for slightly-to-moderately disturbed ecosystems in terms of the 80th and/or 20th percentile values[4] obtained from an appropriate reference system. For stressors that cause problems at high concentrations (e.g. nutrients), the 80th percentile of the reference distribution represents the low-risk trigger value.

In the future, it is expected that EQGs and EQSs for Perth's coastal waters may be informed, in part, by the substantial dataset collected through the PLOOM Program.

Reference values

In this report 'reference values' for each nutrient and primary production water quality parameter have been derived as a measure of the background conditions for each outlet (Table 1.3). Separate reference values have been derived for surface and bottom waters of the marine environment. These reference values were calculated as the 80th percentile of the 'background concentrations' collated from the summer water quality surveys undertaken over the last 12 years (1999-2012)[5]. Background concentrations are the surface and bottom concentrations measured at sampling sites located upstream of the outlet at the time of each summer water quality survey. Note that the 80th percentile of reference values has not been calculated for the shoreline sites.

Table 1.3 Median and 80th percentile values for nutrient and primary production water quality parameters in the marine environment for each of the ocean outlets

	Total phosphorus (µg/L)	Ortho-phosphate (µg/L)	Total nitrogen (µg/L)	Ammonium (µg/L)	Nitrate+ nitrite (µg/L)	Chlorophyll *a* (µg/L)
Ocean Reef–surface waters						
Median	25	7	120	1.5	8	0.2
80th percentile	35	8	140	5.0	11	0.4
Ocean Reef–bottom waters						
Median	23	7	120	1.5	9	0.2
80th percentile	35	8	135	4.9	11	0.5
Swanbourne–surface waters						
Median	17	5	120	1.5	1	0.3
80th percentile	33	6	150	3.0	3	0.5
Swanbourne–bottom waters						
Median	17	5	120	1.5	2	0.4
80th percentile	34	6	157	3.0	3	0.5
Sepia Depression–surface waters						
Median	20	5	113	1.5	3	0.4
80th percentile	32	6	160	5.7	5	0.5
Sepia Depression–bottom waters						
Median	18	5	110	1.5	3	0.4
80th percentile	32	6	150	4.0	3	0.6

Note:
1. Values in this table are rounded

In ANZECC/ARMCANZ (2000), the recommended approach for physical and chemical stressors is that the median concentration of independent samples taken at a test site should be compared with the relevant guideline values. Where suitable reference site data are available, the comparison should be against the 80th (or 20th) percentile of the reference site data. The summer water quality surveys have not been specifically designed to provide information suitable for these types of comparisons. For contextual purposes only, in this report, the water quality parameters measured for each of the individual sampling sites

[4] *A percentile is a value on a scale of one hundred that indicates the percent of a distribution that is equal to or below it. For example, the 80th percentile is greater than or equal to 80% of all values – conversely, 80% of all values are less than or equal to the 80th percentile.*

[5] *These years were selected on the basis that the same laboratory (MAFRL) has been responsible for undertaking water quality analysis over this period, thereby minimising the potential for between-laboratory differences within the data set (see DALSE 2004a).*

within the sampling grid are compared with the ANZECC/ARMCANZ (2000) guidelines and the 80th percentile of reference values. In addition, the median concentrations of each of the water quality parameters measured were calculated for sites located within 250 m of the diffuser and greater than 250 m from the diffuser. This distance nominally represents the region encapsulating the initial stages of treated wastewater mixing, as indicated by historical initial dilution modelling.

Water quality guidelines for recreational waters

The ANZECC/ARMCANZ (2000) water quality guidelines for microbiological characteristics for primary and secondary contact recreation in marine waters are listed in Table 1.4. At Sepia Depression, licence conditions previously required counts of *Enterococci* spp. to meet guidelines for primary contact recreation outside a prescribed boundary; inside the post-upgrade boundary, primary contact was excluded (Figure 5.22). The boundary was updated in 2002 with a smaller exclusion area derived using computer modelling of dispersion and die-off of faecal streptococci.

The counts of *Enterococci* spp. from the summer water quality survey at Sepia Depression are compared against the relevant ANZECC/ARMCANZ (2000) guidelines. For consistency, the ANZECC/ARMCANZ (2000) microbiological guidelines for *Enterococci* spp. have been applied at all three of Perth's ocean outlets. The National Health and Medical Research Council (NHMRC) *Guidelines for Managing Risks in Recreational Water* (2005) has moved away from the traditional regulatory schemes for microbial quality of recreational water. The NHMRC instead advocates the use of a combination of a qualitative risk grading of faecal loading in a recreational water environment, supported by direct and regular measurement of appropriate faecal indicators.

Table 1.4 ANZECC/ARMCANZ (2000) water quality guidelines for microbiological characteristics for primary and secondary contact recreation in marine waters

***Enteroccocci* spp. (1)**	**ANZECC/ARMCANZ (2000) Marine waters**
Primary contact recreation	35 MPN/100 mL
Secondary contact recreation	230 MPN/100 mL

Notes:
1. ANZECC/ARMCANZ (2000) guidelines for *Enterococci* spp. are provided for primary and secondary contact recreation and are based on median values and maximum number in any one sample of 60–100 organisms/100 mL (primary) or 450–700 organisms/100 mL (secondary). The *Enterococci* spp. are the major component of the faecal streptococci group.
2. Counts of *Enterococci* spp. are shown as Most Probable Number (MPN)/100 mL

Source: ANZECC/ARMCANZ (2000)

In this report, the median counts of *Enterococci* spp. were calculated for sites located within 250 m of the diffuser and greater than 250 m from the diffuser at Ocean Reef and Swanbourne. At Sepia Depression, the median counts of *Enterococci* spp. were calculated for those sites inside and outside the post-upgrade boundary.

It should be noted that the microbiological water quality guidelines are not intended to be used as the basis for establishing conditions for the discharge of treated wastewaters. Public health concerns relating to primary (whole-body) contact recreation are not considered to be an issue because there is no recreational use of the waters within the vicinity of the ocean outlets. The NHMRC (2005) *Guidelines for Managing Risks in Recreational Water* identifies that the first step in the framework for microbial quality assessment of recreational waters is the question "Is the water body used for contact recreation?" If the response is 'No', the water-body should remain unclassified, to be reassessed if use changes.

1.2.3 Environmental quality criteria for the maintenance of seafood safe for human consumption

The EPA (2005) environmental quality criteria for maintenance of seafood safe for human consumption are listed in Table 1.5. The Environmental Quality Guidelines (EQGs) are a measure of the potential threat to human health. The Environmental Quality Standards (EQSs) are intended to "confidently predict whether there is a significant risk to the health of human consumers" (EPA 2005). The important subtext is that these criteria were developed for Cockburn Sound where aquaculture or commercial and amateur harvesting of wild seafood species occurs. They were not intended to be used as the basis for establishing conditions for the discharge of treated wastewaters to Perth's coastal waters. In addition, the EQO Seafood Safe for Human Consumption is primarily concerned with the harvesting and consumption of raw shellfish (meaning filter feeding bivalve molluscs, e.g. oysters, mussels, clams, pipis, scallops, cockles, and razor clams), and not other forms of seafood (e.g. fin fish, abalone, crayfish, etc.). Human health concerns relating to consumption of shellfish are not considered an issue at the outfalls as there is no aquaculture within 250 m of the diffusers and no known harvesting of shellfish in the waters 1–2 km offshore. In addition, any exceedance of the EQC for thermo-tolerant coliforms (TTC) is to be viewed conservatively. The Department of Health (DoH) discourages the public from taking wild shellfish, recommending instead that shellfish are only consumed if harvested commercially and under strict monitoring programs. The DoH has further indicated that "It is impossible to guarantee the safety of eating wild shellfish without having a comprehensive monitoring program that tests the waterway concerned for harmful microorganisms and toxins" and has formally advised DEC that, in the absence of a full monitoring program, the application of the TTC criteria (EPA 2005) is insufficient to protect those who wish to collect and eat wild shellfish.

Table 1.5 Environmental quality criteria for the maintenance of seafood safe for human consumption

Thermo-tolerant coliforms	EPA (2005)
EQG [(1)]	14 CFU/100 mL
EQS [(2)]	70 CFU/100 mL

Notes:
1. The EQG is based on median values with no more than 10% of the samples exceeding 21 CFU/100 mL.
2. The EQS is based on median values with no more than 10% of the samples exceeding 85 CFU/100 mL.
3. Concentrations of thermal-tolerant coliforms are shown as Colony Forming Units (CFU)/100 mL

Source: EPA (2005)

2. Survey Methods

2.1 Wind, wave and tide conditions

Information on the prevailing wind conditions (wind speed and direction) at Ocean Reef[6], Swanbourne[7] and Sepia Depression[8] immediately prior to and over the duration of each summer water quality survey was provided by the Bureau of Meteorology.

Information on the significant wave height and wave period was provided by the Department of Transport (DoT) from a wave rider buoy located southwest of Rottnest Island in a water depth of 48 m. Attenuation of the wave energy, due to refraction and diffraction processes around the offshore reefs, will cause the wave height near the outlets to be considerably lower than that observed offshore of Rottnest Island. Water surface elevations were provided by the DoT from a gauge in Fremantle Fishing Boat Harbour.

This information was used to describe the prevailing wind, wave and tide conditions at each location immediately prior to and during the summer water quality surveys. The prevailing flow conditions determine which sampling grid was used for the summer water quality survey at each outlet (Section 2.5; DAL 2001).

2.2 Discharge from the outlets

Flow-proportionate composite samples of treated wastewater were collected from each of the WWTPs over the 24-hour period prior to and during the annual summer water quality survey at each outlet and the characteristics of the treated wastewater samples determined.

2.3 Surface drogue movement

At the commencement of the summer water quality survey at each outlet, a surface drogue was released over the centre of the operational outlet diffuser (Outlet B for Ocean Reef). The location of the drogue was recorded at intervals[9] throughout the summer water quality survey using an on-board global positioning system (GPS). Surface drogue tracking provides an estimate of mean surface current and this information is used in the initial dilution modelling (Section 2.4).

2.4 Initial dilution modelling

2.4.1 Model

The VPLUMES program is an initial dilution model accepted for use by the United States Environmental Protection Agency (http://www.epa.gov/). The initial dilution phase occurs from the point of discharge to a point of maximum rise or fall (e.g. reaching the surface of the water body) of the plume.

These numerical models are designed to model the near-field behaviour of plumes; that is, the behaviour in the region where the plume first jets into the surrounding waters and then (in the case of positively buoyant plumes) rises and mixes with the surrounding waters. These models capture simple features of the surrounding environment such as depth at point of discharge, net current and wind speed. However, because the models do not take into account broader scale bathymetry and hydrodynamics, they generally do not accurately predict the far-field behaviour; that is, the behaviour after the plume has reached the surface or is fully mixed in the water column. Three-dimensional baroclinic or barotropic hydrodynamic models are required to better estimate far-field behaviour.

The UM3 initial dilution model, which is part of the Visual Plumes (VPLUMES) suite of dilution models (Frick et al. 2001), was applied to the discharges from each outlet for ambient conditions and treated wastewater flows at the time of the surveys.

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[6] *Bureau of Meteorology Site Number 009214*

[7] *Bureau of Meteorology Site Number 009215*

[8] *Bureau of Meteorology Site Number 009256 (Garden Island)*

[9] *At Sepia Depression, only the GPS points for drogue release and pick-up locations were recorded*

2.4.2 Model set-up

The model set-up parameters selected to represent the outlet diffuser, flows and ambient conditions at Ocean Reef, Swanbourne and Sepia Depression at the time of the surveys are presented in Table 2.1.

Table 2.1 Initial dilution model set-up parameters for the ocean outlets at Ocean Reef, Swanbourne and Sepia Depression

Diffuser characteristics	**Ocean Reef (outlet A) 07/02/2012**	**Ocean Reef (outlet B) 07/02/2012**	**Swanbourne 24/01/2012**	**Sepia Depression 21/02/2012**
Port diameter (1)	0.125 m	0.16 m	0.17 m (1)	0.135 m
Port elevation	0.76 m	0.84 m	1 m	0.75 m
Number of open ports	50 open (50 total)	48 open (48 total)	20 open (20 total)	68 open (68 total)
Port spacing (2)	4 m	4 m	5 m	4.65 m
Port orientation	Alternating horizontal	Alternating horizontal	Tee discharge horizontal, aligned N-S	Alternating horizontal
Water depth	10 m	10 m	11 m	20 m
Ambient conditions at time of sampling				
Temperature (3)	Surface: 23.16°C Bottom: 22.85°C		Surface: 25.1°C Bottom: 24.4°C	Surface: 23.8°C Bottom: 23.7°C
Salinity (3)	Surface: 35.63 Bottom: 35.70		Surface: 36.2 Bottom: 36.1	Surface: 36.2 Bottom: 36.5
Surface current (based on drogue)	0.0452 m/s Bearing 283.78°		0.1011 m/s Bearing 269.22°	0.1369 m/s Bearing 354.24°
Discharge characteristics				
Flow	122.43 ML/d	122.43 ML/d	69.05 ML/d	138.26 ML/d
Temperature	28.8°C	28.8°C	27.0°C	25.0°C
Salinity	0.40	0.40	0.662	0.493

Notes:

1. Equivalent diameter for a 0.15 x 0.15 m square section.
2. In the case of alternate ports, they are all assumed to be on one side of the diffuser and 'port spacing' is the distance between each port irrelevant of the actual position on either side of the diffuser. For T-shaped risers, it is assumed that all ports are on the one side of the diffuser with the spacing equal to half of the spacing between the risers.
3. Ambient conditions for Ocean Reef have been taken from site 55; for Swanbourne at site 53; and for Sepia Depression at site 55.

The surface drogue tracking at each location provides an accurate estimate of mean surface current with good agreement among velocities calculated from the nine observations taken over the duration of each of the water quality surveys[10]. The mean direction[11] of the surface current was also estimated from the surface drogue tracking locations. The mean surface currents were used to synthesise vertical velocity profiles based on the findings of Pattiaratchi et al. (1995) who installed current meters at 3 m and 7 m above the seabed at the Ocean Reef outlet and at 3 m and 13 m above the seabed near the Sepia Depression outlet. The difference between the mean currents at these depths was used as an indication of a likely linear decrease in current speeds from the surface to the seabed[12]. At Ocean Reef it was estimated that the current speed dropped by approximately 1.2% per metre depth and at Sepia Depression it was estimated that the current speed dropped by approximately 3.8% per metre depth. There were no current measurements undertaken at the Swanbourne outlet as part of the Pattiaratchi et al. (1995) study, so the difference between mean currents at Ocean Reef was also used as an indication of the likely linear decrease in current speeds at Swanbourne.

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[10] *Current velocity at Sepia Depression was calculated from the drogue release and pick-up points, the only two drogue GPS points captured.*

[11] *The current direction was assumed to remain constant throughout the water column.*

[12] *Two sets of ambient conditions are set in the model, one at the surface (0 m) and one at approximately one metre above the seabed. The current speed is set to linearly decrease to zero from this depth to the seabed.*

2.5 Water quality sampling

2.5.1 Sampling locations

Offshore water samples were collected from 35 offshore sites (34 at Sepia Depression) within a rectangular sampling grid appropriate for the prevailing flow conditions at each outlet on the day of the survey (Appendix B; DAL 2001). The sampling grid was chosen after 2–3 drogue readings to determine the predominant flow direction. The actual position of each sampling site was recorded using an on-board GPS. In addition, 9 shoreline sites located along the coast adjacent to each of the ocean outlets were sampled.

2.5.2 Sample collection

At each offshore site, water samples were collected from the surface (1 m depth) and the bottom (approximately 2 m above the seafloor) of the water column. The samples were collected with two electric bilge pumps (one for the surface and one for the bottom samples). Prior to collecting a sample at each site, the pumps were operated for approximately 30 s to flush the delivery hose. The shoreline samples were obtained by filling the sample containers directly in waist-deep water.

At the surface and the bottom of each of the offshore sites and at each shoreline site, the following samples were collected:

- two 125 mL unfiltered samples for total phosphorus and total nitrogen analysis;
- two 10 mL filtered samples (onsite through a 45 µm filter) for ortho-phosphate, ammonium and nitrate+nitrite analysis;
- one 10 mL sample for fluorometric chlorophyll *a* analysis; and
- one 250 mL sample for thermo-tolerant coliform and faecal streptococci analysis.

Prior to collecting a sample at each site, the sample containers (with the exception of pre-sterilised sample bottles used for the microbiological analysis) were flushed with seawater. Immediately after collection all the samples were placed on ice in the dark.

2.5.3 Replicate samples

During each survey, three replicate samples of nutrients were obtained from surface waters at a single offshore site in the sampling grid. The samples were compared to identify variance in the measured water quality parameters, which may be introduced by small-scale spatial variability in the water column or by variability associated with laboratory analyses.

2.5.4 Water column structure

A multi-parameter water quality sensor (SBE 19+ [Ocean Reef] or YSI 6600 [Swanbourne and Sepia Depression]) was lowered through the water column at seven or eight of the offshore sites in the sampling grid at each of the outlets to provide information on the physical structure of the water column, i.e. vertical profiles of temperature, salinity and dissolved oxygen. The selected sites were located along a north—south transect through the middle of each sampling grid, with additional sites measured around the diffuser.

2.5.5 Laboratory analysis

The nutrient and primary production analyses were undertaken by the Marine and Freshwater Research Laboratory (MAFRL), Murdoch University, and the microbiological analyses were conducted by the PathCentre (Perth, Western Australia) using the analytical methods identified in Table 2.2.

The measurement of chlorophyll *a* by fluroescence was performed on unfiltered water samples collected in the field and kept on ice in the dark for return to the laboratory. The sample flourescence was measured the same day using a Turner Designs Trilogy Benchtop Fluorometer (Model 7200-042). The Fluorometer was calibrated against acetone extracted chlorophyll *a* samples that were collected from a number of corresponding sites. Water samples collected for the measurement of chlorophyll *a* and phaeophytin (acetone extraction method) were filtered in the field onto Whatman 47mm GF/C glass-fibre filter papers, placed on ice and kept in the dark for transport. In the laboratory, filter papers were ground with

90% acetone and extraction occurred over 24 hours. Chlorophyll *a* and phaeophytin were measured using a spectrophotometer following extraction.

Ortho-phosphate was analysed by the ascorbic acid method (Johnson & Petty 1982), nitrate+nitrite by copper-cadmium reduction (Johnson & Petty 1983) and ammonium using the alkaline phenate method (Switala 1993). Total nitrogen and total phosphorus were determined from autoclave digests with potassium persulphate (Valderrama 1981). All nutrient analyses were carried out on a Lachat Quick-Chem 8500 Automated Flow Injection Analyser in accordance with NATA accreditation.

Occasionally the concentration of a particular parameter in a sample was below the reporting limits. The lower reporting limit for thermo-tolerant coliforms and *Enterococci* spp. is dependent on the maximum sample volume that can be processed. For the purposes of calculating statistics and data presentation, concentrations or counts below the reporting limit were assumed to be half the reporting limit (e.g. <3 µg/L becomes 1.5 µg/L).

Table 2.2 Analytical methods and reporting limits for each of the water quality parameters measured during the summer water quality surveys

Parameter	Analytical method	Reporting limit	Unit
Nutrients			
Total phosphorus	Lachat automated flow injection analyser (Valderrama 1981)	5[1]	µg P/L
Ortho-phosphate	Lachat automated flow injection analyser (Johnson & Petty 1982)	2[1]	µg P/L
Total nitrogen	Lachat automated flow injection analyser (Valderrama 1981)	50[1]	µg N/L
Ammonium	Lachat automated flow injection analyser (Switala 1993)	3[1]	µg N/L
Nitrate+nitrite	Lachat automated flow injection analyser (Johnson & Petty 1983)	2[1]	µg N/L
Primary production			
Chlorophyll *a*	Fluorometric	0.1[2]	µg/L
Chlorophyll *a*	Acetone extraction	0.1[1]	µg/L
Phaeophytin	Acetone extraction	0.1[1]	µg/L
Microbiological indicators			
Thermo-tolerant coliforms	Membrane filtration	Dilution dependent[3]	CFU/100 mL
Faecal streptococci (as *Enterococci* spp.)	Membrane filtration	Dilution dependent[3]	MPN/100 mL

Notes:

1. The reporting limit is calculated as the constituent concentration that produces a signal 10 standard deviations above the reagent water blank.
2. Instrument reporting limit.
3. The lower assay limit for thermo-tolerant coliform and faecal streptococci are dependent on the dilution of the original sample.

Data analysis and presentation

The water quality data for each sampling site are presented as bar plots. Dot distribution plots are presented to illustrate the spatial variation in water quality parameters within the sampling grid. It should be emphasised that although individual sites may exceed ANZECC/ARMCANZ (2000) guidelines or the 80th percentile of reference values, this does not imply that an EQG or EQS has been exceeded. EQG and EQS exceedance criteria are based on median values of samples taken from many sites.

Summer Water Quality Survey

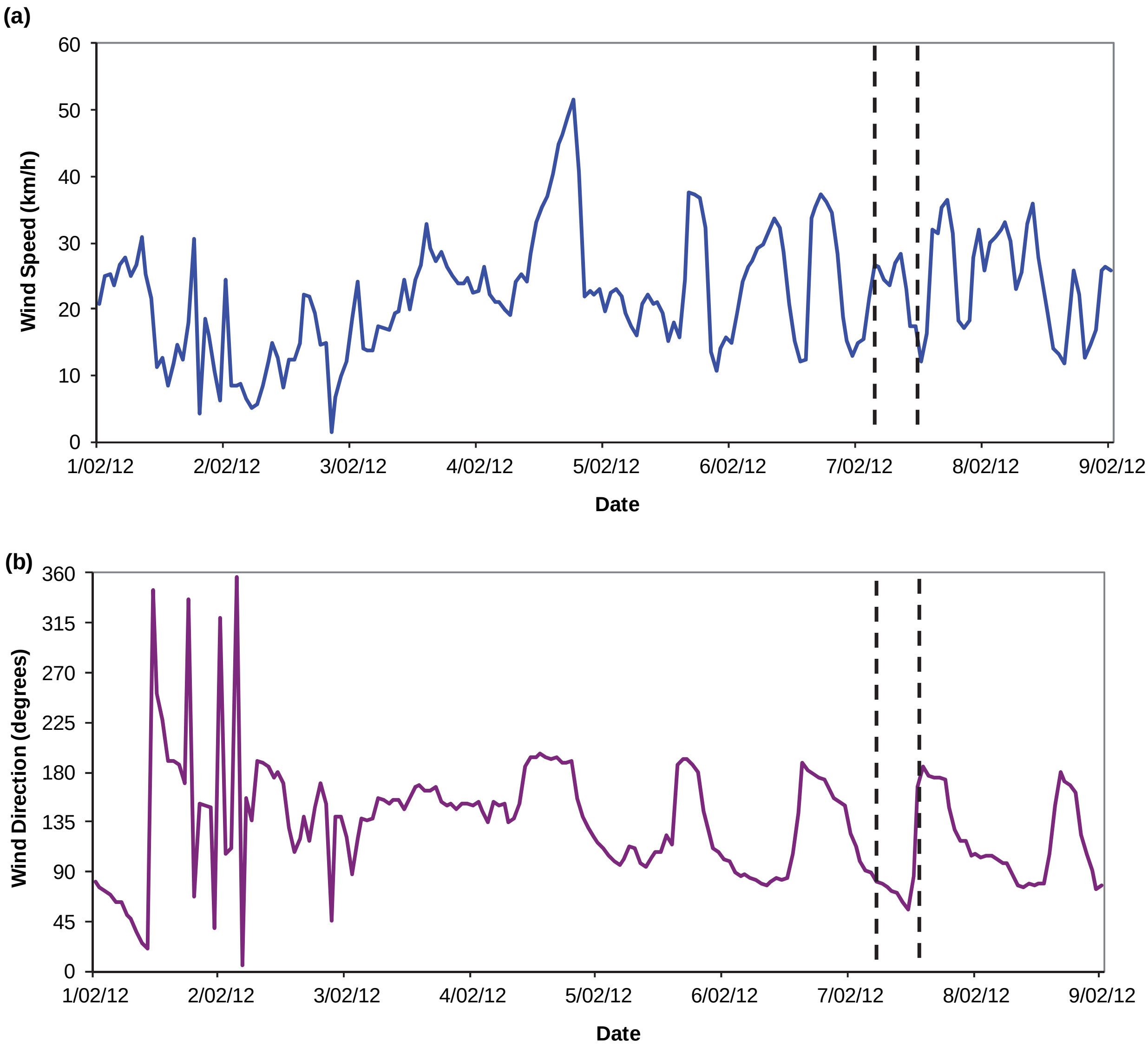
Ocean Reef

07 February 2012

3. Ocean Reef Summer Water Quality Survey – Results and Interpretation

3.1 Wind, wave and tide conditions

The survey at Ocean Reef was undertaken on 15 February 2011. For 24 hours prior to the survey, the winds at Ocean Reef were fresh easterlies (average 31.8 km/h), changing to fresh southerlies (average 34.2 km/h) before declining to gentle easterlies (average 15.1 km/h). During the survey wind was from the east, changing from moderate (average 25.4 km/h) to gentle (average 15.5 km/h).



Note:
1. Dashed lines (- -) show approximate timing of the summer water quality survey

Figure 3.1 Hourly averages of (a) wind speed and (b) wind direction, prior to and during the summer water quality survey at Ocean Reef, 07 February 2012

For 24 hours prior to the survey, the average significant wave height[13] offshore from Rottnest Island was 1.8 m[14], with an average peak wave period[15] of 12.3 s[14] (Figure 3.2a and b). During the survey the average offshore significant wave height was 1.3 m and the average peak wave period decreased to 10.3 s. The survey was conducted during a rising tide (Figure 3.2c).

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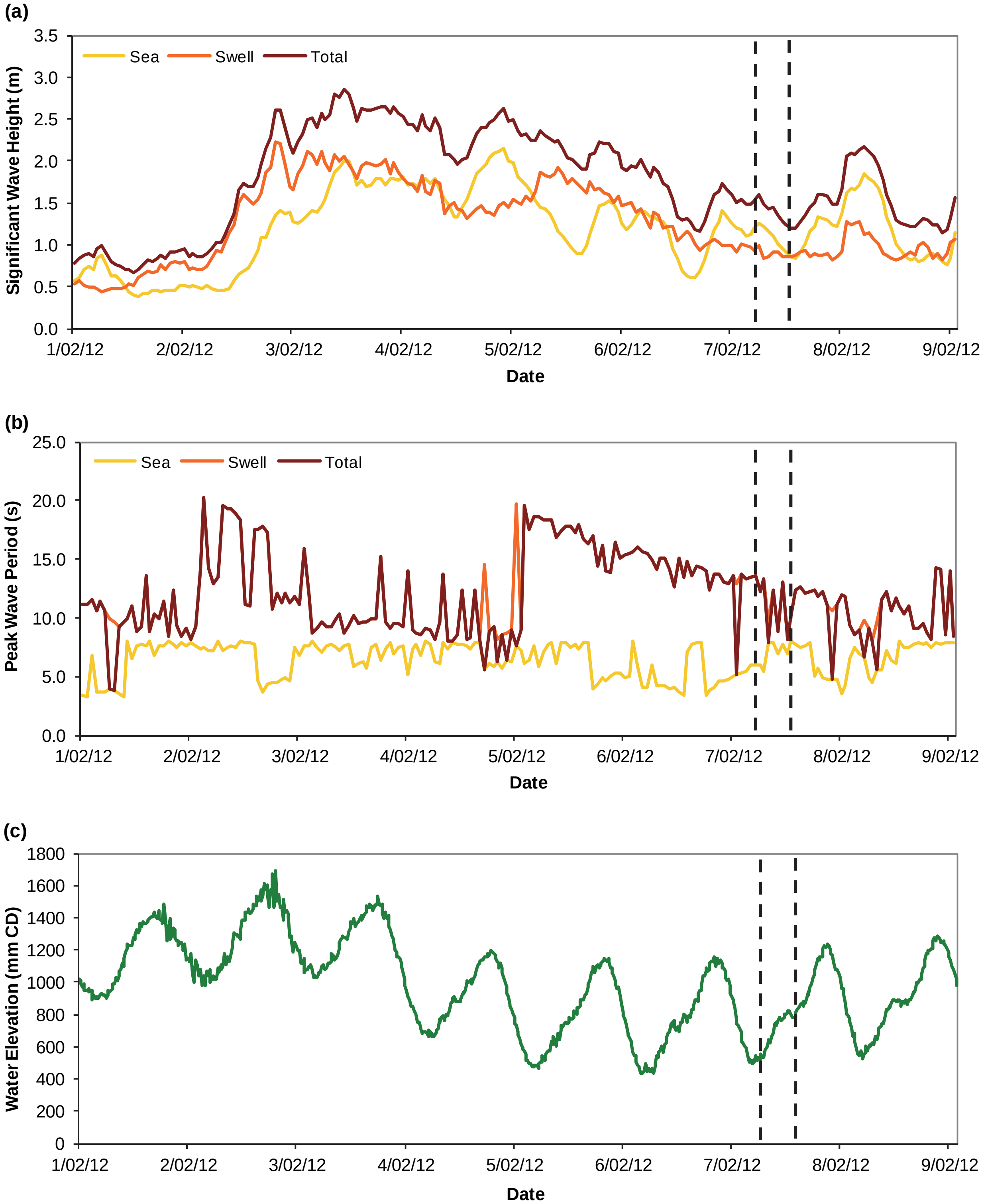
13 The significant wave height (in metres) is defined as the average height of the highest one-third of waves recorded (Source: http//www.dpi.wa.gov.au/).

14 Values presented are for the 'total' wave conditions, that is, the combined sea and swell conditions.

15 The wave period (in seconds) is the time between consecutive wave crests. The peak wave period is the wave period of those waves that are producing the most energy in a wave record.



Note:

1. Dashed lines (- -) show approximate timing of the summer water quality survey

Figure 3.2 **(a) Significant wave heights (offshore Rottnest Island), (b) peak wave periods (offshore Rottnest Island) and (c) water level elevation (Fremantle Fishing Boat Harbour), prior to and during the summer water quality survey at Ocean Reef, 07 February 2012**

3.2 Discharge from outlets

The characteristics of the treated wastewater from Beenyup WWTP measured from a 24 hour composite sample collected prior to and during the survey at Ocean Reef on 07 February 2012 are presented in Table 3.1. At the time of the survey, 50 ports were operational on Outlet A and 48 ports were operational on Outlet B.

Table 3.1 Characteristics of Beenyup WWTP treated wastewater on 07 February 2012

Parameter	Concentration/counts (07/02/2012)
Total phosphorus	8,000 µg/L
Total nitrogen	13,000 µg/L
Ammonia	290 µg/L
Nitrate+nitrite	Not analysed by laboratory
Thermo-tolerant coliforms	180,000 CFU/100 mL
Enterococci spp.	20,000 MPN/100 mL
Total suspended solids	11 mg/L
Biological oxygen demand	5 mg/L
Total flow	122.4ML/d

3.3 Surface drogue movement

The surface drogue, released above the centre of the Outlet B diffuser at the beginning of the survey, drifted in a west—northwest direction with an average velocity of 0.045 m/s (Figure 3.3). At the time of the survey it is expected that the discharged treated wastewater would be advecting to the north and offshore of the diffuser.

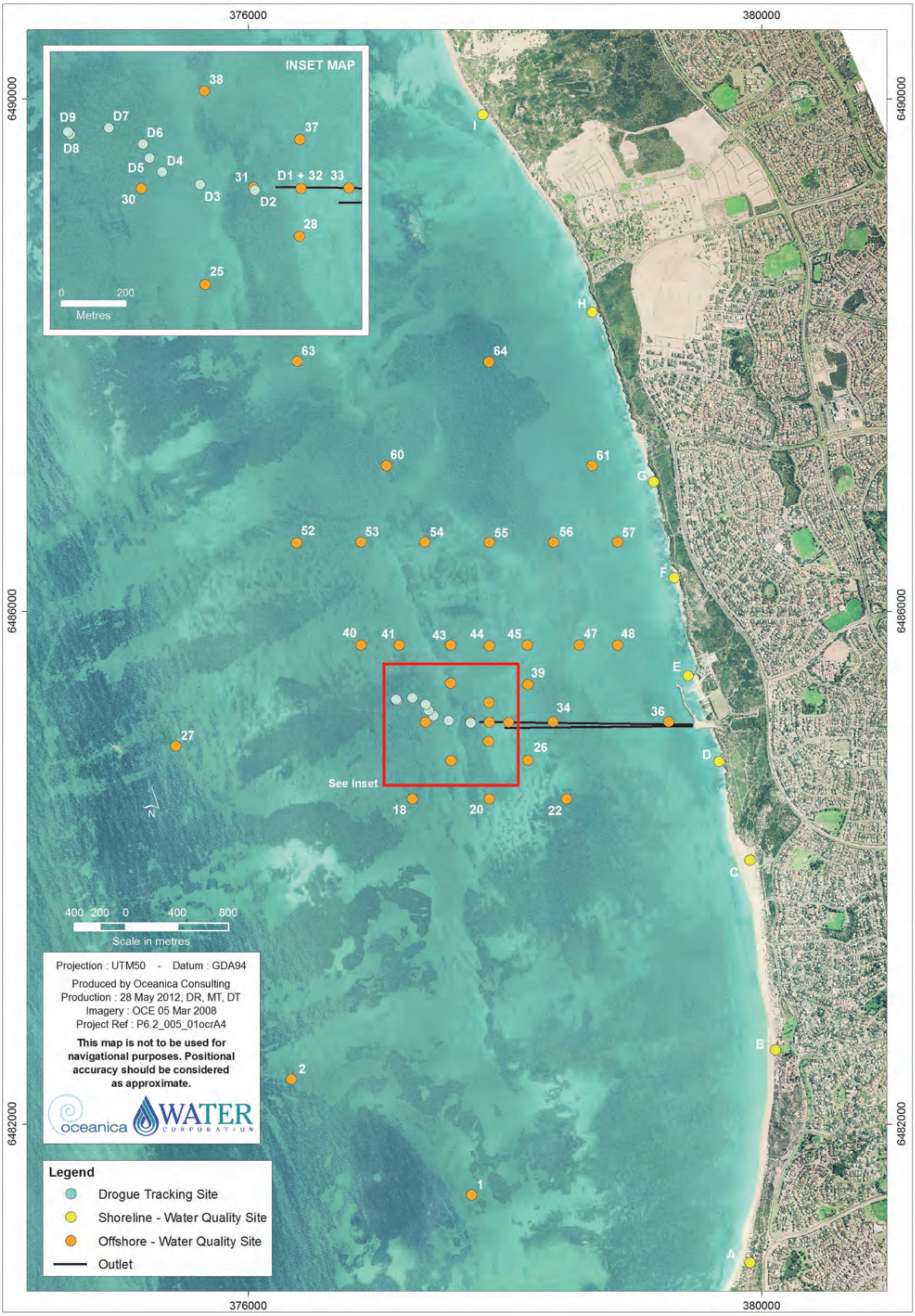


Figure 3.3 **Ocean Reef ocean outlets summer water quality survey sites and drogue tracking sites, 07 February 2012**

3.4 Initial dilution modelling

For the ambient conditions at the time of the summer water quality survey on 07 February 2012, the modelling predicted average initial dilutions of 1:77 for Outlet A and 1:64 for Outlet B and centreline dilutions of 1:46 for Outlet A and 1:39 for Outlet B (Figure 3.4a and Figure 3.5a). The plume was predicted to first reach the surface within approximately 3–4 m (horizontal distance) from the discharge point (see the ambient boundary[16] of the plume in Figure 3.4b and Figure 3.5b). The full model output is included in Appendix C.

(a) (b)

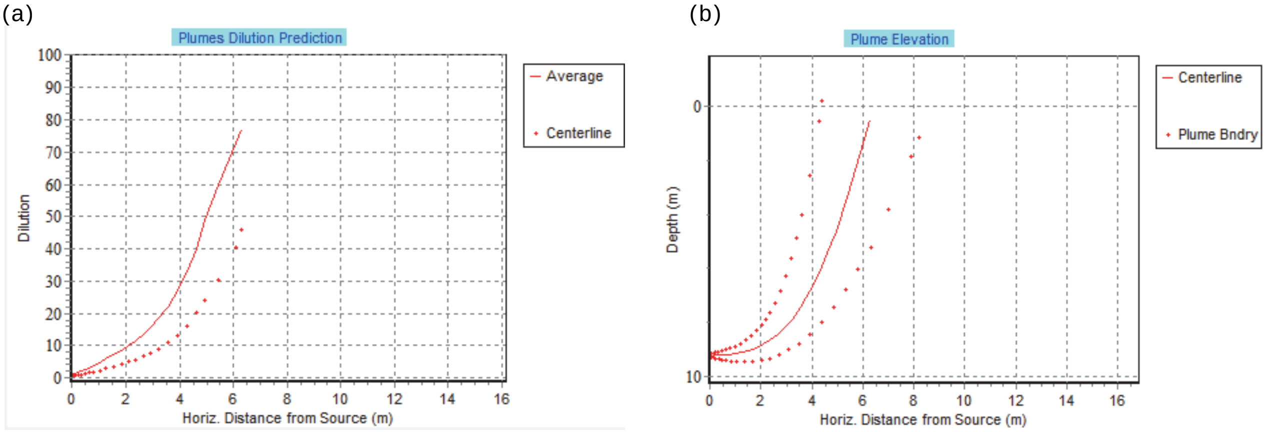


Figure 3.4 UM3 initial dilution modelling results for (a) predicted average and centreline dilutions and (b) predicted plume elevation trajectory for Outlet A, during the summer water quality survey at Ocean Reef, 07 February 2012

(a) (b)

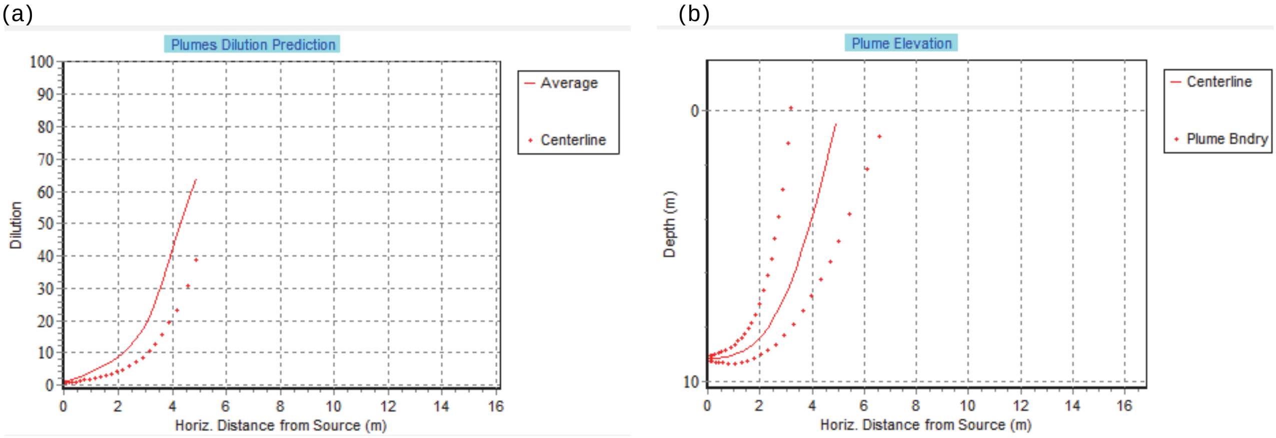


Figure 3.5 UM3 initial dilution modelling results for (a) predicted average and centreline dilutions and (b) predicted plume elevation trajectory for Outlet B, during the summer water quality survey at Ocean Reef, 15 February 2011

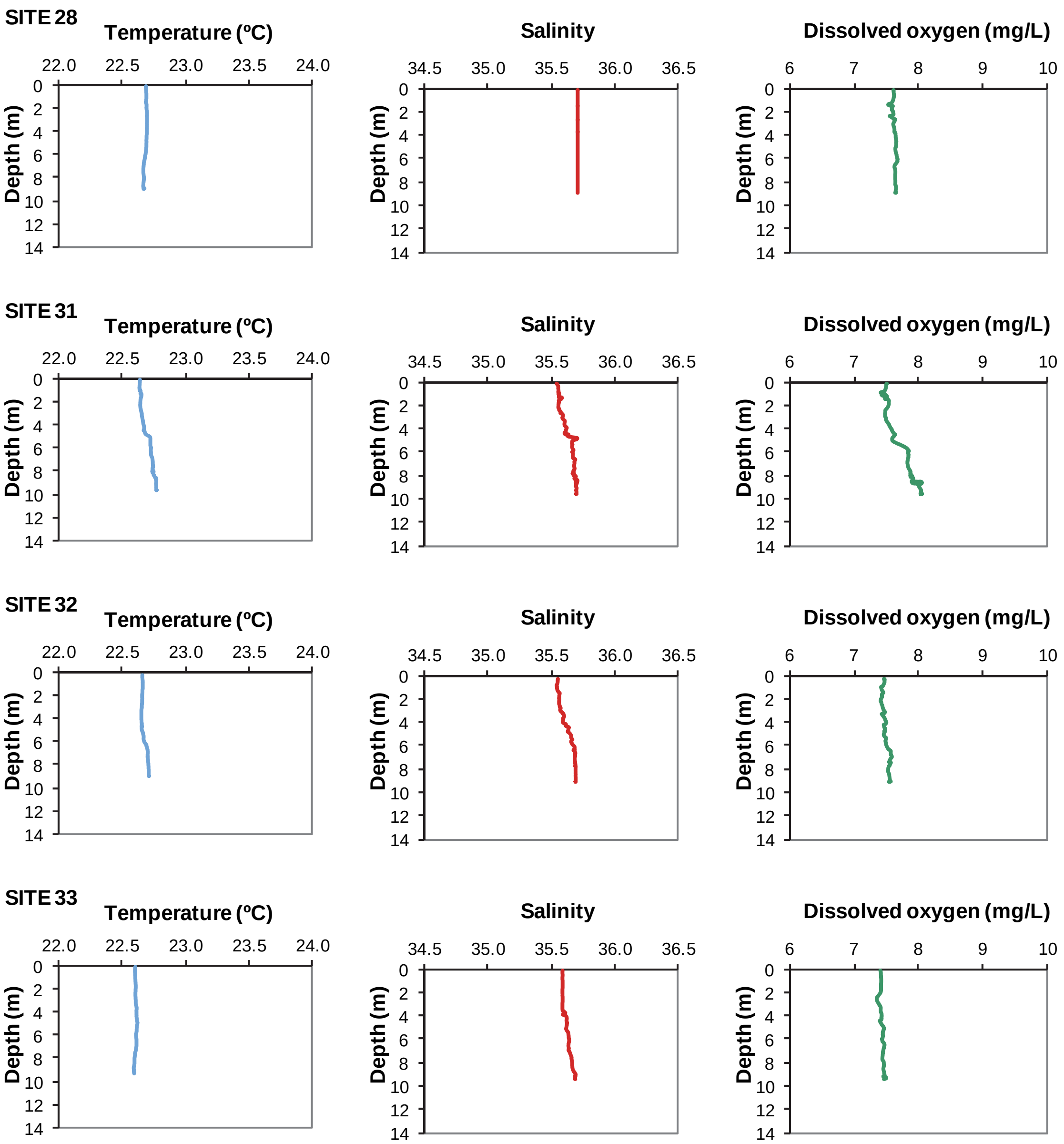
3.5 Water quality

The grid for northerly flow conditions at Ocean Reef was sampled during the survey on 07 February 2012, as easterly and southerly winds prevailed during the survey period (Section 3.1). Water samples were collected from the surface and bottom waters of the 35 offshore sites and from 9 shoreline sites (Figure 3.3). Tables containing the concentrations of all water quality parameters taken during the summer water quality survey are included in Appendix D.

[16] *The ambient boundary corresponds to the plume boundary at which concentrations are estimated to be equal to ambient conditions*

3.5.1 Water column structure

Water column structure was recorded at eight sites (sites 28, 31, 32, 33, 37, 44, 55 and 64). Water temperature varied from 22.59 to 23.60°C, salinity varied from 35.54 to 35.76[17] and dissolved oxygen varied from 7.36 to 8.30 mg/L (equivalent to 105% to 118% saturation) (Figure 3.6). Profiles showed a decline in water temperature of 0.5°C and 1.0°C for sites 55 and 64 respectively, from the surface to 4 m depth. Sites 55 and 64 were located 1399 m and 2808 m to the north of the diffuser, respectively. Salinity showed very little change with depth across all sites, with the greatest range occurring at sites 31 and 32 (range of 0.15 between minimum and maximum values). Sites 31 and 64 showed an increase in dissolved oxygen from 7.5 to 8 mg/L between 6 and 10 m depth, while site 37 showed a similar increase in dissolved oxygen between 8 and 10 m depth. Sites 31, 37 and 64 were located 147 m, 151 m, and 2808 m from the diffuser, respectively. Site 55, located 1399 m from the diffuser, showed a distinct dissolved oxygen profile compared to the other sites. Dissolved oxygen at this site increased from 7.2 mg/L just below the surface to 8.3 mg/L at 6 m depth, then decreased to below 8.0 mg/L after 10 m depth.



[17] *Salinity throughout this report is referred to without units according to the Practical Salinity Scale. On this scale salinity is defined as the ratio of conductivities and therefore cannot have units. Seawater typically has a salinity in the range of 34-36.*

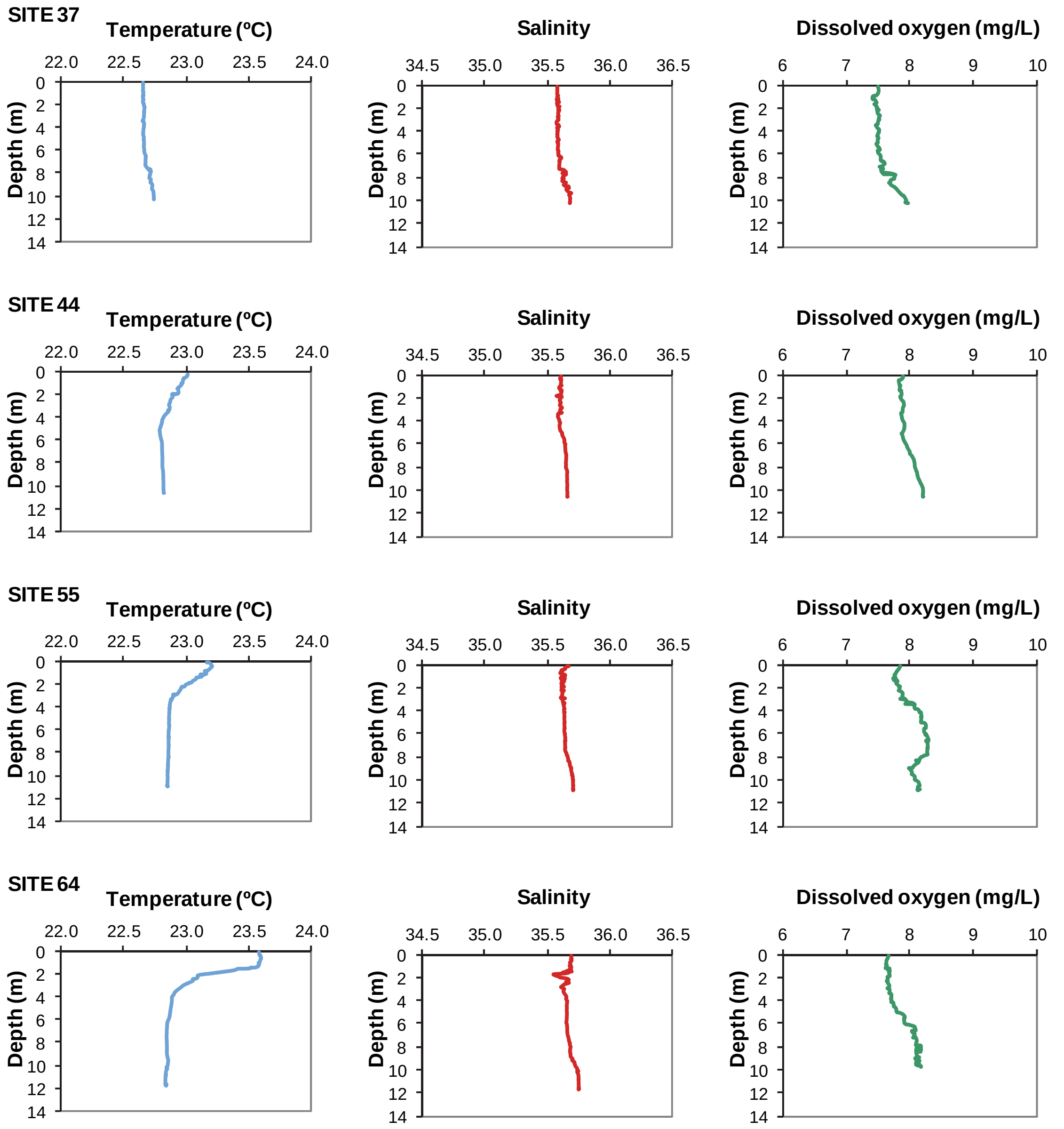


Figure 3.6 **Temperature, salinity and dissolved oxygen vertical profiles at selected sampling sites during the summer water quality survey**

The effect of the discharged wastewater on the physical structure of the water column is illustrated in Figure 3.7. Note that the colour scales used in this figure range from the minimum to the maximum of each parameter, thus exaggerating small differences in measurements. Water temperature was slightly cooler in the immediate vicinity of the outlet, but began increasing at approximately 500 m north (Figure 3.7a). There was a layer of warmer water at the surface, also starting approximately 500 m north of the outlet. Salinity of the water was lower in surface waters immediately above and to the north of the outlet (Figure 3.7b). Water density showed an increasing gradient with depth to the north of the outlet, although water density was more uniform in the immediate vicinity of the outlet (Figure 3.7c). The profiles of temperature, salinity and density were taken in a south—north direction and therefore may not have captured the full extent of the discharged wastewater plume.

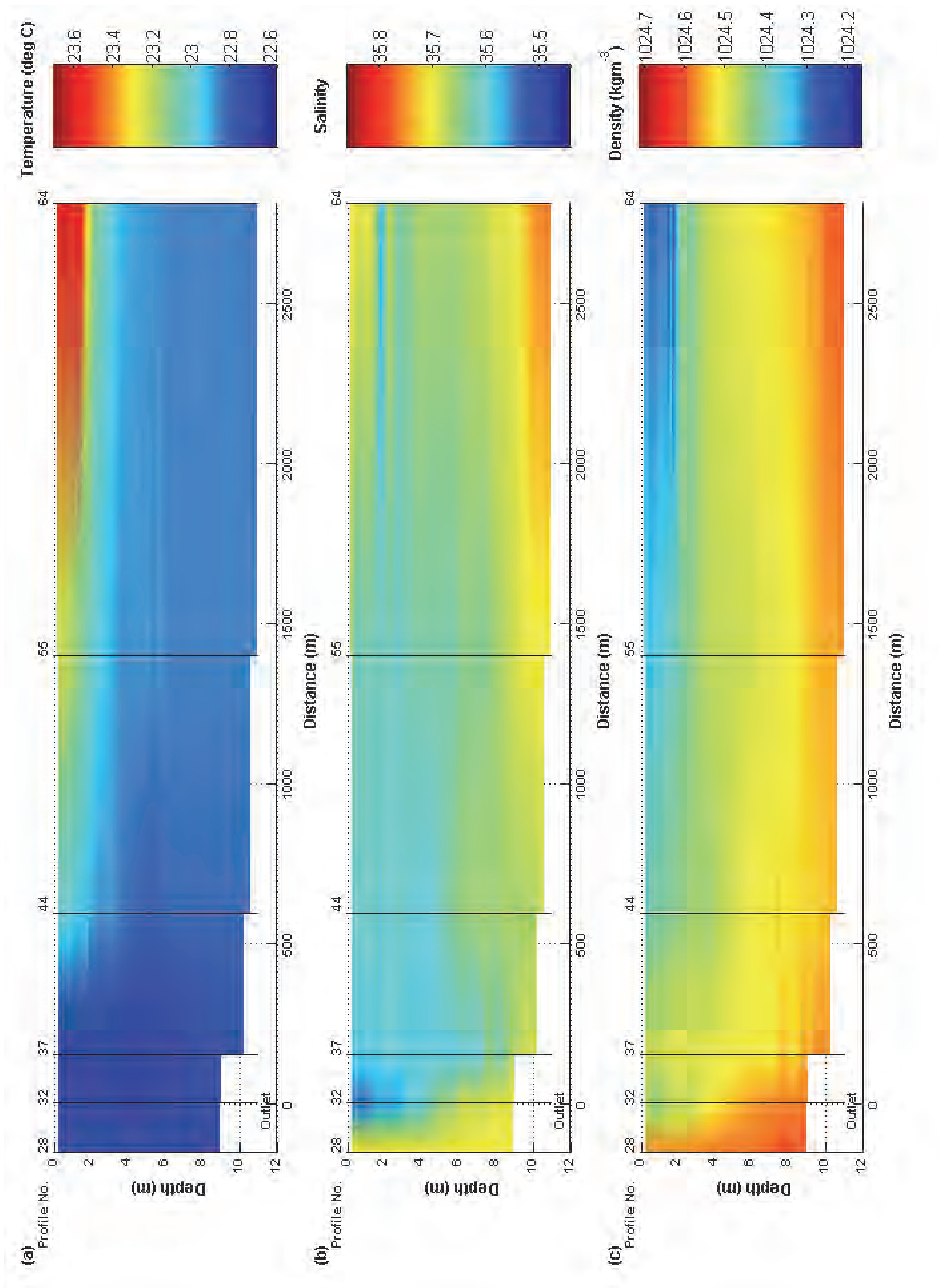


Figure 3.7 **(a) Temperature, (b) salinity and (c) density profiles along a south to north transect during the summer water quality survey at Ocean Reef, 07 February 2012**

3.5.2 Replicate samples

Variance in measurements of water quality parameters may be introduced by small-scale spatial variability in the water column or by variability among laboratory analyses. To examine the range of this variance, three surface samples were collected at site 1 (Table 3.2). The results indicated that in general, the variability amongst replicates was small. The mean value of these replicate samples was used as representative of the water quality parameters at site 1.

Table 3.2 Replicate surface samples from site 1, Ocean Reef, 07 February 2012

Parameter	Ammonia	Ortho-phosphate	Nitrate+nitrite	Total phosphorus	Total nitrogen
Units	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
Reporting limit	**<3**	**<2**	**<2**	**<5**	**<50**
Surface rep 1	1.5	7.0	8.0	16.0	100.0
Surface rep 2	1.5	7.0	9.0	17.0	100.0
Surface rep 3	1.5	8.0	9.0	16.0	90.0
Mean	*1.5*	*7.3*	*8.7*	*16.3*	*96.7*
Parameter	**Chlorophyll a** *(Flourometery)*	**Chlorophyll a** *(Acetone)*	**Phaeophytin**	**Thermal coliforms**	**Entrococci**
Units	**µg/L**	**µg/L**	**µg/L**	**CFU/100mL**	**MPN/100mL**
Reporting limit	**<0.1**	**<0.1**	**<0.2**	**<10**	**<10**
Surface rep 1	0.3	0.4	0.1	5	5
Surface rep 2	0.3	0.3	0.1	5	5
Surface rep 3	0.3	0.2	0.1	5	5
Mean	*0.3*	*0.3*	*0.1*	*5.0*	*5.0*

Note:
1. Measurements below the reporting limit are listed as half the reporting limit

3.5.3 Nutrient concentrations and distributions

Total Nitrogen (TN)

- The highest offshore surface concentration of TN, 220 µg/L, was recorded at site 38, located 426 m northwest of the diffuser (Figure 3.8). The next highest concentration was 170 µg/L at site 20, 150 µg/L at site 32, and 140 µg/L at sites 31, 33 and 37. Site 32 was located directly on top of the diffuser, while sites 20, 31, 33 and 37 were located 601 m south, 147 m west, 150 m east, and 151 m north of the diffuser, respectively.
- The highest offshore bottom water concentration of TN, 140 µg/L, was recorded at sites 20, 48 and 55, located 601 m south, 1166 m northeast, and 1399 m north of the diffuser, respectively. The next highest concentration (130 µg/L) occurred at site 38, located 426 m northwest of the diffuser.
- The concentrations of TN at all surface and bottom sites were below the ANZECC/ARMCANZ (2000) guideline for TN of 230 µg/L. Surface and bottom concentrations of TN measured at 32 sites (91%) were below the 80th percentile of reference values (140 µg/L [surface] and 135 µg/L [bottom])
- Localised increases in TN concentrations were observed at most shoreline sites, with concentrations ranging from 150 µg/L (site D) to 220 µg/L (site E) (Figure 3.8). All shoreline sites had TN concentrations below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L.
- Spatial patterns in TN concentrations (Figure 3.9) revealed localised increases near the diffuser, as well as north and south of the diffuser, for both surface and bottom waters. All surface and bottom sites had TN concentrations that were below the ANZECC/ARMCANZ (2000) guideline.

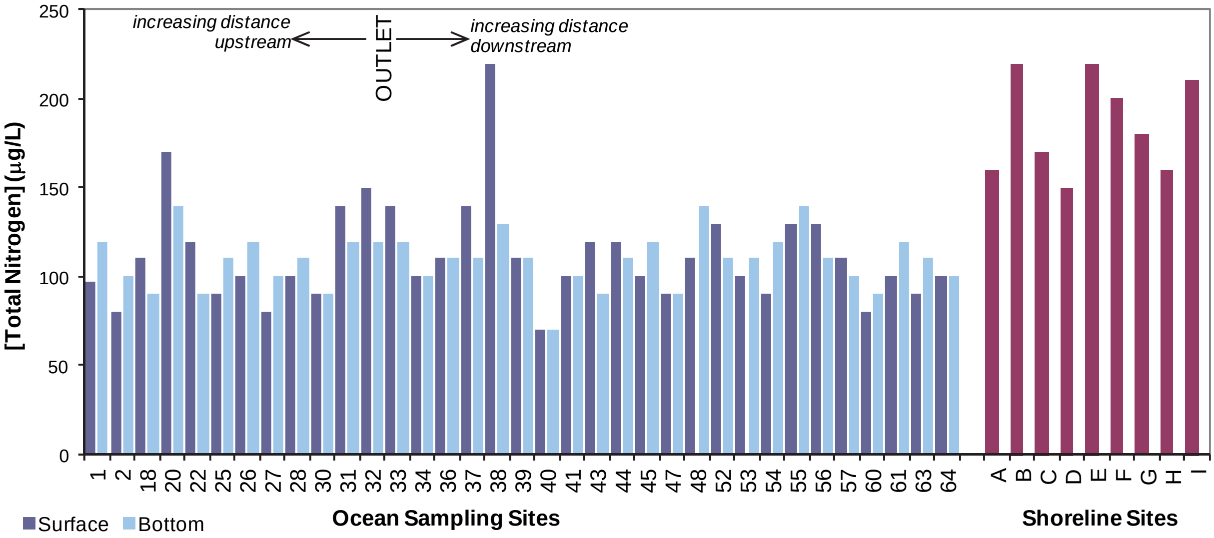
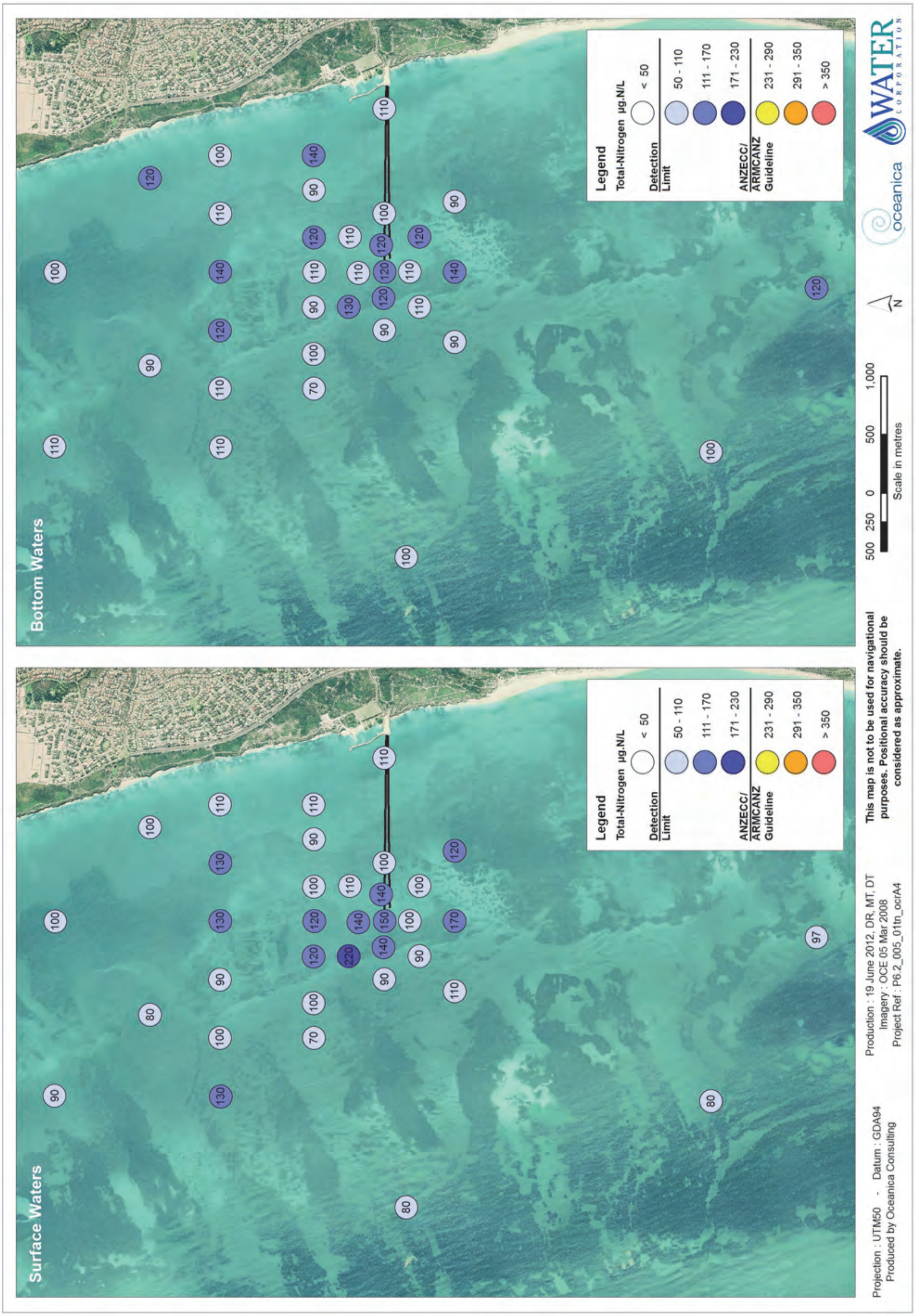


Figure 3.8 **Total nitrogen concentrations at surface, bottom and shoreline sites sampled at Ocean Reef, 07 February 2012**



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 3.9 Spatial distribution of total nitrogen in surface and bottom water samples from Ocean Reef, 07 February 2012

Ammonium Nitrogen (NH_4^+)

- All surface and bottom sites had NH_4^+ concentrations below the reporting limit (3 µg/L) (Figure 3.10).
- Surface and bottom water sites did not exceed the ANZECC/ARMCANZ (2000) guideline of 5 µg/L or the 80th percentile of reference values, 5 µg/L (surface and bottom).
- Shoreline sites B and E had NH_4^+ concentrations below the reporting limit (3 µg/L). The remaining shoreline sites had NH_4^+ concentrations ranging from 5 µg/L (site A) to 14.5 µg/L (site G). Six shoreline sites (67%) were above the ANZECC/ARMCANZ (2000) guideline of 5 µg/L (sites C, D, F, G, H and I).
- No spatial trends in NH_4^+ concentrations were visible (Figure 3.11).

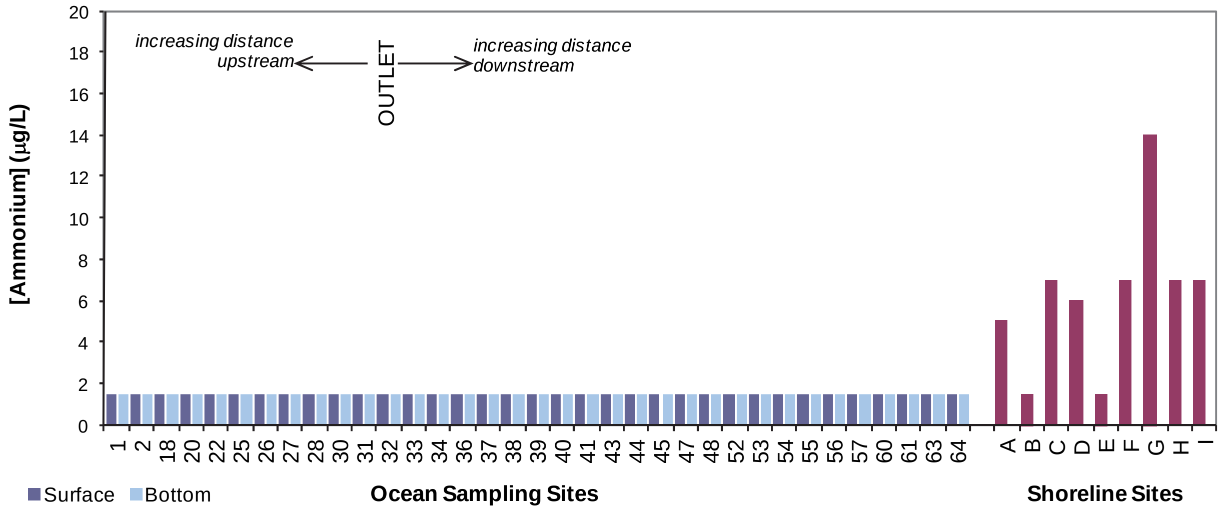
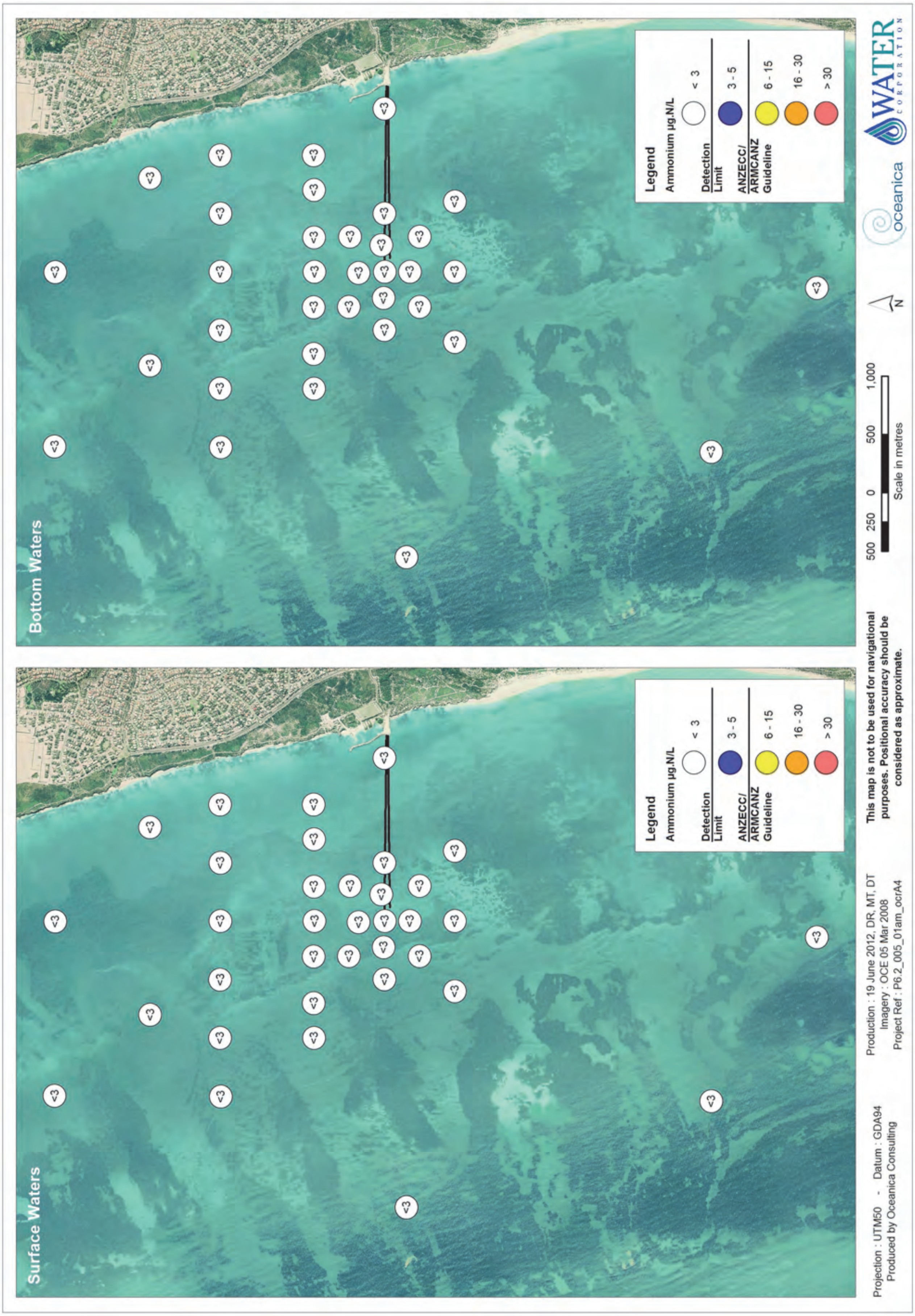


Figure 3.10 Ammonium concentrations at surface, bottom and shoreline sites sampled at Ocean Reef, 07 February 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 3.11 Spatial distribution of ammonium in surface and bottom water samples from Ocean Reef, 07 February 2012

Nitrate+Nitrite Nitrogen (NO_2^-+NO_3^-)

- The highest offshore surface concentration of $NO_2^-+NO_3^-$ was 56 µg/L at site 32, located directly above the diffuser. The next highest concentrations were 45 µg/L, 44 µg/L, and 43 µg/L at sites 31 (located 147 m west of the diffuser), 37 (located 151 m north) and 38 (located 426 m northwest) (Figure 3.12).
- The highest offshore bottom concentration of $NO_2^-+NO_3^-$ was 19 µg/L at site 45 (located 669 m northeast of the diffuser), followed by 16 µg/L at site 33 (located 150 m east of the diffuser (Figure 3.12).
- The concentrations of $NO_2^-+NO_3^-$ at 13 surface (37%) and 19 bottom (54%) sites were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Surface concentrations of $NO_2^-+NO_3^-$ at 24 sites (69%) and bottom concentrations at 28 sites (80%) were within the range of the 80th percentile of reference values, 11 µg/L (surface and bottom).
- The $NO_2^-+NO_3^-$ concentrations at shoreline sites ranged from 4 µg/L (at site A) to 95 µg/L (site E). All sites were all above the ANZECC/ARMCANZ (2000) guideline of 5 µg/L, except for site A. The reason for the elevated $NO_2^-+NO_3^-$ concentrations at shoreline sites is unknown, but may be due to the decay of beach wrack, the locations of stormwater drains or elevated nitrogen levels in groundwater.
- Spatial patterns in $NO_2^-+NO_3^-$ concentrations (Figure 3.13) revealed that for surface waters, concentrations exceeding the ANZECC/ARMCANZ (2000) guideline occurred nearby, to the north, west and south of the diffuser. For bottom waters, $NO_2^-+NO_3^-$ concentrations exceeding the ANZECC/ARMCANZ (2000) guideline were concentrated nearby the diffuser, with additional localised exceedances occurring to the north, west and south.

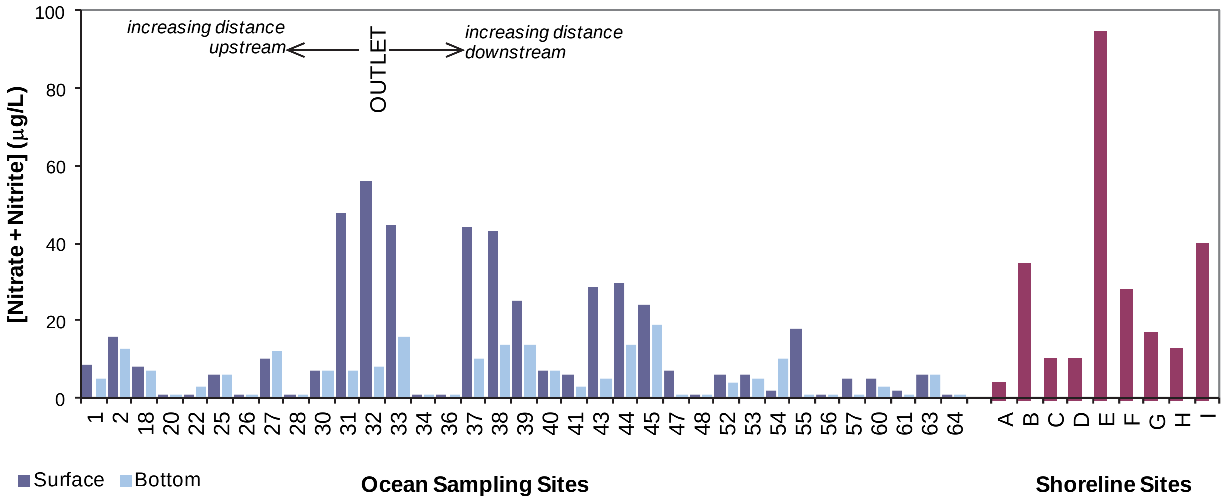
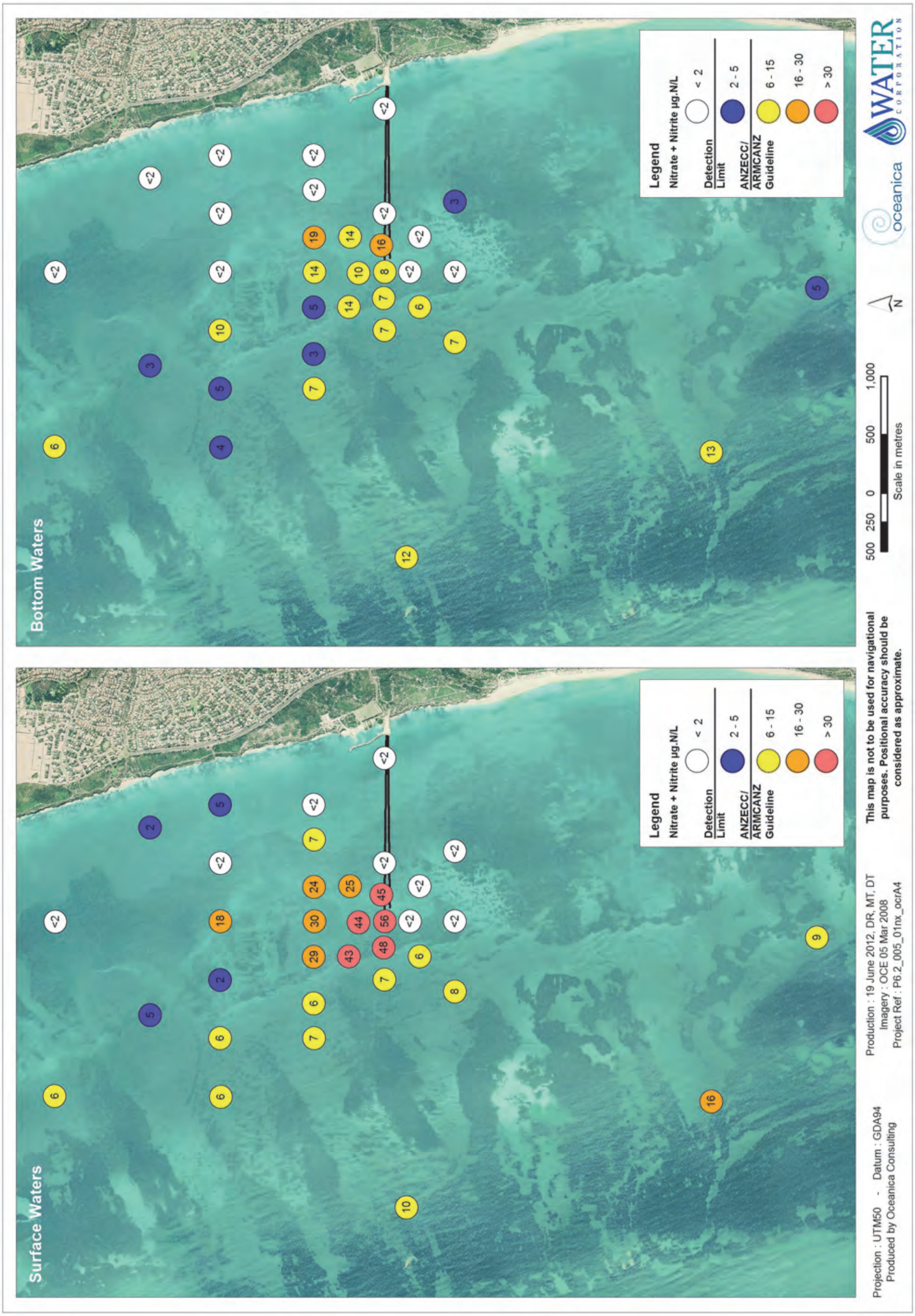


Figure 3.12 Nitrate+nitrite concentrations at surface, bottom and shoreline sites sampled at Ocean Reef, 07 February 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 3.13 Spatial distribution of nitrate+nitrite in surface and bottom water samples from Ocean Reef, 07 February 2012

Total Phosphorus (TP)

- The highest offshore surface concentrations of TP was 53 µg/L at site 32, located directly above, the diffuser. The next highest surface concentrations of TP were 48 µg/L at site 31, 44 µg/L at sites 33 and 37, and 43 µg/L at site 38. Sites 31, 33, 37 and 38 are located 147 m west, 150 m east, 151 m north and 426 m northwest of the diffuser, respectively (Figure 3.14).
- The highest offshore bottom concentration of TP was 30 µg/L at site 45, located 669 m northeast of the diffuser. The next highest bottom concentrations of TP were 26 µg/L, 25 µg/L and 24 µg/L at sites 33, 39 and 44 respectively. Sites 33, 39 and 44 were located 150 m east, 421 m northeast, and 595 m north of the diffuser, respectively (Figure 3.14).
- The concentrations of TP at 24 surface (69%) and 29 bottom (83%) sites were below the ANZECC/ARMCANZ (2000) guideline of 20 µg/L. Surface concentrations of TP at 30 sites (86%) and bottom concentrations at 35 sites (100%) were within the range of the 80^{th} percentile of reference values, 35 µg/L (surface and bottom).
- The TP concentrations at shoreline sites ranged from 18 µg/L at site H to 30 µg/L at site B. TP concentrations at 4 shoreline sites (E, F, G, H) were below the ANZECC/ARMCANZ (2000) guideline of 20 µg/L.
- Spatial patterns in measured TP concentrations (Figure 3.15) revealed that for surface and bottom waters, concentrations exceeding the ANZECC/ARMCANZ (2000) guideline occurred to the north and northeast of the diffuser.

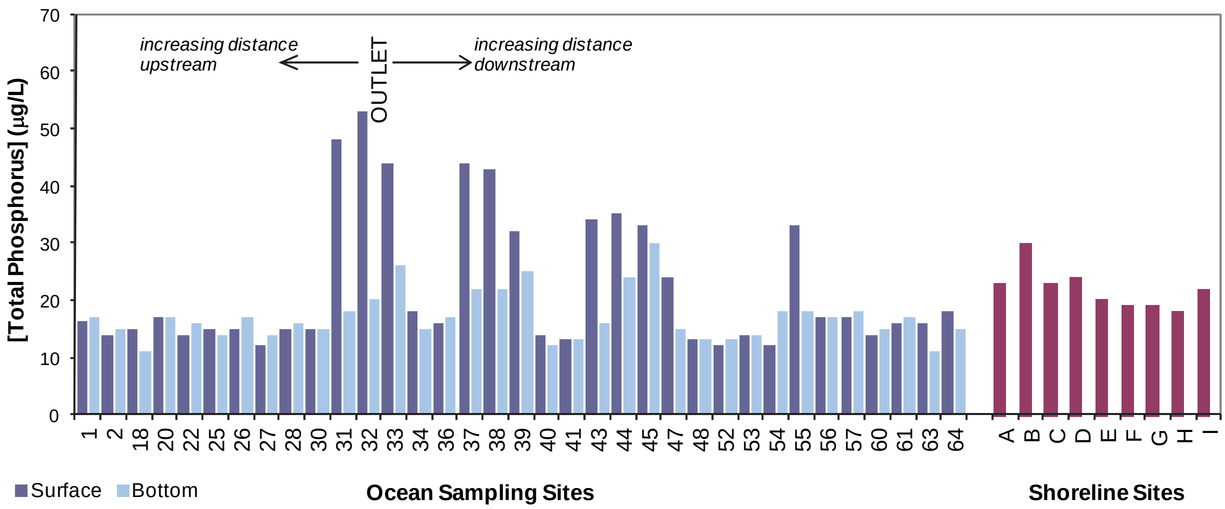
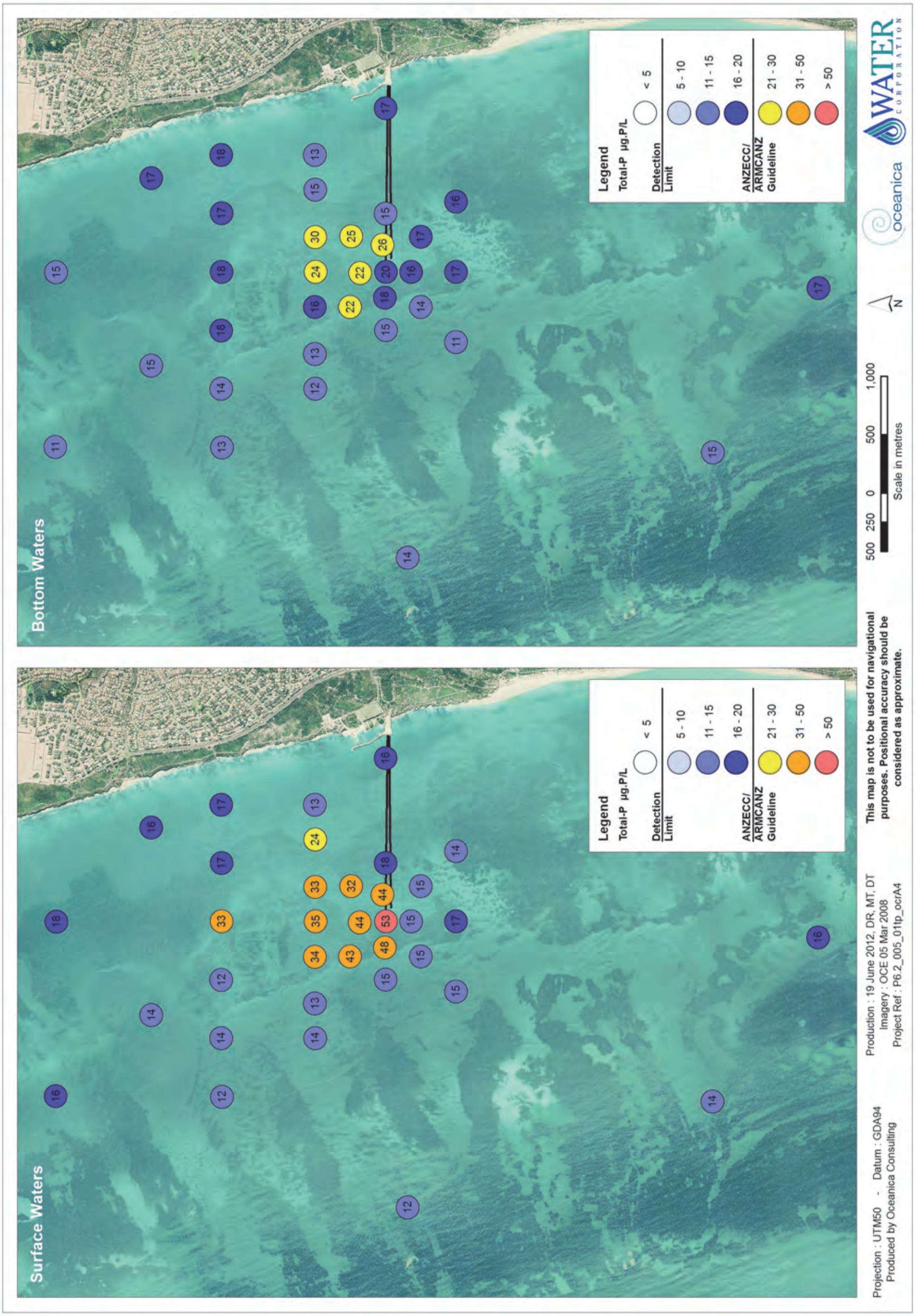


Figure 3.14 Total phosphorus concentrations at surface, bottom and shoreline sites sampled at Ocean Reef, 07 February 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 3.15 Spatial distribution of total phosphorus in surface and bottom water samples from Ocean Reef, 07 February 2012

Ortho-phosphate

- The highest offshore surface concentration of ortho-phosphate was 42 µg/L at site 32, located directly above the diffuser (Figure 3.16). The next highest concentrations were 37 µg/L at site 31, 35 µg/L at site 37, and 33 µg/L at sites 33 and 38. Sites 31, 37, 33 and 38 were located 147 m west, 151 m northeast, 150 m east, and 426 m northwest of the diffuser, respectively.
- The highest offshore bottom concentration of ortho-phosphate was 20 µg/L at site 45, located 669 m northeast of the diffuser (Figure 3.16). The next highest concentration was 14 µg/L at sites 33, 39 and 44, located 150 m east, 421 m northeast, and 595 m north of the diffuser, respectively.
- The concentrations of ortho-phosphate at 19 surface (54%) and 17 bottom (49%) sites were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Surface concentrations of ortho-phosphate at 24 sites (69%) and bottom concentrations at 26 sites (74%) were below the 80^{th} of reference values, 8 µg/L (surface and bottom).
- Ortho-phosphate concentrations at shoreline sites ranged from 3 µg/L (site F) to 8 µg/L (Site B) (Figure 3.16). Shoreline ortho-phosphate concentrations were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L at 4 sites (44%).
- Spatial patterns in ortho-phosphate concentrations (Figure 3.17) showed that for surface and bottom waters, concentrations exceeding the ANZECC/ARMCANZ (2000) guideline occurred mostly nearby and north of the diffuser. Additional isolated exceedances occurred far south of the diffuser.

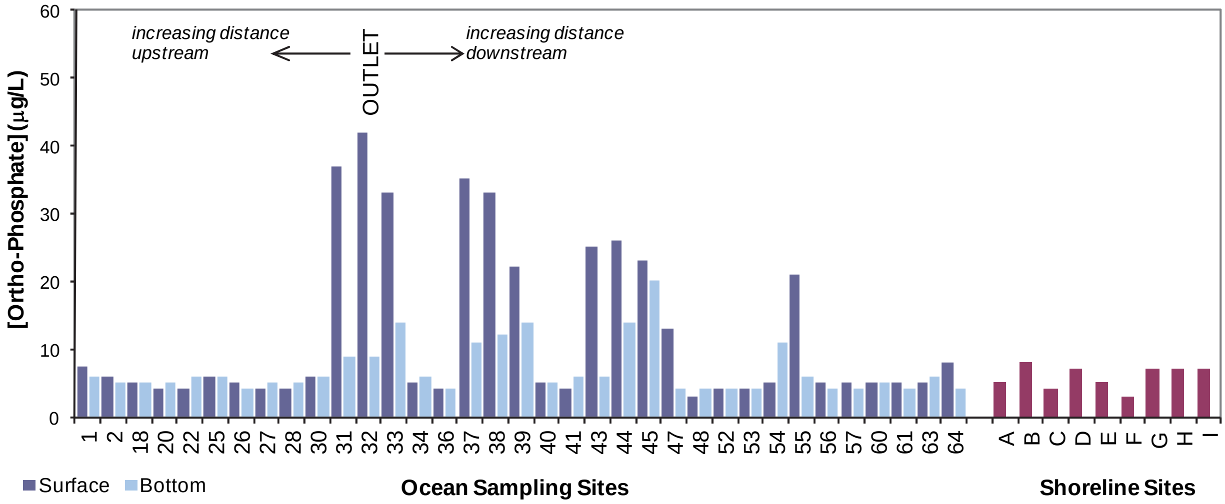
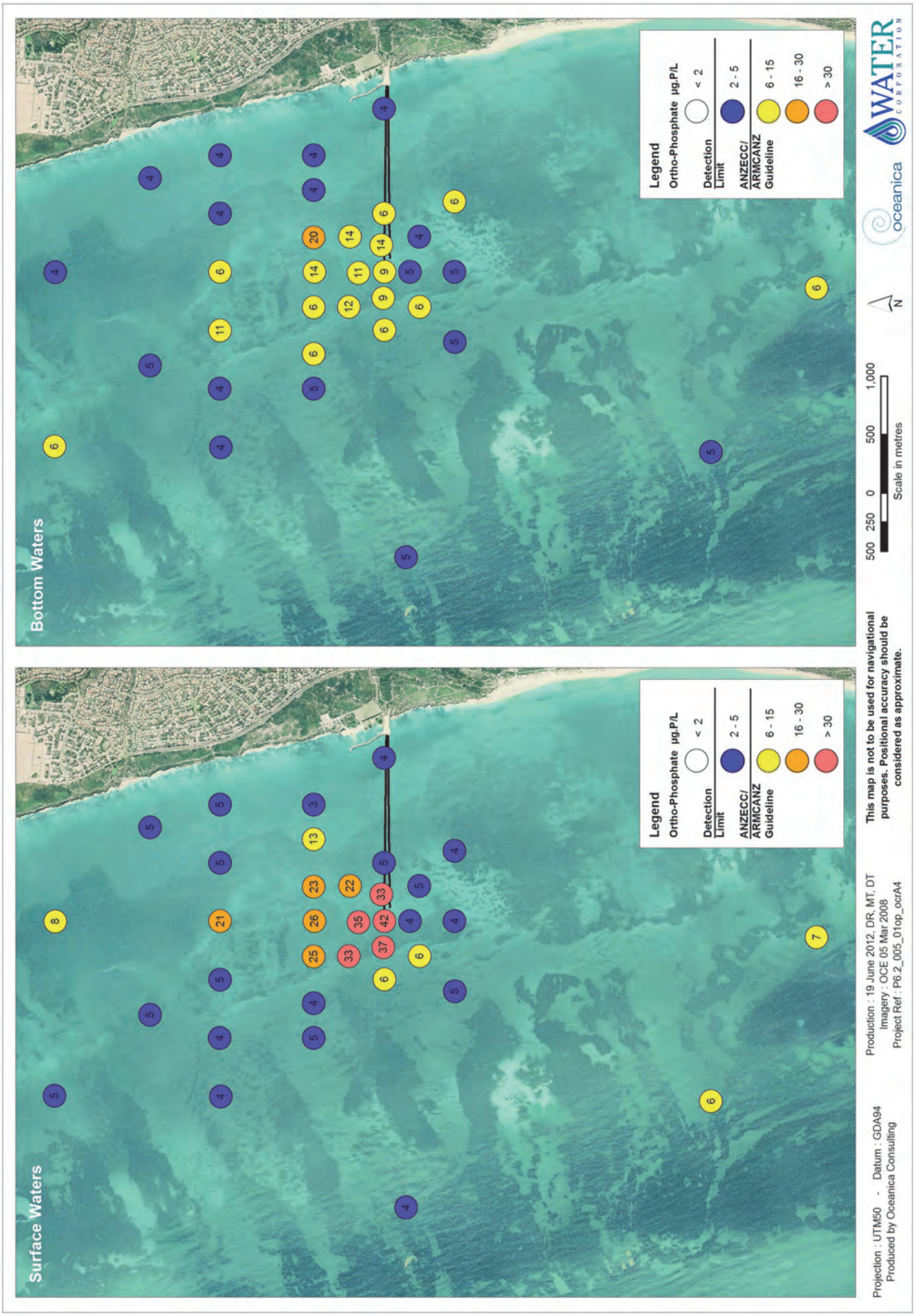


Figure 3.16 Ortho-phosphate concentrations at surface, bottom and shoreline sites sampled at Ocean Reef, 07 February 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 3.17 Spatial distribution of ortho-phosphate in surface and bottom water samples from Ocean Reef, 07 February 2012

3.5.4 Phytoplankton biomass and distribution

Phaeophytin

- Phaeophytin concentrations were measured in surface waters at five offshore sites (sites 1, 27, 36, 44 and 64). All concentrations of phaeophytin were ≤0.2 µg/L.
- Phaeophytin concentrations were also measured at the nine shoreline sites. Concentrations ranged from 0.3 µg/L (site C) to 1.5 µg/L (site B).

Chlorophyll a

- Note: Chlorophyll *a* concentrations at surface and bottom offshore sites were determined in-situ using a fluorometer. The chlorophyll *a* concentration at shoreline sites were analysed using an acetone extraction method.
- Offshore surface concentrations of chlorophyll *a* varied from ≤0.1 to 0.8 µg/L (Figure 3.18). The highest surface concentration of 0.8 µg/L was recorded at sites 47 and 55, located 924 m north and 1399 m north of the diffuser, respectively.
- Offshore bottom concentrations of chlorophyll *a* varied from ≤0.1 to 1.2 µg/L (Figure 3.18). The highest bottom concentration of 1.2 µg/L was recorded at site 55, located 1399 m north of the diffuser.
- The concentration of chlorophyll *a* at 33 surface and bottom sites (94%) were below the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L. 14 surface sites (40%) and 16 bottom sites (46%) had concentrations of chlorophyll *a* below the 80th percentile of reference values, 0.4 µg/L (surface) and 0.5 µg/L (bottom).
- The chlorophyll *a* concentration at shoreline sites ranged from 0.4 µg/L at sites F, G and H, to 1.5 µg/L at site B (Figure 3.18). The chlorophyll *a* concentrations at five of the shoreline sites (56%) were below the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L.
- Spatial patterns in chlorophyll *a* concentrations (Figure 3.18) showed that for surface and bottom waters, concentrations exceeding the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L occurred at isolated locations to the north and northeast of the diffuser.

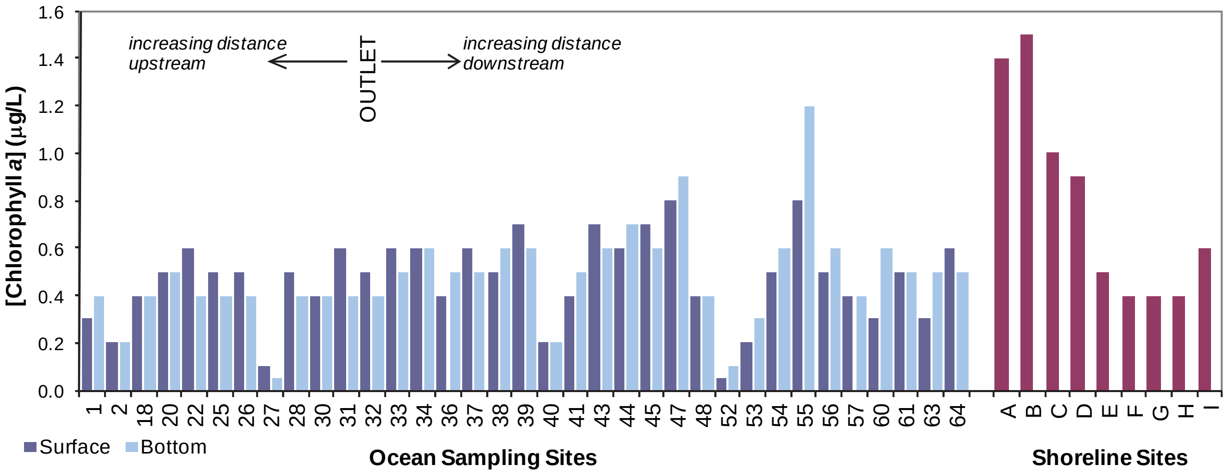
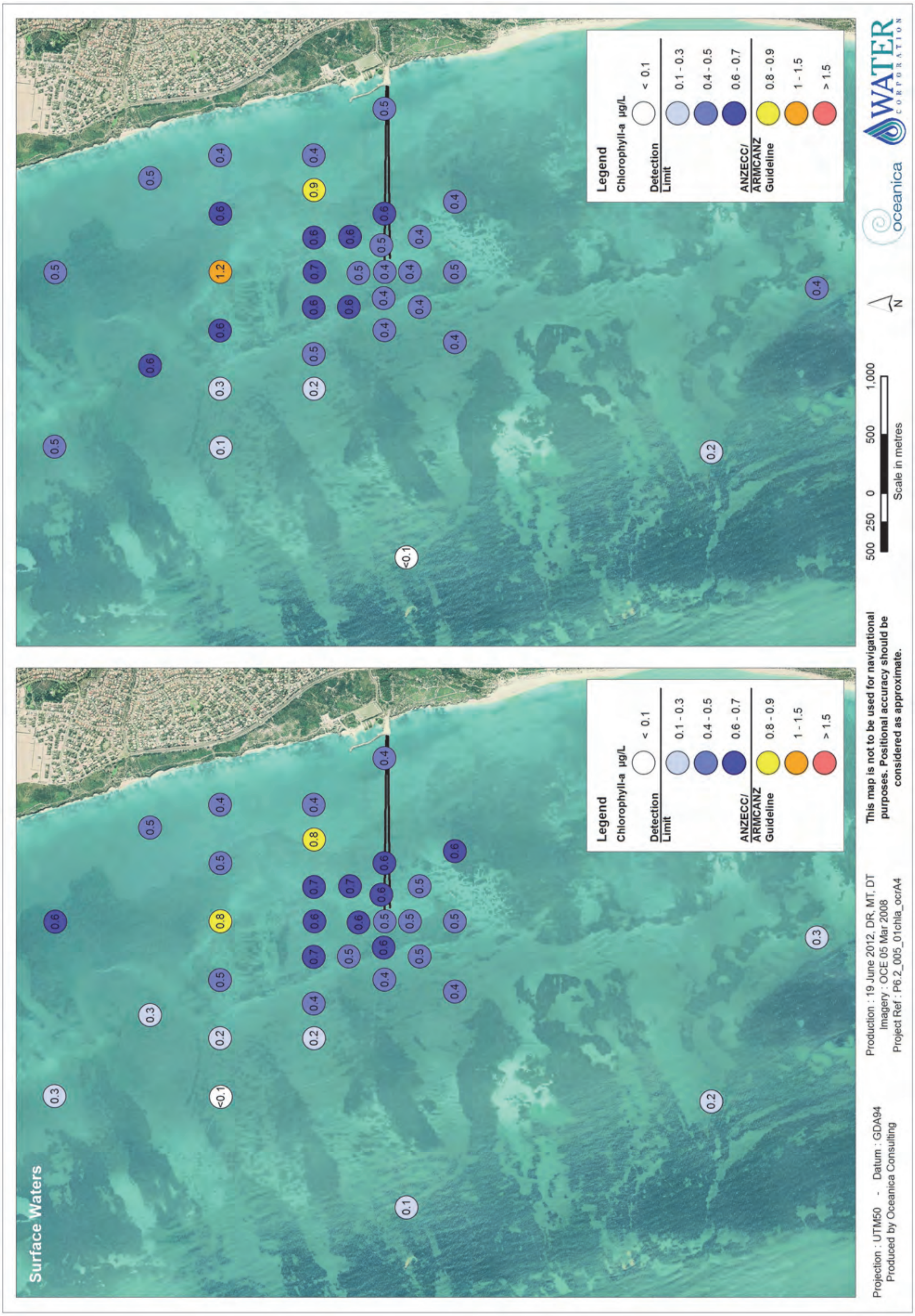


Figure 3.18 Chlorophyll *a* concentrations at surface, bottom and shoreline sites sampled at Ocean Reef, 07 February 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 3.19 Spatial distribution of chlorophyll *a* in surface and bottom water samples from Ocean Reef, 07 February 2012

3.5.5 Bacterial counts and distribution

Thermo-tolerant coliforms (TTC)

- The highest offshore surface count of TTC was 470 CFU/100 mL at site 32, directly above the diffuser (Figure 3.20). The next highest counts were 350 CFU/100 mL at site 33 (150 m east of the diffuser) and 320 CFU/100 mL at site 31 (147 m west of the diffuser).All but four other sites had concentrations of <10 CFU/100 mL.
- The highest offshore bottom count of TTC was 230 CFU/100 mL at site 33, located 150 m east of the diffuser (Figure 3.20). The next highest counts were 80 CFU/100 mL at site 32 (directly above the diffuser) and 64 CFU/100 mL at site 39 (421 m northeast of the diffuser). All but three other sites had concentrations of <10 CFU/100 mL.
- Site A had the highest shoreline TTC count of 20 CFU/100 mL. All other shoreline sites had concentrations of <10 CFU/100 mL.
- The median TTC counts at sites <250 m from the diffuser were above the EQG at surface and bottom sites, and above the EQS at surface sites. Median TTC counts at sites >250 m from the diffuser and shoreline sites were below the EQG and EQS (Table 3.3).
- Spatial patterns of TTC counts (Figure 3.21).showed that for surface and bottom waters, concentrations exceeding the EQG occurred in the immediate vicinity of the diffuser.

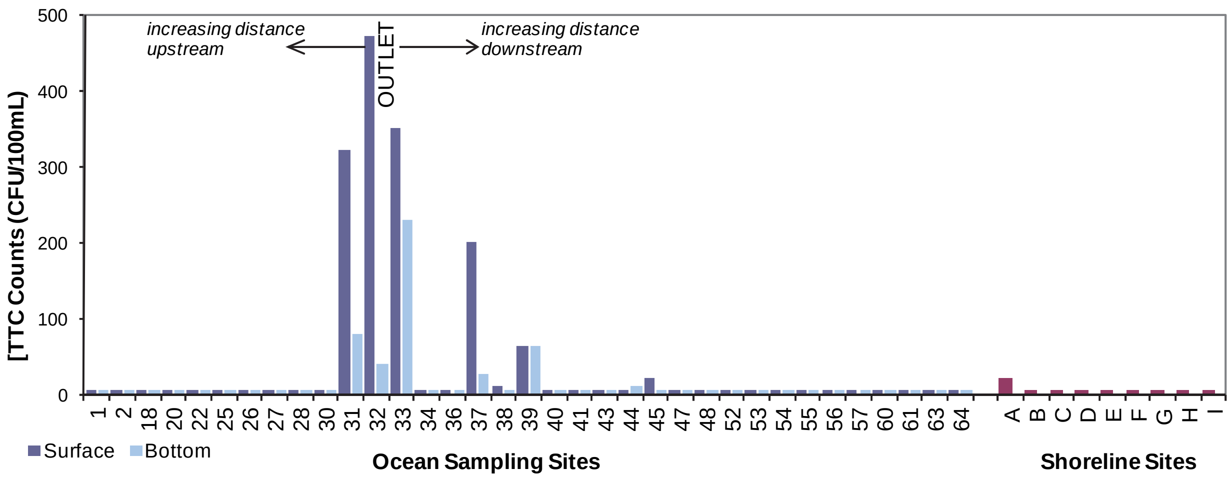
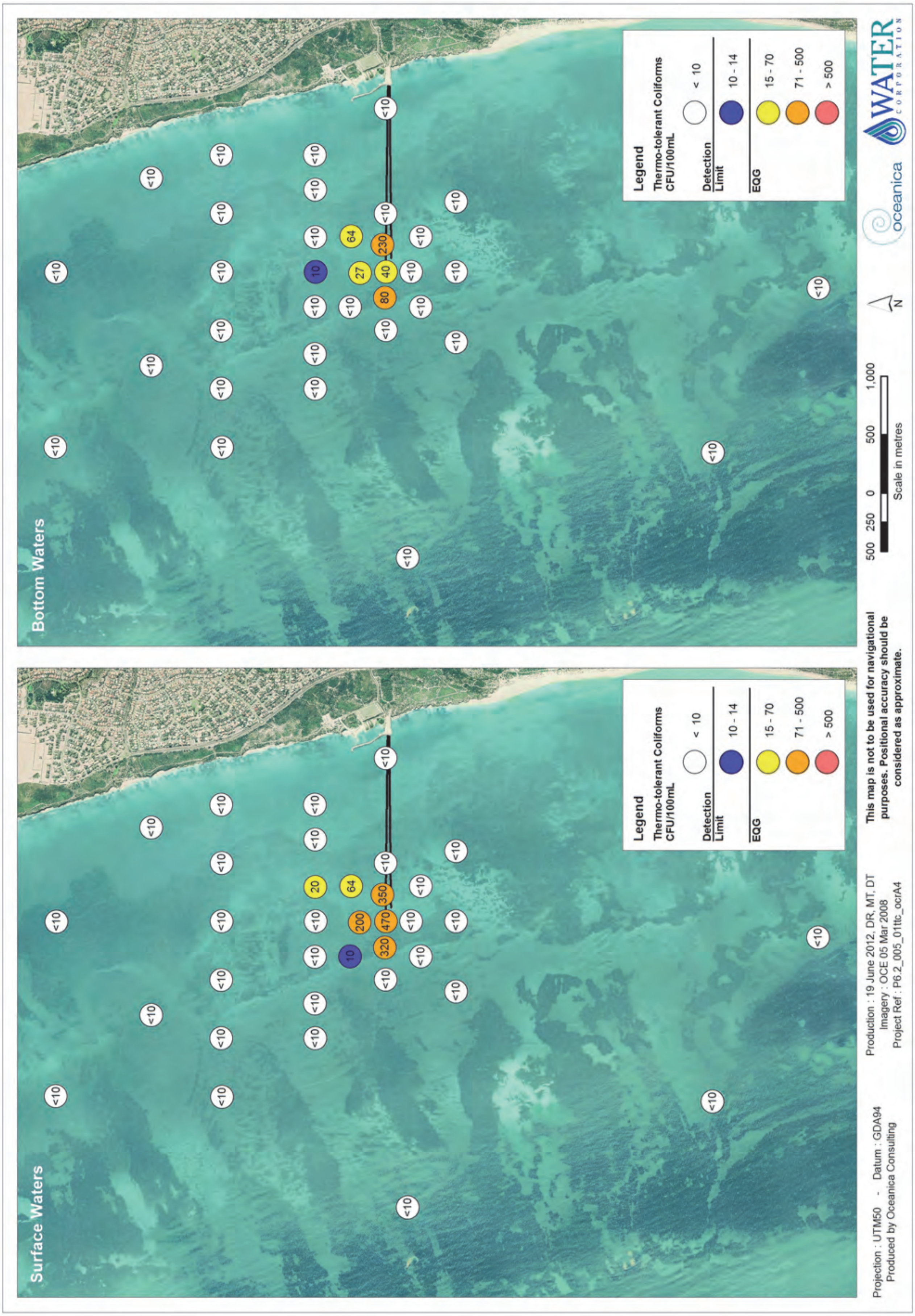


Figure 3.20 **Counts of thermo-tolerant coliforms at surface, bottom and shoreline sites sampled at Ocean Reef, 07 February 2012**

Table 3.3 **Median counts (CFU/100 mL) of thermo-tolerant coliforms at shoreline sites and in surface and bottom waters at offshore sites <250 m and >250 m from the diffuser at Ocean Reef on 07 February 2012**

Sites	Surface	Bottom	EQC (EPA 2005)
<250 m from the diffuser	320	40	14 CFU/100 mL (EQG) 70 CFU/100 mL (EQS)
>250 m from the diffuser	<10 (1)	<10 (1)	
Shoreline	<10 (1)	-	

Note:
1. 10 CFU/100 mL is the lower assay limit for the parameter.



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or EQG

Figure 3.21 Spatial distribution of thermo-tolerant coliform counts in surface and bottom water samples from Ocean Reef, 07 February 2012

Enterococci spp.

- The highest offshore surface count of *Enterococci* spp. was 74 MPN/100 mL at site 32, located directly over the diffuser (Figure 3.22). The next highest counts were 31 MPN/100 mL at site 60 (2154 m northwest), 30 MPN/100 mL at site 31 (147 m west) and 20 MPN/100 mL at site 33 (150 m east). All but two other sites had counts of *Enterococci* spp. <10 MPN/100 mL.
- The highest offshore bottom count of *Enterococci* spp. was 20 MPN/100 mL at sites 33 and 34, located 150 m and 499 m east of the diffuser, respectively (Figure 3.22). At all but five other sites, counts of *Enterococci* spp. were <10 MPN/100 mL.
- All shoreline sites had counts of *Enterococci* spp. <10 MPN/100 mL.
- The median counts for *Enterococci* spp. recorded at shoreline sites and at offshore surface and bottom sites located <250 m and >250 m from the diffuser, and shoreline sites, were below the ANZECC/ARMCANZ (2000) guidelines for primary and secondary contact recreation (Table 3.4).
- Spatial patterns in counts of *Enterococci* spp. (Figure 3.23) showed that for surface waters, concentrations exceeding the ANZECC/ARMCANZ (2000) guideline for primary contact recreation (35 MPN/100 mL) occurred at one site immediately above the diffuser. All other sites in surface and bottom waters had counts of *Enterococci* spp. that were below the ANZECC/ARMCANZ (2000) guideline.

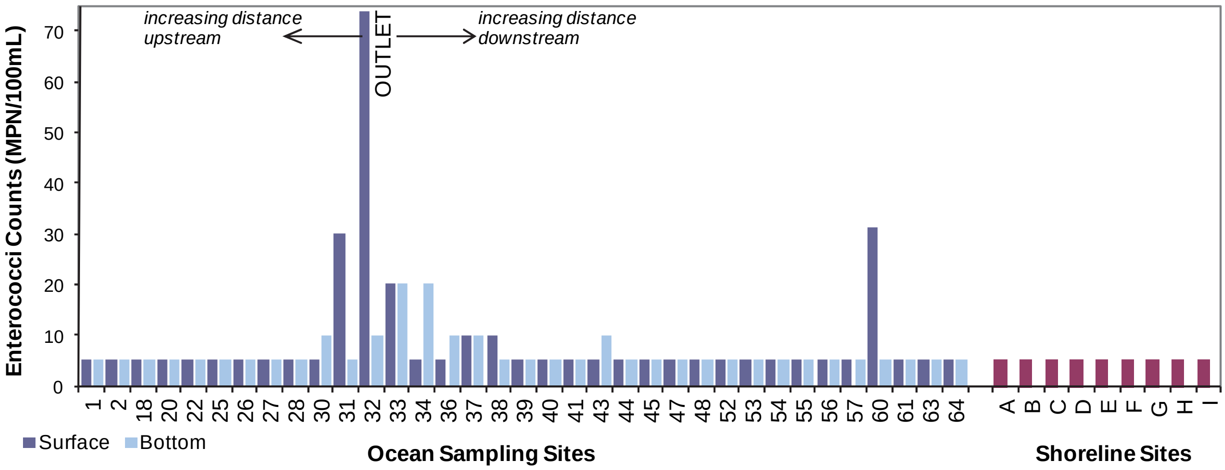
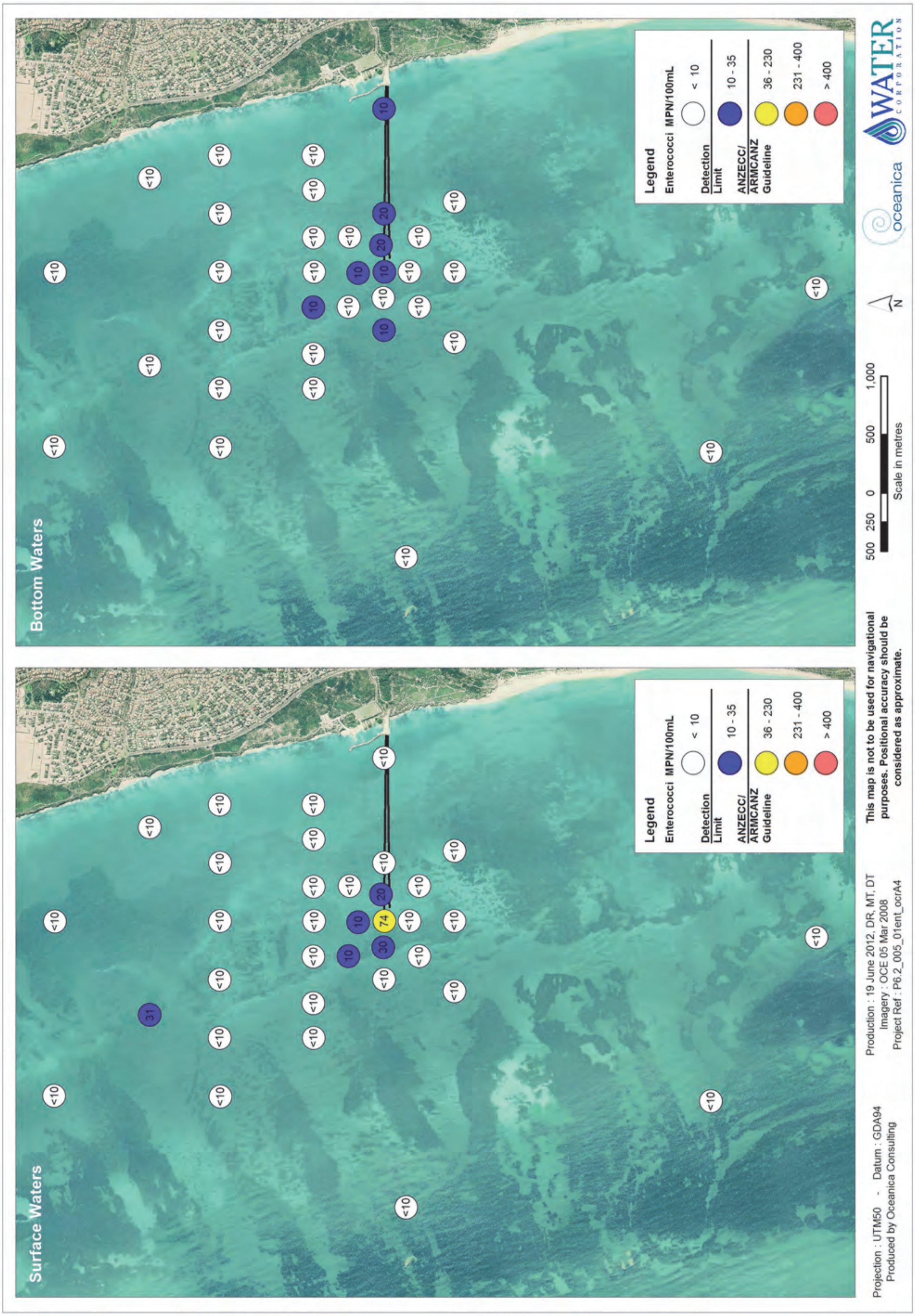


Figure 3.22 **Counts of *Enterococci* spp. at surface, bottom and shoreline sites sampled at Ocean Reef, 07 February 2012**

Table 3.4 **Median counts (MPN 100mL^{-1}) of *Enterococci* spp. at shoreline sites and in surface and bottom waters at offshore sites <250 m and >250 m from the diffuser at Ocean Reef on 07 February 2012**

Sites	Surface	Bottom	ANZECC/ARMCANZ (2000)
<250 m from the diffuser	20	10	35 faecal coliforms/100 mL (1°contact) 230 faecal coliforms/100 mL (2°contact)
>250 m from the diffuser	<10[(1)]	<10[(1)]	
Shoreline	<10[(1)]	-	

Note:
1. 10 MPN/100 mL is the lower assay limit for the parameter.



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 3.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 3.23 Spatial distribution of counts of *Enterococci* spp. in surface and bottom water samples from Ocean Reef, 07 February 2012

3.6 Conclusions

During the survey on 07 February 2012 at Ocean Reef, the treated wastewater plume was initially buoyant (as indicated by the generally higher concentrations of nutrients and microbiological indicators in surface waters than in bottom waters) and was advecting in a northerly direction from the outlet.

The survey provided a one day snapshot of the extent of elevated nutrient concentrations related to the discharge of treated wastewater at the Ocean Reef outlets. Nutrient concentrations in surface and bottom waters were higher near the outlets than at sites located further from the outlets.

The summer water quality surveys were not specifically designed to provide information suitable for comparison with ANZECC/ARMCANZ (2000) guidelines, or with 80^{th} percentile of reference values. For information only, water quality parameters at sites located <250 m and >250 m from the diffuser were compared with the ANZECC/ARMCANZ (2000) guidelines and 80th percentile of reference values. ANZECC/ARMCANZ (2000) suggests that an exceedance of a trigger value should be regarded as an "early warning" and furthermore, that trigger values are not intended as a means of assessing "compliance".

Median concentrations of nitrogen-related nutrients were sometimes above the ANZECC/ARMCANZ (2000) guideline values. In particular, NO_2^-+NO_3^- in surface waters at sites <250 m from the diffuser, sites >250 m from the diffuser and shoreline sites had median concentrations above the 5 µg/L ANZECC/ARMCANZ guideline. Median NO_2^-+NO_3^- concentrations in surface waters at sites <250 m from the diffuser and shoreline sites were also above the 80th percentile of long term reference data (11 µg/L). Median concentrations of NO_2^-+NO_3^- in bottom waters exceeded the ANZECC/ARMCANZ guideline at sites <250 m from the diffuser, but did not exceed the 80th percentile of long term reference data. Ammonia in shoreline waters also had median concentrations which exceeded both the ANZECC/ARMCANZ guideline and the 80th percentile of long term reference data (5 µg/L). Nitrogen is the nutrient limiting primary productivity in Perth's near-shore coastal waters, with nitrogen limitation most pronounced during summer (Lord and Hillman 1995).

The median concentration of ortho-phosphate was above the ANZECC/ARMCANZ (2000) guideline (5 µg/L) and the 80th percentile of long term reference data (8 µg/L) at surface sites <250 m from the diffuser. Median concentrations at shoreline sites were above the ANZECC/ARMCANZ guideline, but below the 80th percentile of long term reference data. In bottom waters, median ortho-phosphate concentrations exceeded the ANZECC/ARMCANZ guideline and the 80th percentile of long term reference data at sites <250 m from the diffuser.

Median concentrations of chlorophyll *a* in surface and bottom waters were below the ANZECC/ARMCANZ (2000) guideline (0.7 µg/L) at sites <250 m and >250 m from the diffuser, and shoreline sites. However, for surface waters <250 m and >250 m from the diffuser, median chlorophyll *a* concentrations were above the 80th percentile of long term reference data (0.4 µg/L). For bottom waters, median concentrations were above the 80th percentile of long term reference data at sites >250 m from the diffuser. Increases in phytoplankton biomass (measured as an increase in chlorophyll *a* concentration) in response to increased nutrient concentrations are not instantaneous. Elevations in phytoplankton biomass are likely to occur downstream from the immediate outlet-mixing environment in a manner that will vary with flow conditions, rather than in the immediate vicinity of the discharge point. This was observed in the 2012 survey, where the highest chlorophyll *a* concentrations in both surface and bottom waters occurred to the north of the diffuser, rather than in the immediate vicinity.

Experience with the PLOOM Program suggests that there is no straightforward mechanism for managing ocean outlets in the open ocean on the basis of establishing guidelines for chlorophyll *a*. General practice has been to manage nutrient impacts by specifying maximum nutrient loads and minimum dilution values. Minimum initial dilutions are specified, which determine maximum contaminant concentrations. These measures identify the extent of influence of the outlet. This approach has been adopted throughout the PLOOM and Perth Coastal Waters Studies.

The microbiological indicators in surface waters showed elevated counts in the immediate vicinity of the diffuser and a decline in counts away from the outlet, indicating die-off of the microbes. Thermo-tolerant coliform counts exceeded the EQG for the maintenance of seafood safe for human consumption in surface and bottom waters <250 m from the diffuser, and exceeded the EQS in surface waters surface waters <250 m from the diffuser. However, the guidelines were met at distances >250 m from the diffuser and at shoreline sites. (Table 3.3, Table 3.5). Counts of *Enterococci* spp. met the guideline for primary contact recreation in all cases (Table 3.4, Table 3.6). Shoreline monitoring found no indication of contamination of any beaches adjacent to the outlets (Table 3.4, Table 3.6).

Table 3.5 Summary comparison of the EPA (2005) EQG with the median concentrations of thermo-tolerant coliforms recorded at shoreline sites and in surface (S) and bottom (B) waters of offshore sites located <250 m and >250 m from the diffuser during the summer water quality survey at Ocean Reef on 07 February 2012

Parameter	Environmental Quality Guideline (EPA 2005) (1)				
	<250 m		>250 m		Shoreline
	S	B	S	B	
Thermo-tolerant coliforms	🟥	🟥	🟩	🟩	🟩

Notes:
1. For the maintenance of seafood safe for human consumption
2. 🟥 = median values > EQG
3. 🟩 = median values ≤ EQG

Table 3.6 Summary comparison of the ANZECC/ARMCANZ (2000) guideline with the median concentrations of *Enterococci* spp. recorded at shoreline sites and in surface (S) and bottom (B) waters of offshore sites located <250 m and >250 m from the diffuser during the summer water quality survey at Ocean Reef on 07 February 2012

Parameter	ANZECC/ARMCANZ (2000) (1)				
	<250 m		>250 m		Shoreline
	S	B	S	B	
Enterococci spp. (1)	🟩	🟩	🟩	🟩	🟩

Notes:
1. Results for primary contact recreation
2. 🟥 = median values > ANZECC/ARMCANZ (2000) guideline
3. 🟩 = median values ≤ ANZECC/ARMCANZ (2000) guideline

The results from the summer water quality survey on 07 February 2012 indicate that the Ocean Reef outlet was operating effectively. The plume of treated wastewater rapidly dissipated. Despite elevated levels of water quality parameters at some individual sites outside the immediate zone of influence of the outlet, the water quality conditions required for ecosystem protection and public health criteria were met.

Summer Water Quality Survey

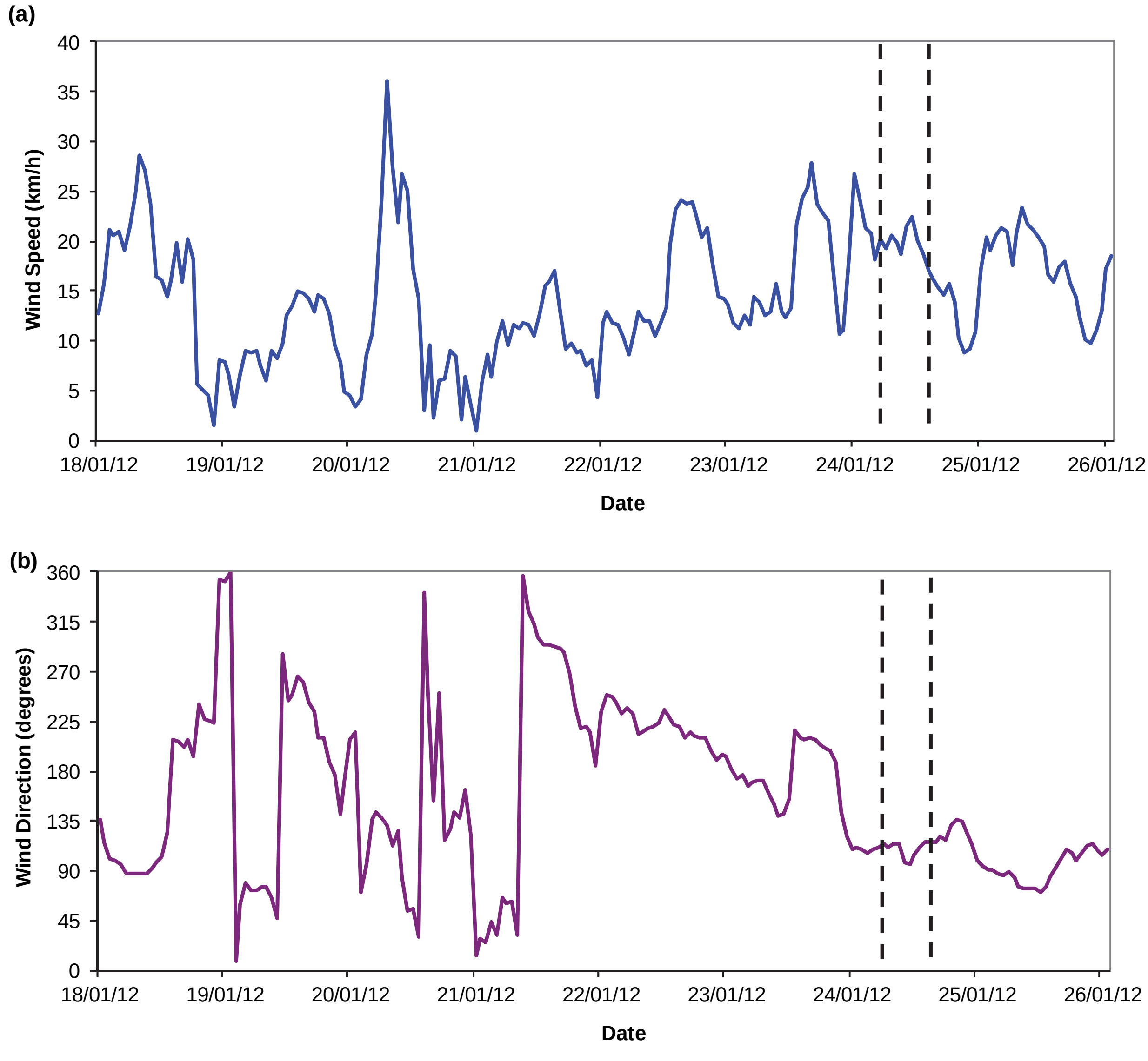
Swanbourne

24 Januray 2012

4. Swanbourne Summer Water Quality Survey – Results and Interpretation

4.1 Wind, wave and tide conditions

The survey at Swanbourne was undertaken on 24 January 2012. For 24 hours prior to the survey, the winds at Swanbourne were gentle southerlies (average 13.6 km/h) increasing to moderate (average 24.0 km/h) then changing to moderate easterlies (average 20.9 km/h). Conditions during the survey were moderate easterlies (average 20.3 km/h) decreasing to gentle (average 16.6 km/h).



Note:
1. Dashed lines (- -) show approximate timing of the summer water quality survey.

Figure 4.1 Half-hourly averages of (a) wind speed and (b) wind direction, prior to and during the summer water quality survey at Swanbourne, 24 January 2012

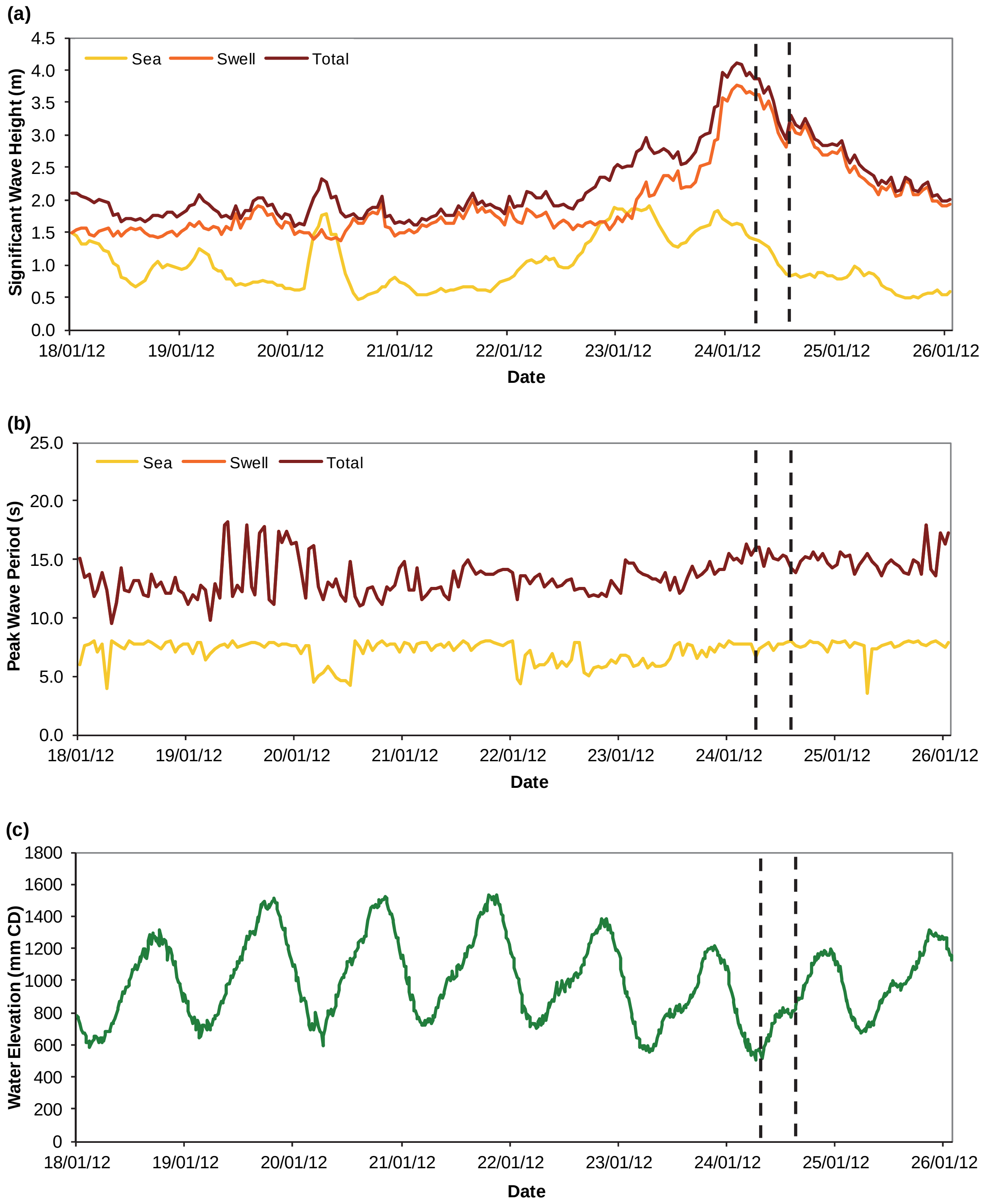
For the 24 hours prior to the survey, the average significant wave height[18] offshore from Rottnest Island was 2.1 m[19], with an average peak wave period[20] of approximately 13.3 s[13] (Figure 4.2a and b). During the survey the average offshore significant wave height

[18] The significant wave height (in metres) is defined as the average height of the highest one-third of waves recorded (Source: http//www.dpi.wa.gov.au/).

[19] All significant wave heights and wave periods presented are for the 'total' wave conditions, that is, the combined sea and swell conditions.

[20] The wave period (in seconds) is the time between consecutive wave crests. The peak wave period is the wave period of those waves that are producing the most energy in a wave record.

increased to 3.3 m and the average peak wave period increased to 15.0 s. The survey was conducted during a rising tide (Figure 4.2c).



Notes:

1. Dashed lines (- -) show approximate timing of the summer water quality survey.
2. For the time period shown, the swell component of peak wave period (graph (b)) exactly matched the total wave period.

Figure 4.2 **(a) Significant wave heights (offshore Rottnest Island), (b) peak wave periods (offshore Rottnest Island) and (c) water level elevation (Fremantle Fishing Boat Harbour), prior to and during the summer water quality survey at Swanbourne, 24 January 2012**

4.2 Discharge from outlet

The characteristics of the treated wastewater from Subiaco WWTP measured from a 24 hour composite sample collected prior to and during the survey at Swanbourne on 24 January 2012 are presented in Table 4.1. At the time of the survey, all 20 ports were operational.

Table 4.1 Characteristics of the Subiaco WWTP treated wastewater on 24 January 2012

Parameter	Concentration/Counts (24/01/2012)
Total phosphorus	6,900 µg/L
Total nitrogen	12,000 µg/L
Ammonium	4,700 µg/L
Nitrate+nitrite	6,600 µg/L
Thermo-tolerant coliforms	270,000 CFU/100 mL
Enterococci spp.	8,700 MPN/100 mL
Total suspended solids	10 mg/L
Biological oxygen demand	5 mg/L
Total flow	69.1 ML/d

4.3 Surface drogue movement

Assessment of drogue movement and calculation of current velocity at Swanbourne was based on the drogue release and pick-up points, as these were the only recorded drogue locations. The drogue was released in the middle of the diffuser and was picked up directly west of the diffuser, travelling at an average velocity of 0.10 m/s (Figure 4.3). Based on drogue movement and wind conditions at the time of the summer water quality survey, it is expected that the discharged treated wastewater would be advecting to the north and offshore of the diffuser.

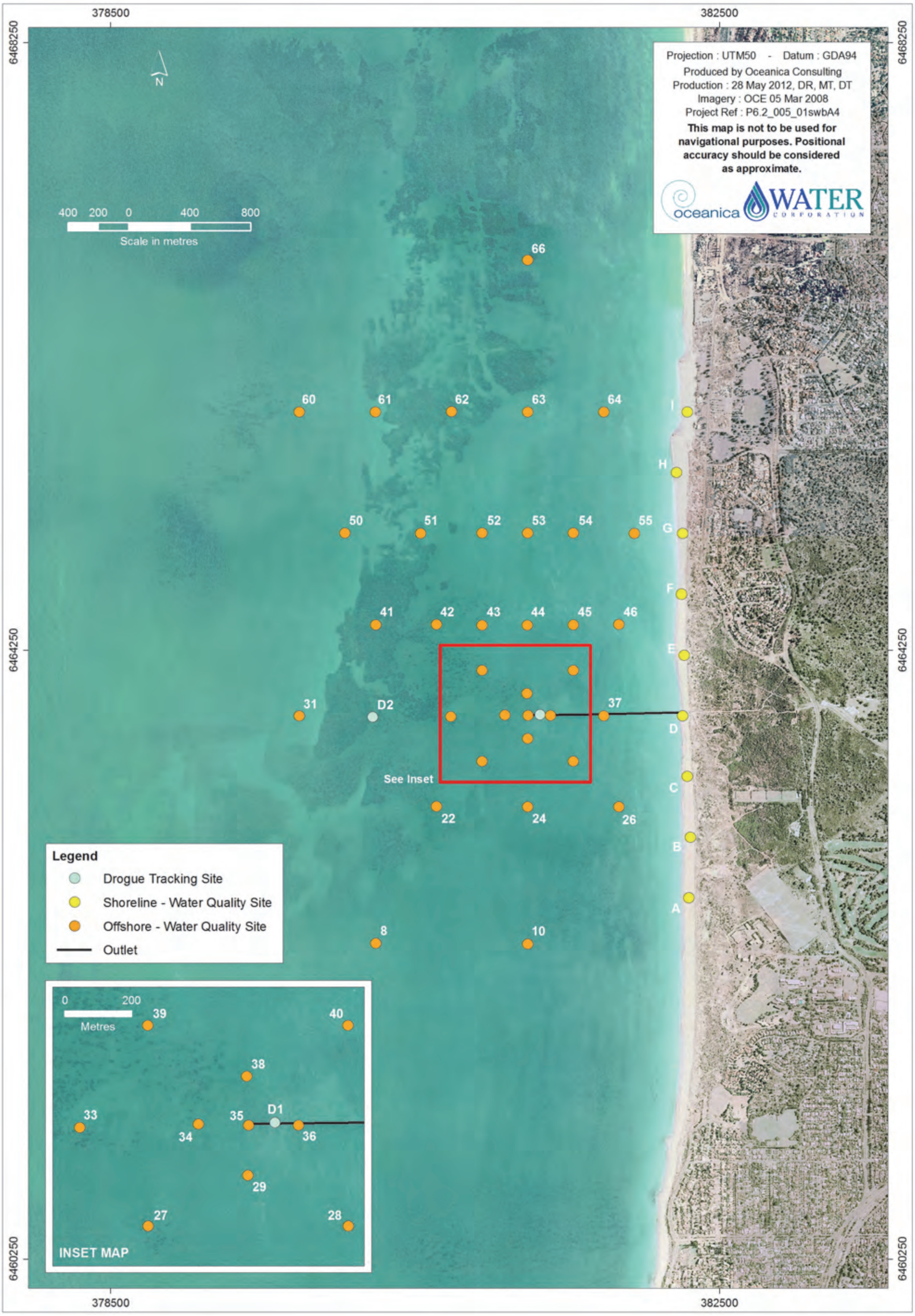


Figure 4.3 Swanbourne ocean outlet summer water quality survey sites and drogue tracking sites, 24 January 2012

4.4 Initial dilution modelling

For the ambient conditions at the time of the summer water quality survey on 24 January 2012, the modelling predicted an average initial dilution of 1:67 and a centreline dilution of 1:44 (Figure 4.4a). The plume was predicted to first reach the surface within approximately 3 m (horizontal distance) from the discharge point (see the ambient boundary[21] of the plume in Figure 4.4b). The full model output is included in Appendix C.

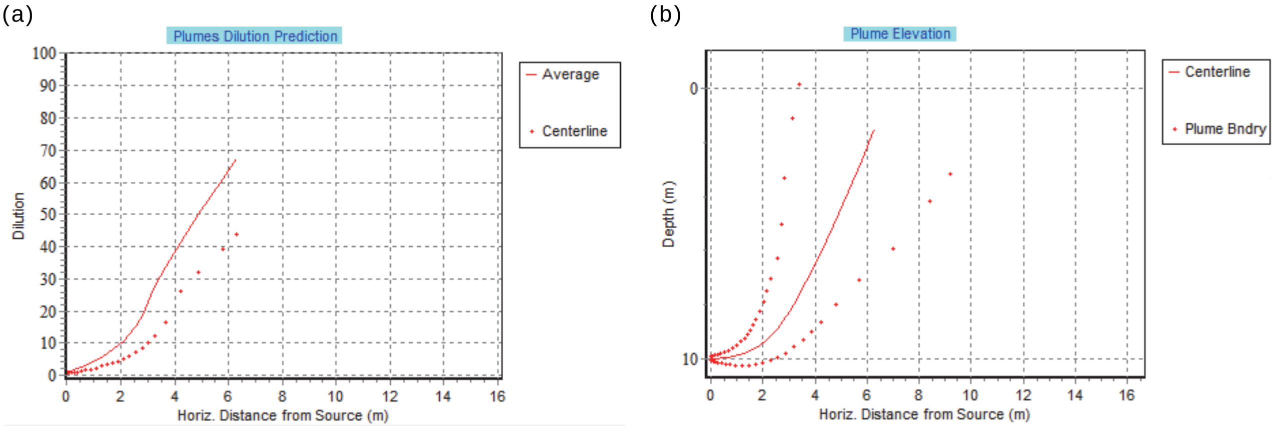


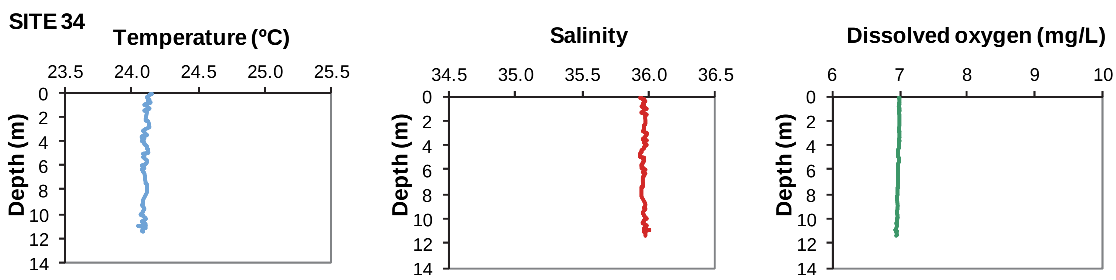
Figure 4.4 UM3 initial dilution modelling results for predicted average and centreline dilutions (a) and predicted plume elevation trajectory (b), during the summer water quality survey at Swanbourne, 24 January 2012

4.5 Water quality

The grid for northerly flow conditions at Swanbourne was sampled during the survey on 24 January 2012, as the drogue moved in a westerly direction (Section 4.3) and prevailing winds were from the southeast (Figure 4.1b). Water samples were collected from the surface and bottom waters of 35 offshore sites and 9 shoreline sites (Figure 4.3). Tables containing the concentrations of all water quality parameters taken during the summer survey are included in Appendix D.

4.5.1 Water column structure

Water column structure was recorded at seven sites (34, 35, 36, 38, 44, 53 and 63). Water temperature varied from 24.05 to 25.35 °C, salinity varied from 35.69 to 36.26[22] and dissolved oxygen varied from 6.69 to 7.16 mg/L (equivalent to 100% to 105% saturation) (Figure 4.5). Profiles showed a decline in temperature between 2 m and 6 m depth of 0.5 °C at site 53 and nearly 1.0 °C at site 63. Temperature at site 44 also showed a decline of 0.5 °C between 2 and 10 m depth. Salinity profiles showed generally constant salinities around 36 at most sites, although site 38 had a layer of less saline water between 0 and 2 m depth. At all sites, dissolved oxygen fluctuated little with depth, remaining steady at approximately 7 mg/L.



[21] *The ambient boundary corresponds to the plume boundary at which concentrations are estimated to be equal to ambient conditions*

[22] *Salinity throughout this report is referred to without units according to the Practical Salinity Scale. On this scale salinity is defined as the ratio of conductivities and therefore cannot have units. Seawater typically has a salinity in the range of 34-36.*

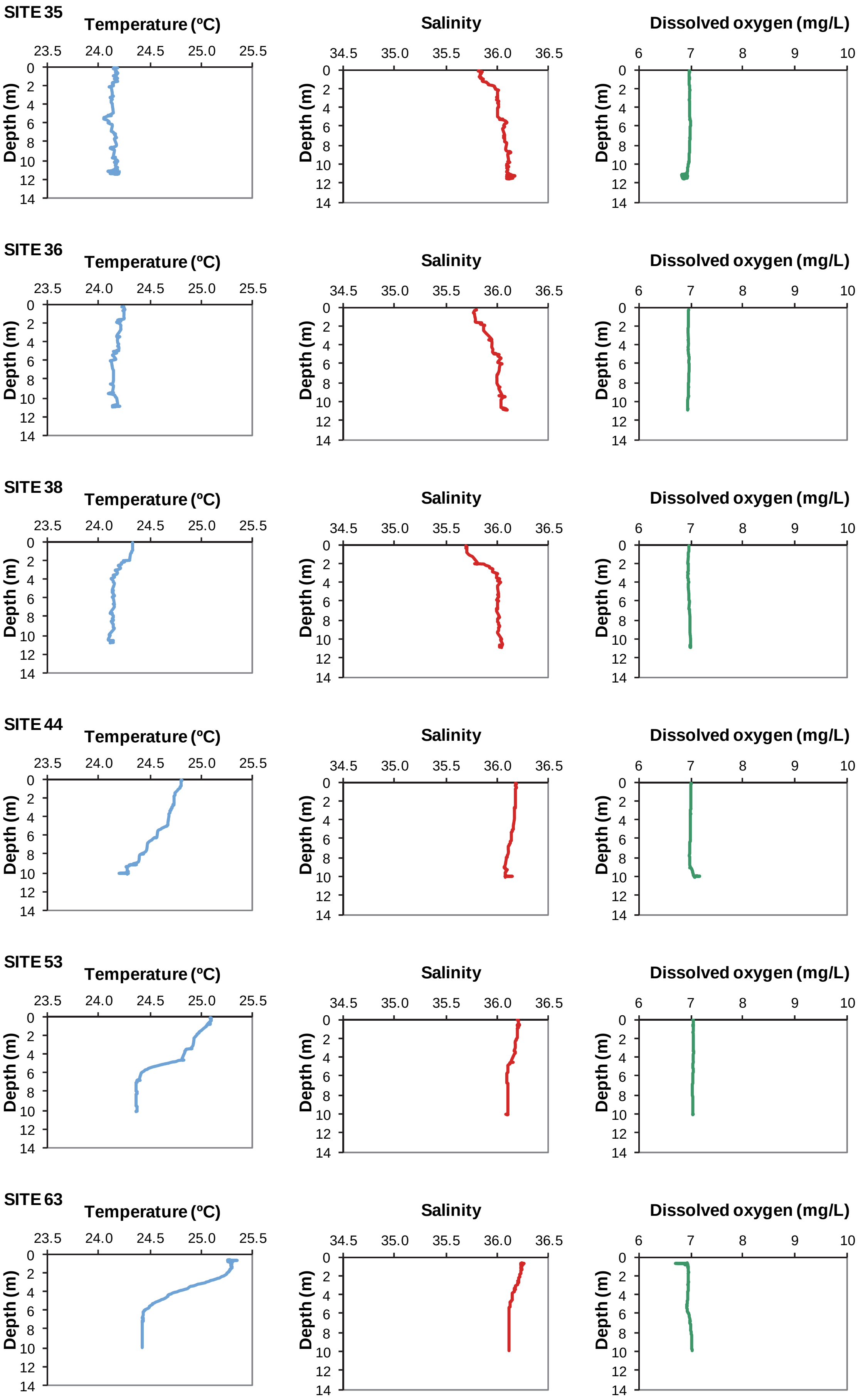
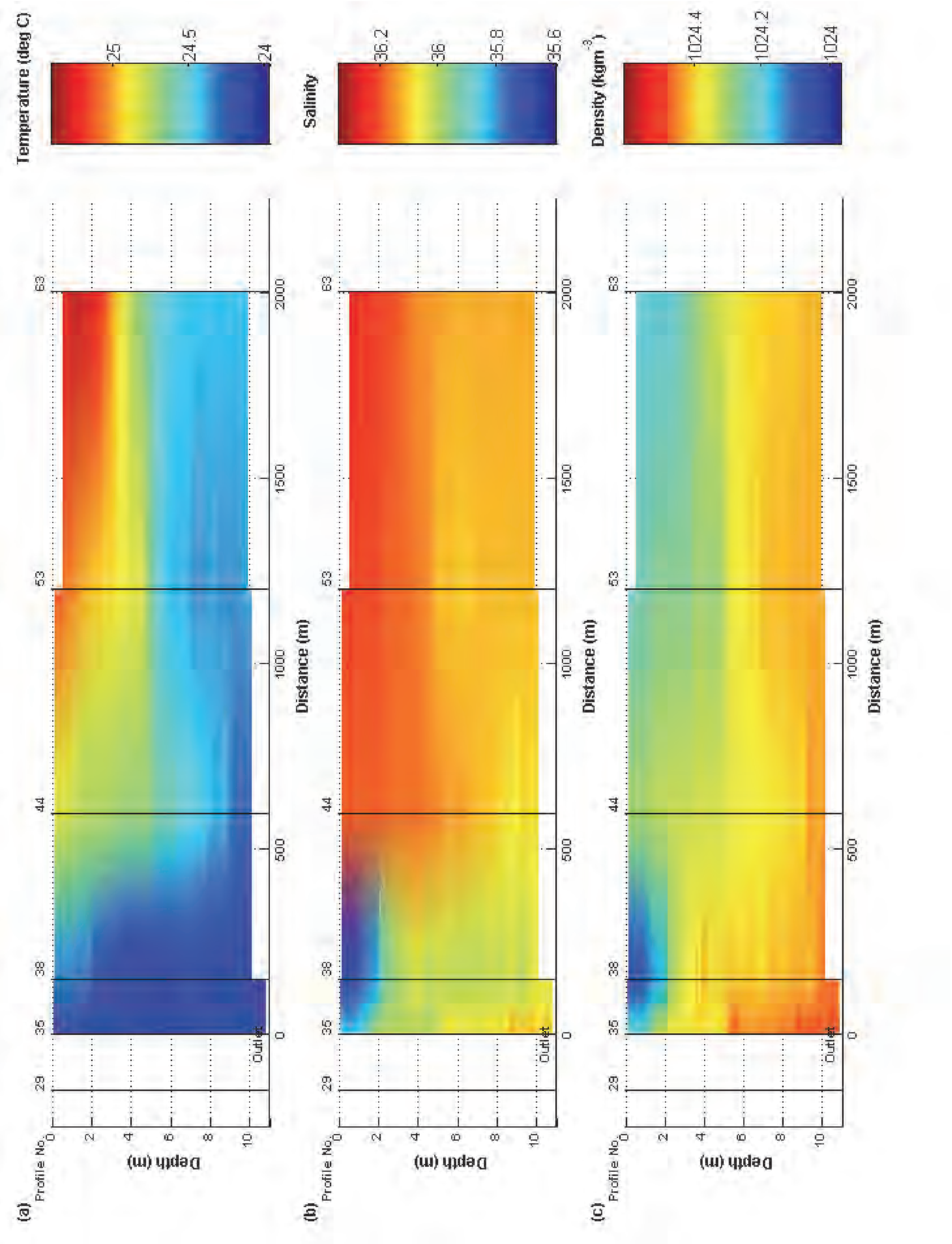


Figure 4.5 **Temperature, salinity and dissolved oxygen vertical profiles at selected sampling sites during the summer water quality survey at Swanbourne, 24 January 2012**

The effect of the discharged wastewater on the physical structure of the water column is illustrated in Figure 4.6. Note that the colour scales used in this figure range from the minimum to the maximum of each parameter, thus exaggerating small differences in measurements. Water temperature was slightly cooler in the immediate vicinity of the outlet, but began increasing at approximately 500 m north (Figure 4.6a). There was a layer of warmer water at the surface, also starting approximately 500 m north of the outlet. Salinity of the water was lower in surface waters immediately above and to the north of the outlet (Figure 4.6b). Water density showed an increasing gradient with depth throughout the transect, however this gradient was most pronounced in the immediate vicinity (within 250 m) of the outlet (Figure 4.6c). The profiles of temperature, salinity and density were taken in a south-north direction and therefore may not have captured the full extent of the discharged wastewater plume.



Note:

1. Water parameters were not sampled at site 29, south of the diffuser.

Figure 4.6 **(a) Temperature, (b) salinity and (c) density profiles along a south to north transect during the summer water quality survey at Swanbourne, 24 January 2012**

4.5.2 Replicate samples

Variance in measurements of water quality parameters may be introduced by small-scale spatial variability in the water column or by variability among laboratory analyses. To examine the range of this variance, three surface samples were collected at site 10 (Table 4.2). The results indicated that in general, the variability amongst replicates was small. The mean value of these replicate samples was used as representative of the water quality parameters at site 10.

Table 4.2 Replicate surface samples from site 10, Swanbourne, 24 January 2012

Parameter	**Ammonia**	**Ortho-phosphate**	**Nitrate+Nitrite**	**Total Phosphorus**	**Total Nitrogen**
Units	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
Reporting Limit	**<3**	**<2**	**<2**	**<5**	**<50**
Surface rep 1	1.5	2	1	12	100
Surface rep 2	1.5	2	1	12	130
Surface rep 3	1.5	2	1	12	100
Mean	*1.5*	*2.0*	*1.0*	*12*	*110*
Parameter	**Chlorophyll** *a* *(Flourometery)*	**Chlorophyll** *a* *(Acetone)*	**Phaeophytin**	**Thermal coliforms**	**Entrococci**
Units	**µg/L**	**µg/L**	**µg/L**	**CFU/100mL**	**MPN/100mL**
Reporting Limit	**<0.1**	**<0.1**	**<0.2**	**<10**	**<10**
Surface rep 1	0.3	0.3	0.1	5	5
Surface rep 2	0.4	0.3	0.1	5	5
Surface rep 3	0.4	0.4	0.1	5	5
Mean	*0.4*	*0.3*	*0.1*	*5*	*5*

Note:
1. Measurements below the reporting limit are listed as half the reporting limit

4.5.3 Nutrient concentrations and distribution

Total Nitrogen (TN)

- In surface waters offshore, the highest concentration of TN, 190 µg/L, was recorded at site 35, located directly above the diffuser (Figure 4.7). The next highest TN concentrations of 180 µg/L were recorded at sites 8 and 38, located 1801 m southwest and 147 m north of the diffuser, respectively.
- The highest offshore bottom water concentration of TN, 290 µg/L, was recorded at site 53, located 1200 m north of the diffuser (Figure 4.7). The next highest concentration was 200 µg/L at site 36, located 151 m east of the diffuser.
- The concentration of TN at all 35 offshore surface sites (100%) and 34 bottom sites (97%) was below the ANZECC/ARMCANZ (2000) guideline for TN of 230 µg/L. Surface concentrations of TN at 29 sites (83%) and bottom concentrations at 25 sites (71%) were below the 80th percentile of reference values (150 µg/L [surface] and 157 µg/L [bottom]).
- At shoreline sites, the highest TN concentration (210 µg/L) was recorded at sites C and G, while the lowest TN concentration (110 µg/L) was recorded at site A. The concentrations of TN at all shoreline sites were below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L.
- There were no distinct spatial patterns in locations of sites with elevated TN concentrations (Figure 4.8), particularly as most sites were below the ANZECC/ARMCANZ (2000) guideline. The one exception was in bottom waters at site 53, located 1200 m north of the diffuser.

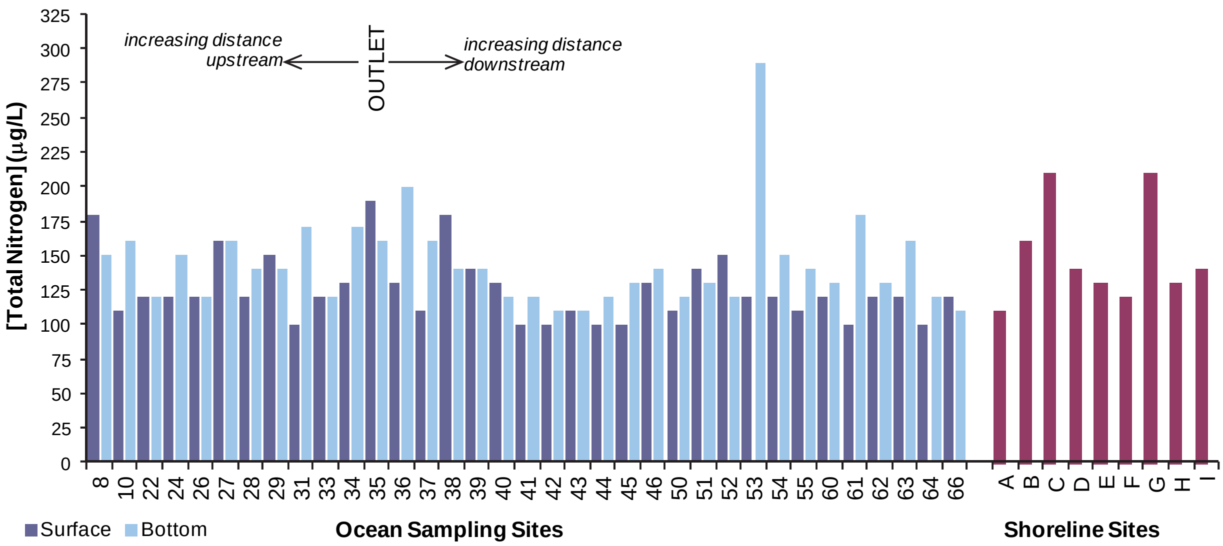
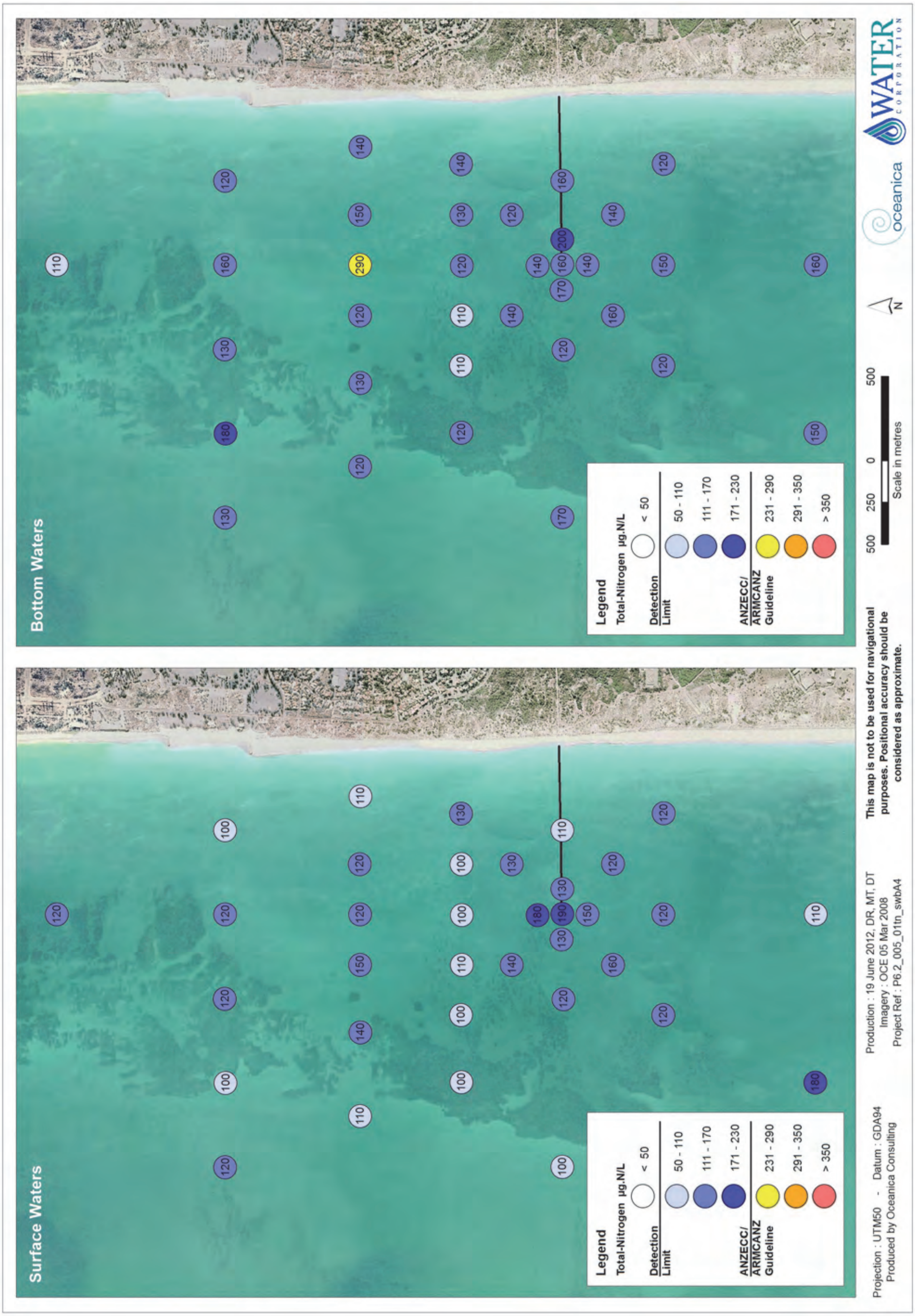


Figure 4.7 Total nitrogen concentrations at surface, bottom and shoreline sites sampled at Swanbourne, 24 January 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 4.8 Spatial distribution of total nitrogen in surface and bottom water samples from Swanbourne, 24 January 2012

Ammonium Nitrogen (NH4+)

- The concentration of NH_4^+ at all offshore surface sites was below the 3 µg/L detection limit (Figure 4.9).
- The highest offshore bottom water NH_4^+ concentration of 30 µg/L was recorded at site 53, located 1200 m north of the diffuser (Figure 4.9). The next highest concentration in bottom waters was 4 µg/L at site 37, located 500 m east of the diffuser. All other sites had NH_4^+ concentrations below the reporting limit (3 µg/L).
- The concentrations of NH_4^+ at all surface sites (100%) were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L, and below the 80th percentile of reference values, 3 µg/L. Concentrations of NH_4^+ at 34 bottom water sites (97%) were below the ANZECC/ARMCANZ (2000) guideline, while 33 sites (94%) were below the reference value.
- NH_4^+ concentrations at shoreline sites ranged from 1.5 - 13 µg/L, with the highest concentration recorded at site C. The concentration of NH_4^+ at 6 shoreline sites (67%) was below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L.
- There were no distinct spatial patterns in the concentration of NH_4^+ in surface or bottom waters, particularly as all sites except bottom waters at site 53 were below the ANZECC/ARMCANZ (2000) guideline (Figure 4.10).

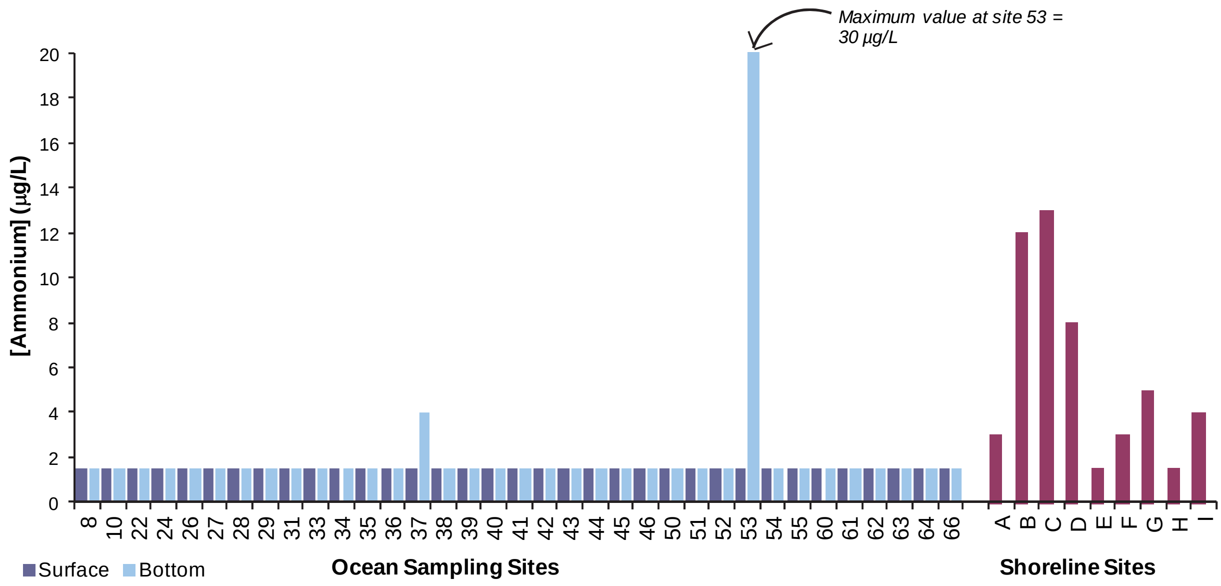
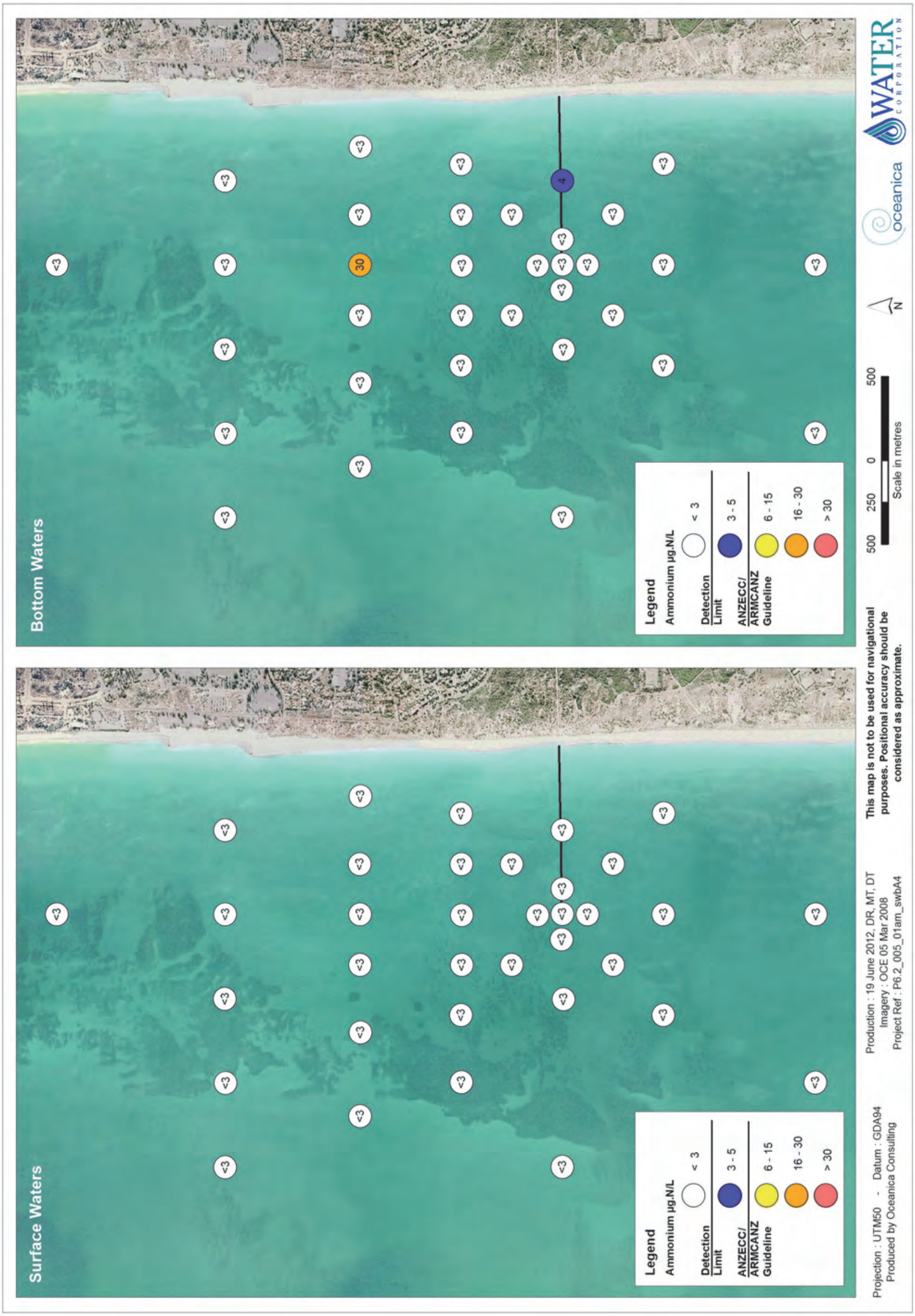


Figure 4.9 Total ammonium concentrations at surface, bottom and shoreline sites sampled at Swanbourne, 24 January 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 4.10 Spatial distribution of ammonium in surface and bottom water samples from Swanbourne, 24 January 2012

Nitrate+Nitrite Nitrogen (NO_2^-+NO_3^-)

- The highest offshore surface concentrations of $NO_2^-+NO_3^-$ were 58 µg/L at site 38 (located 147 m north of the diffuser), 47 µg/L at site 35 (directly above the diffuser) and 30 µg/L at site 29 (149 m south of diffuser) (Figure 4.11).
- The highest offshore bottom concentrations of $NO_2^-+NO_3^-$ were 34 µg/L at site 36 (located 151 m east of the diffuser) and 12 µg/L at site 34, located 149 m west of the diffuser (Figure 4.11).
- The concentrations of $NO_2^-+NO_3^-$ at 24 surface sites (69%) and 29 bottom sites (83%) were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Surface concentrations of $NO_2^-+NO_3^-$ at 20 sites (57%) and bottom concentrations at 25 sites (71%) were below the 80th percentile of reference values, 3 µg/L (surface and bottom).
- The concentration of $NO_2^-+NO_3^-$ at shoreline sites ranged from 2 µg/L (site I) to 10 µg/L (site G). Four shoreline sites had $NO_2^-+NO_3^-$ concentrations above the ANZECC/ARMCANZ (2000) guideline (sites A, E, F, G); the remaining sites were below the guideline.
- Spatial patterns in $NO_2^-+NO_3^-$ concentrations (Figure 4.12) revealed localised increases above the ANZECC/ARMCANZ (2000) guideline of 5 µg/L in surface and bottom waters nearby and to the north and west of the diffuser.

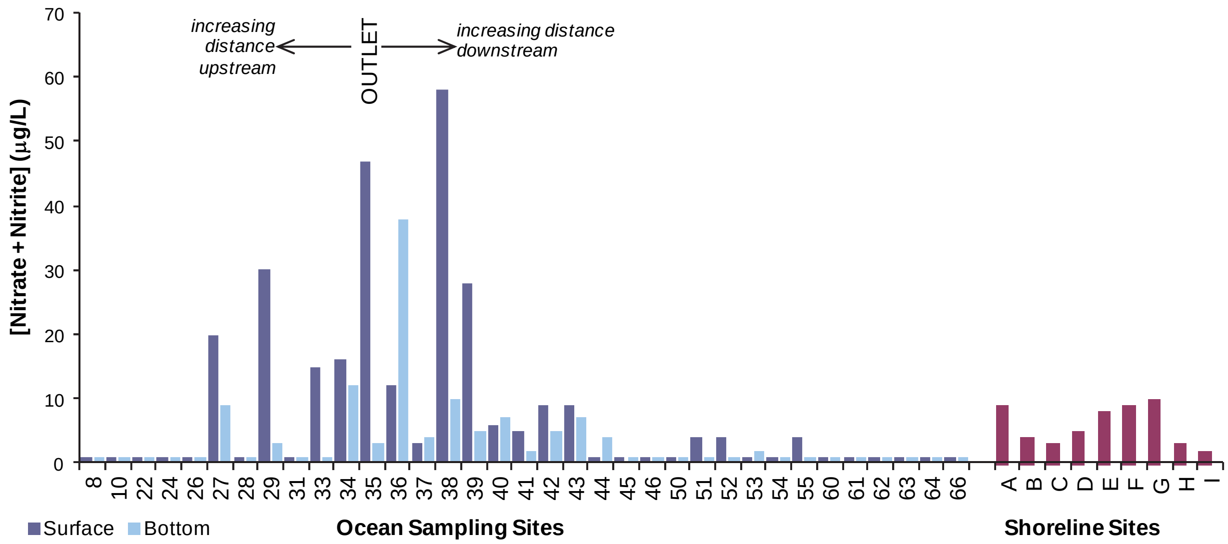
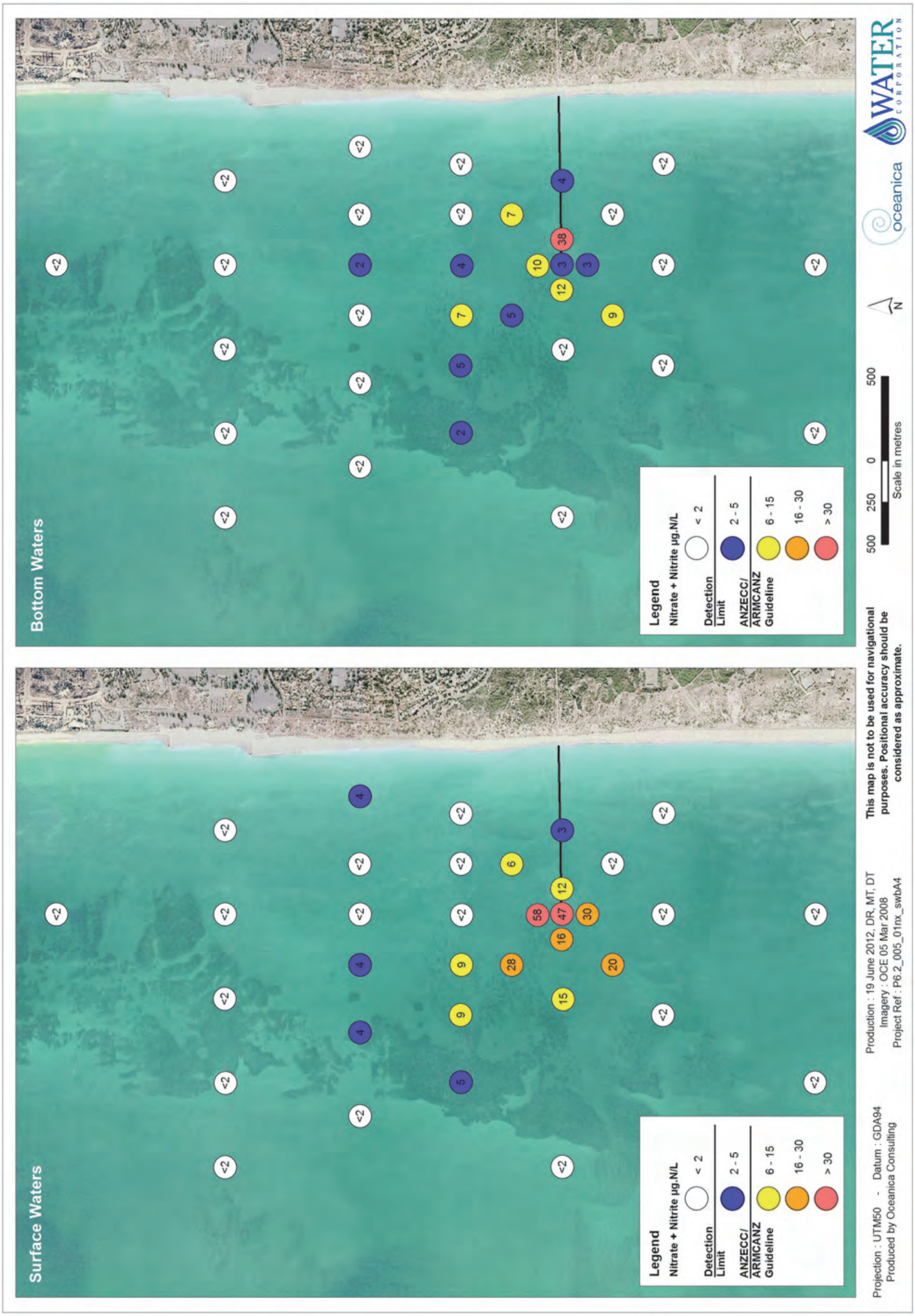


Figure 4.11 Total nitrate+nitrite concentrations at surface, bottom and shoreline sites sampled at Swanbourne, 24 January 2012



Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 4.12 Spatial distribution of nitrate+nitrite in surface and bottom water samples from Swanbourne, 24 January 2012

Total Phosphorus (TP)

- The three highest offshore surface concentrations of TP were 65 µg/L at site 38, 59 µg/L at site 35 and 36 µg/L at site 29 (Figure 4.13). Sites 38, 35 and 29 were located 147 m north, directly above, and 149 m south of the diffuser, respectively.
- The highest offshore bottom concentration of TP was 50 µg/L at site 36, located 151 m east of the diffuser. TP concentrations in bottom waters at all other sites ranged from 11 µg/L to 22 µg/L.
- The concentration of TP at 27 surface sites (77%) and 31 bottom sites (89%) were below the ANZECC/ARMCANZ (2000) guideline of 20 µg/L. Surface concentrations of TP at 32 sites (91%) and bottom concentrations 34 sites (97%) were below the 80th percentile of reference values (33 µg/L [surface] and 34 µg/L [bottom]).
- The TP concentrations at shoreline sites ranged between 21 µg/L and 25 µg/L. All sites were above the ANZECC/ARMCANZ (2000) guideline of 20 µg/L.
- Spatial patterns in TP concentrations (Figure 4.14) revealed localised increases above the ANZECC/ARMCANZ (2000) guideline in surface and bottom waters nearby the diffuser, and in surface waters west of the diffuser.

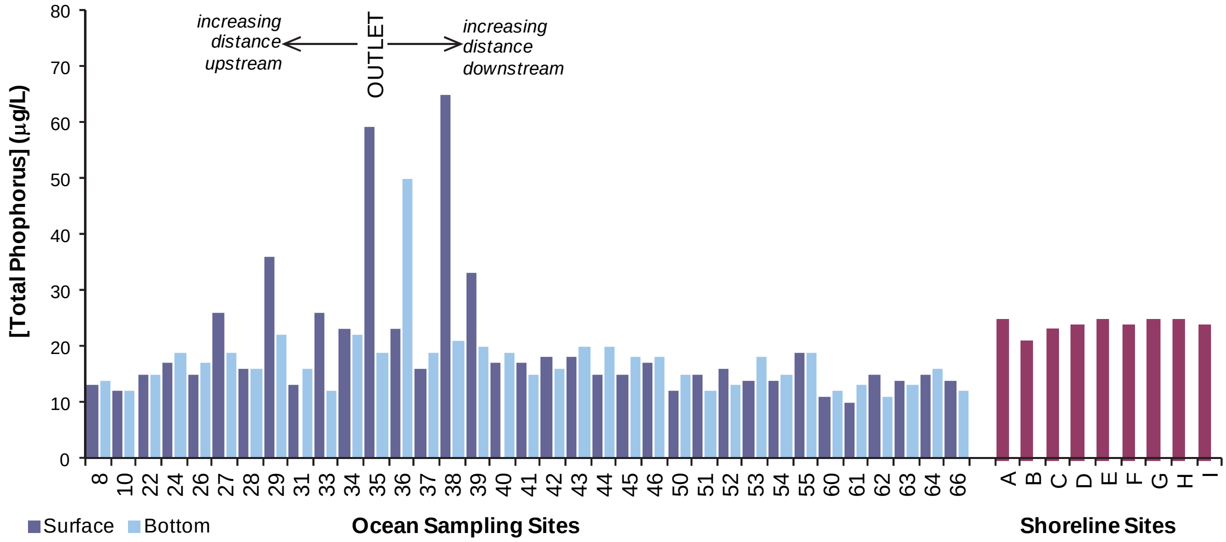
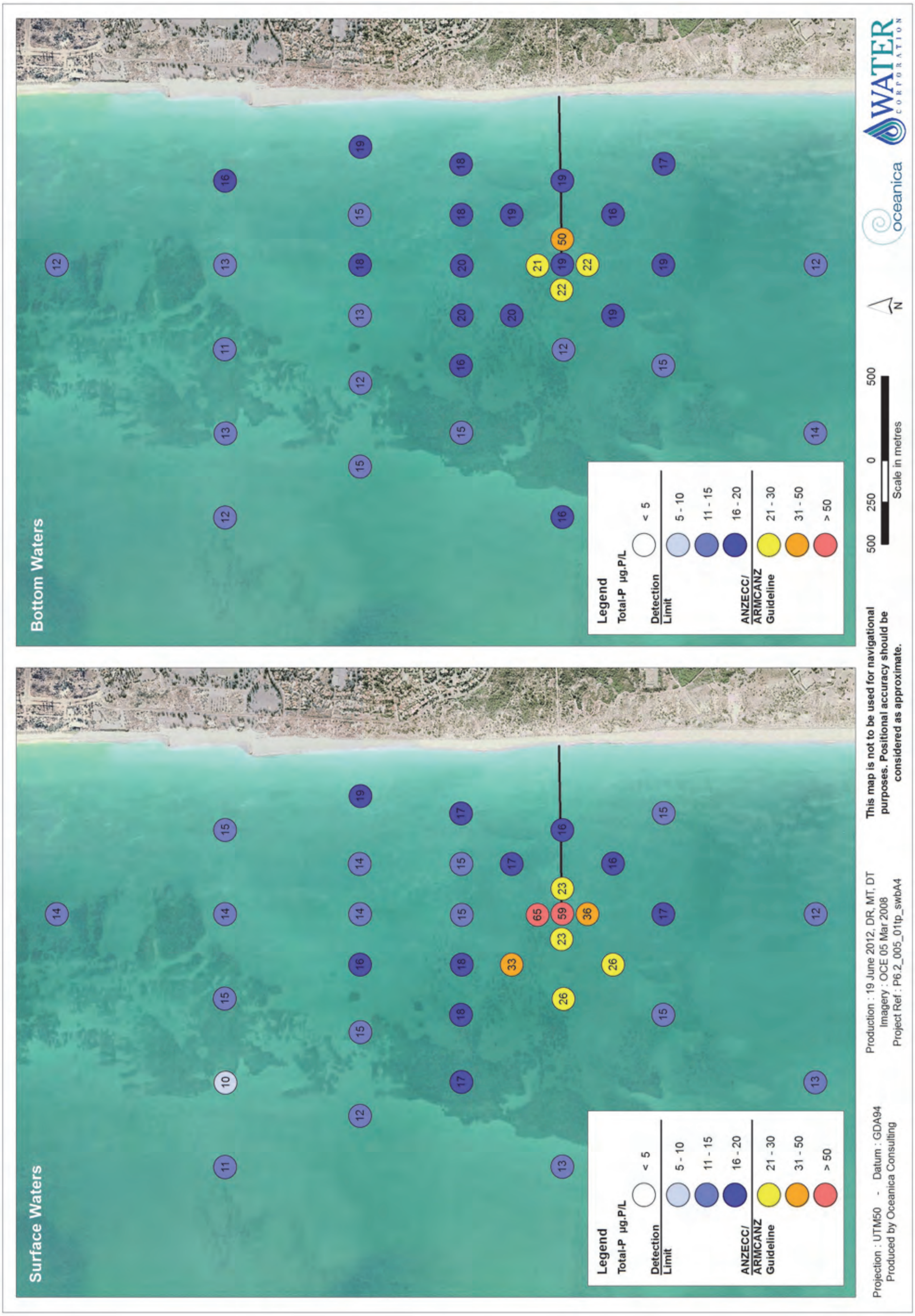


Figure 4.13 **Total phosphorus concentrations at surface, bottom and shoreline sites sampled at Swanbourne, 24 January 2012**



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 4.14 Total phosphorus concentrations at surface, bottom and shoreline sites sampled at Swanbourne, 24 January 2012

Ortho-phosphate

- The highest offshore surface concentrations of ortho–phosphate were 50 µg/L at site 38, 43 µg/L at site 35 and 23 µg/L at site 29 (Figure 4.15). Sites 38, 35 and 29 were located 147 m north, directly above, and 149 m south of the diffuser, respectively.
- The highest offshore bottom concentrations of ortho–phosphate were 34 µg/L at site 36 (151 m east of the diffuser) and 8 µg/L at sites 34 and 38 (149 m west and 147 m north of the diffuser, respectively; Figure 4.15).
- The concentrations of ortho–phosphate at 22 surface sites (63%) and 28 bottom sites (80%) were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Surface concentrations of ortho–phosphate at 25 sites (71%) and bottom concentrations at 28 sites (80%) were below the 80th percentile of reference values, 6 µg/L (surface and bottom waters).
- The concentration ortho–phosphate at shoreline sites ranged from 6 to 10 µg/L. All shoreline sites had ortho–phosphate concentrations above the ANZECC/ARMCANZ (2000) guideline.
- Spatial patterns in ortho–phosphate concentrations (Figure 4.16) revealed localised increases above the ANZECC/ARMCANZ (2000) guideline in surface and bottom waters nearby and to the north of the diffuser. Concentrations in surface waters at some sites west of the diffuser also exceeded the ANZECC/ARMCANZ (2000) guideline.

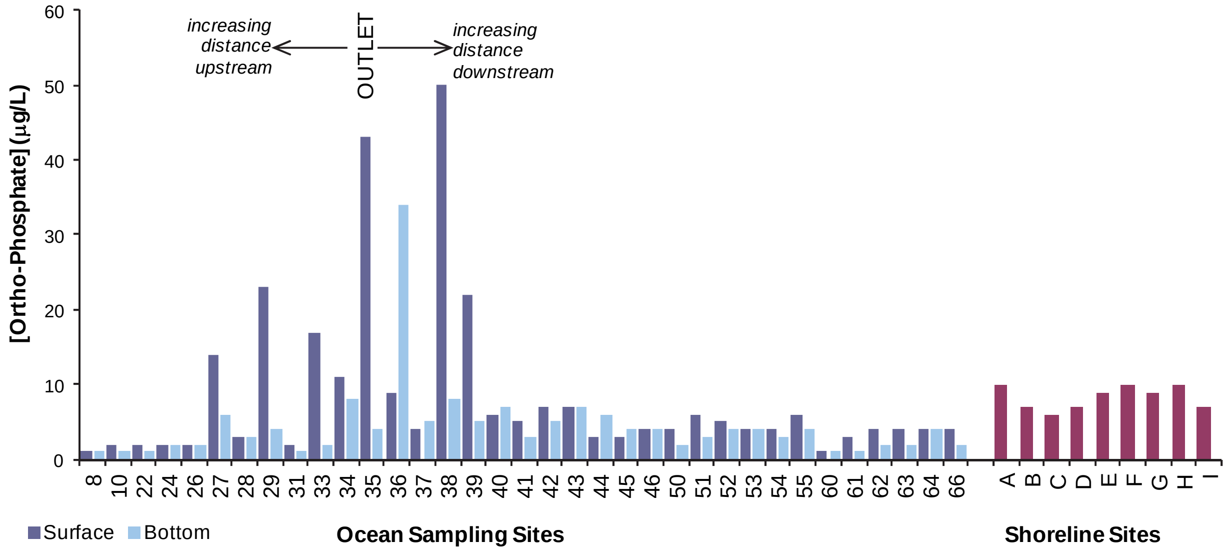
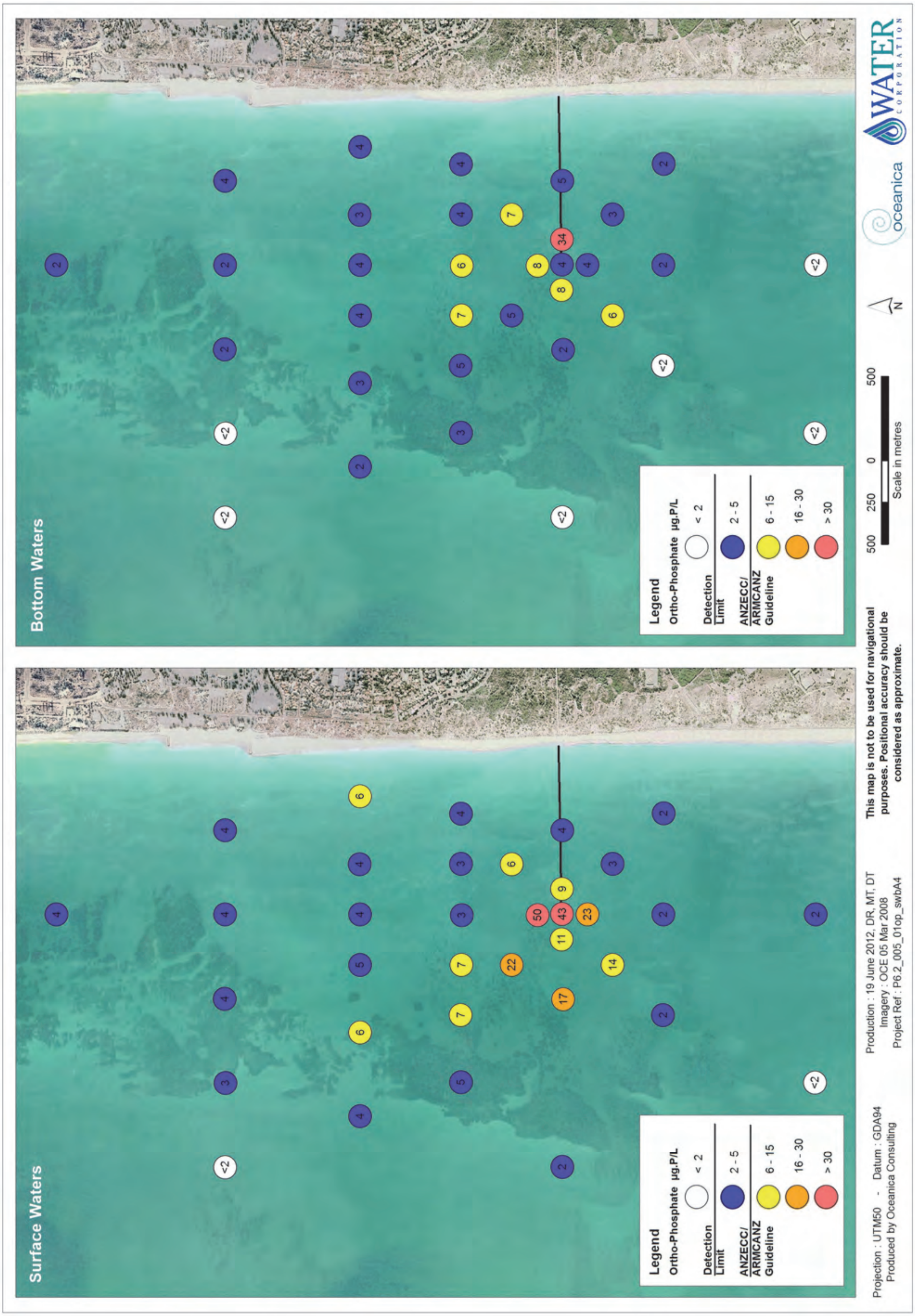


Figure 4.15 Ortho–phosphate concentrations at surface, bottom and shoreline sites sampled at Swanbourne, 24 January 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 4.16 Spatial distribution of ortho-phosphate concentrations in surface and bottom water samples from Swanbourne, 24 January 2012

4.5.4 Phytoplankton biomass and distribution

Phaeophytin

- Phaeophytin concentrations were measured in offshore surface waters at five sites (10, 31, 54, 55 and 66). Concentrations for all offshore sites were below the 0.2 µg/L detection limit.
- Phaeophytin levels were also measured at the nine shoreline sites, where concentrations were 0.3 µg/L at site B, 0.5 µg/L at site C, and 0.4 µg/L at all other sites.

Chlorophyll a

- Note: Chlorophyll a concentrations at surface and bottom offshore sites were determined in-situ using a fluorometer. The chlorophyll a concentration at shoreline sites were analysed using acetone extraction.
- Offshore surface and bottom concentrations of chlorophyll *a* varied between <0.1 µg/L and 0.9 µg/L (Figure 4.17). The highest concentration in surface waters was 0.8 µg/L at site 33, located 504 m west of the diffuser. The highest concentration in bottom waters was 0.9 µg/L at site 55, located 1389 m northeast of the diffuser.
- The concentrations of chlorophyll *a* at 34 surface sites (97%) and 32 bottom sites (91%) were below the ANZECC/ARMCANZ (2000) guideline (0.7 µg/L). Surface concentrations of chlorophyll *a* at 25 surface sites (71%) and 26 bottom sites (74%) were below the 80th percentile of reference values, 0.50 µg/L (surface and bottom waters).
- The chlorophyll *a* concentrations at shoreline sites ranged from 0.5 to 0.8 µg/L. All shoreline sites were below the ANZECC/ARMCANZ (2000) guideline for chlorophyll *a* of 0.7 µg/L., except for site C.
- Spatial patterns in chlorophyll *a* concentrations in bottom waters (Figure 4.18) revealed that localised increases above the ANZECC/ARMCANZ (2000) guideline occurred to the northeast of the diffuser. Only one surface site (33) had a TN concentration that was above the ANZECC/ARMCANZ (2000) guideline.

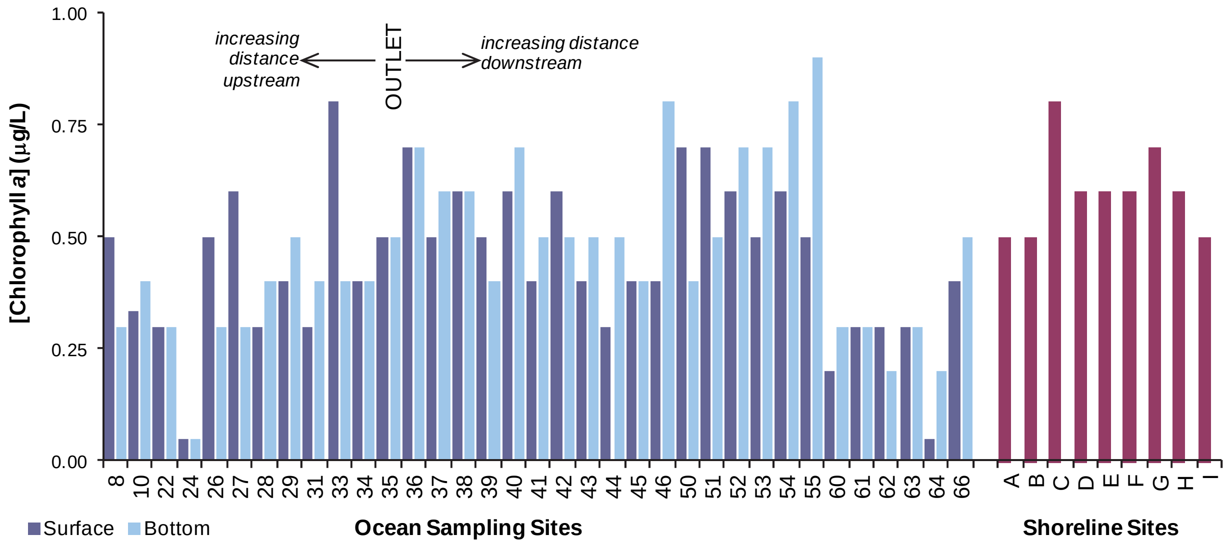
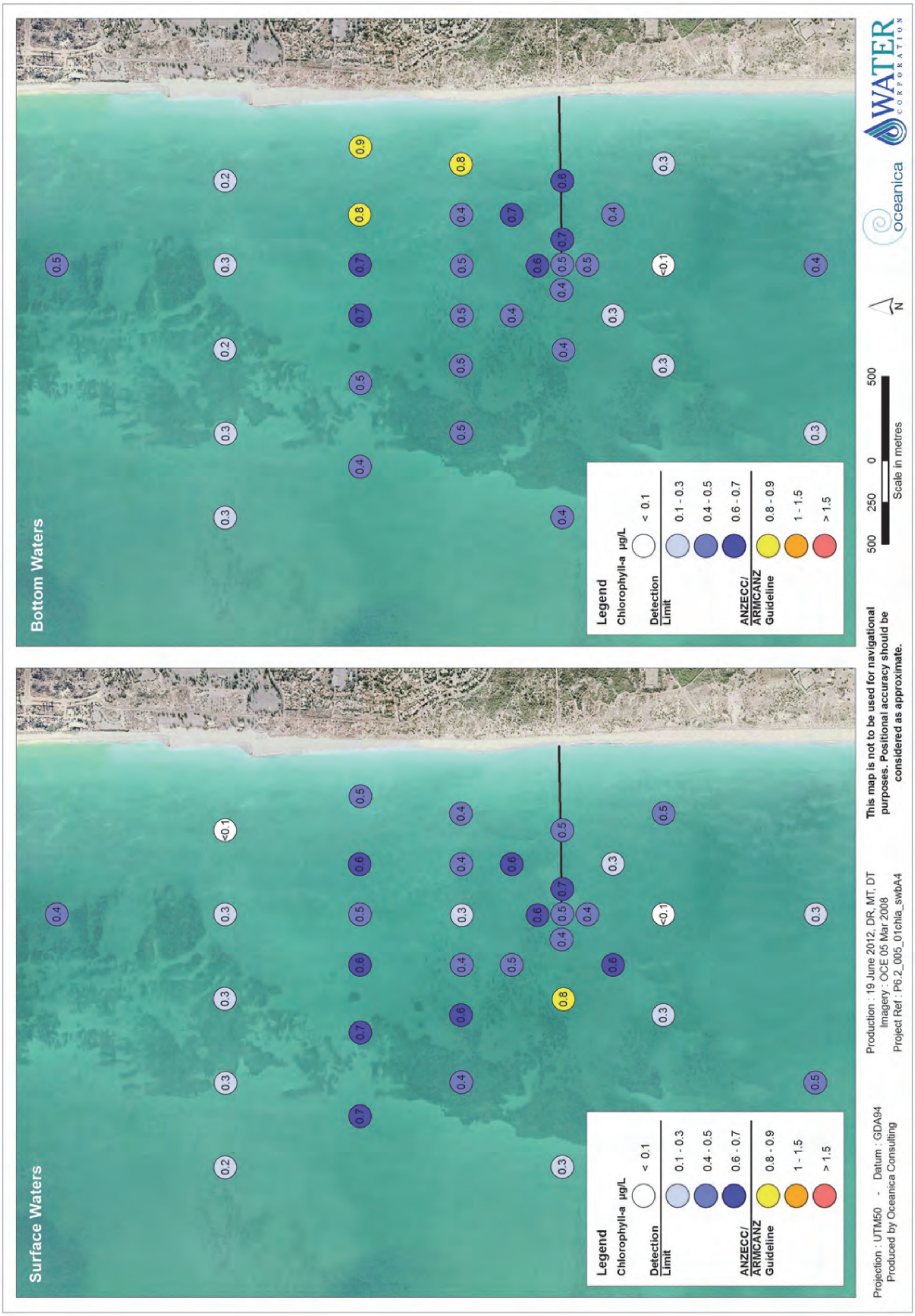


Figure 4.17 Chlorophyll *a* concentrations at surface, bottom and shoreline sites sampled at Swanbourne, 24 January 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 4.18 Spatial distribution of chlorophyll *a* concentrations in surface and bottom water samples from Swanbourne, 24 January 2012

4.5.5 Bacterial counts and distribution

Thermo–tolerant coliforms (TTC)

- The highest offshore surface count of TTC was 650 CFU/100 mL at site 35, located directly above the diffuser. The next highest TTC counts were 440 CFU/100 mL at site 36 (151 m east of diffuser) and 340 CFU/100 mL at site 38 (147 m north of the diffuser) (Figure 4.19).
- The highest offshore bottom count of TTC was 60 CFU/100 mL at site 36, located 151 m east of the diffuser (Figure 4.19). The next highest TTC count in bottom waters was 10 CFU/100 mL at sites 29, 35 and 38. These sites were located 149 m south, directly above, and 147 m north of the diffuser, respectively. All other sites had TTC counts <10 CFU/100 mL.
- All shoreline sites had TTC counts <10 CFU/100 mL, except site A, which had a TTC count of 10 CFU/100 mL.
- The median counts for TTC in surface waters in the immediate vicinity of the diffuser (<250 m) exceeded the EQG and EQS for safe seafood consumption. The median counts for TTC in bottom waters <250 m from the diffuser, surface and bottom waters >250 m from the diffuser, and shoreline waters were below the EQG and EQS guidelines.
- Spatial patterns in offshore TTC counts (Figure 4.20) revealed elevated counts exceeding the EQS for secondary contact (70 CFU/100 mL) in surface waters in the immediate vicinity of the diffuser. In bottom waters, TTC counts above the EQG for primary contact (14 CFU/100 mL) occurred at site 36, located 151 m east of the diffuser. Sites outside the immediate vicinity of the diffuser did not have elevated TTC counts.

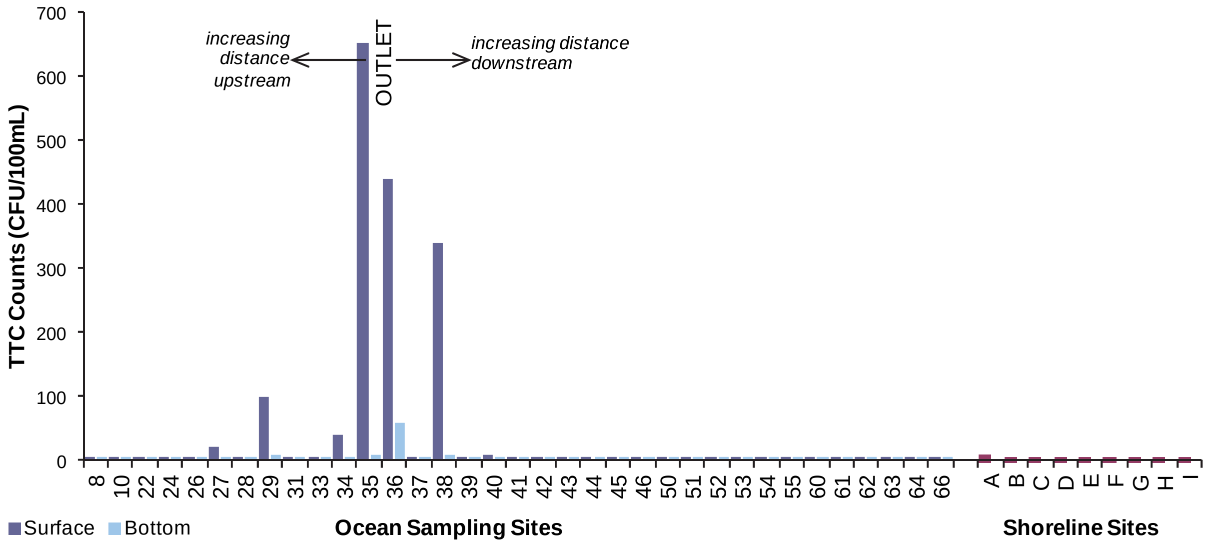
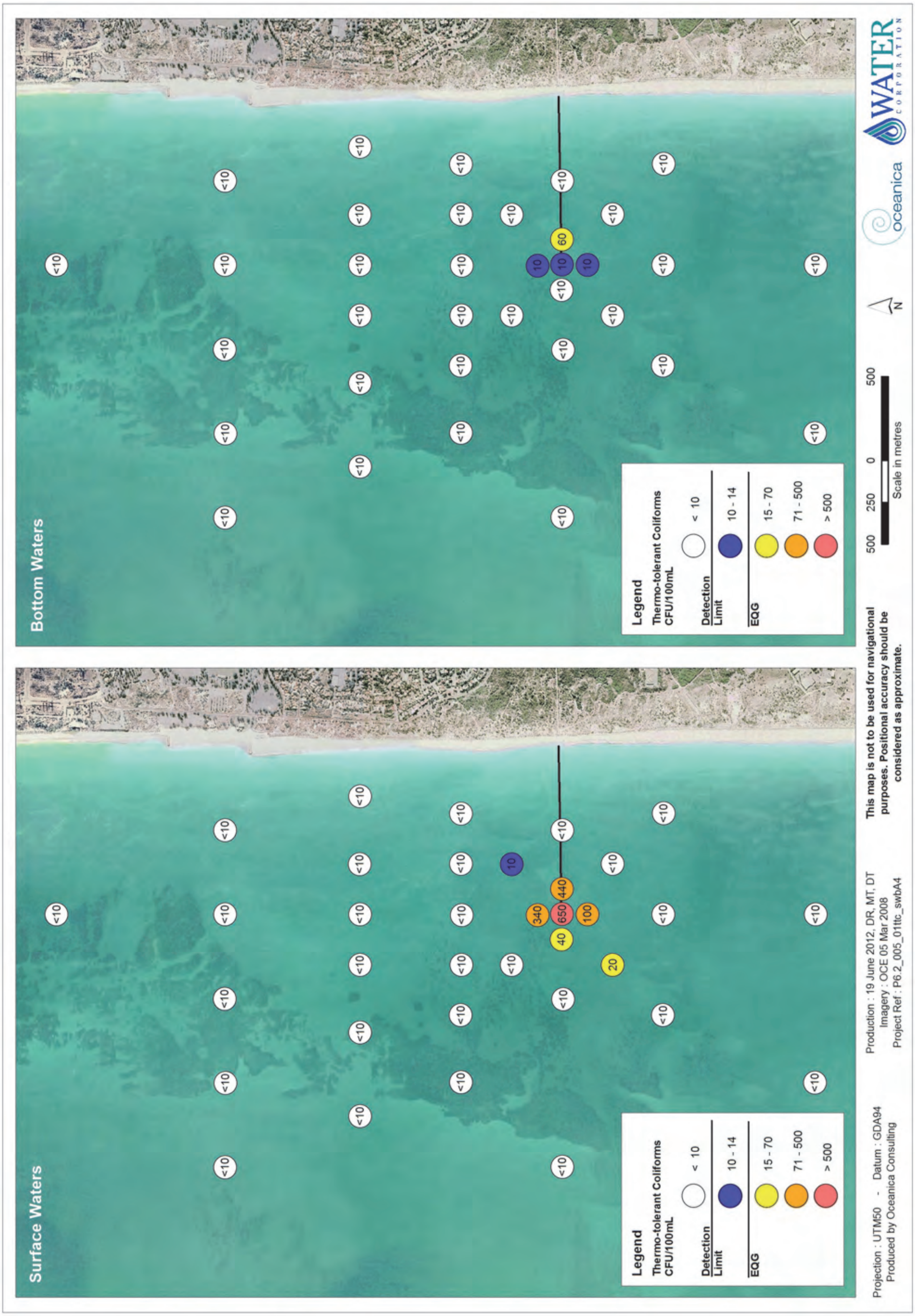


Figure 4.19 Thermo-tolerant coliform counts at surface, bottom and shoreline sites sampled at Swanbourne, 24 January 2012

Table 4.3 Median counts (CFU/100 mL) of thermo-tolerant coliforms at shoreline sites and in surface and bottom waters at offshore sites <250 m and >250 m from the diffuser at Swanbourne on 24 January 2012

Sites	Surface	Bottom	EQC (EPA 2005)
<250 m from the diffuser	340	10	14 CFU/100 mL (EQG) 70 CFU/100 mL (EQS)
>250 m from the diffuser	<10(1)	<10(1)	
Shoreline	<10(1)	-	

Note:
1. 10 CFU/100 mL is the lower assay limit for the parameter.



Notes:
1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or EQG

Figure 4.20 Spatial distribution of thermo-tolerant coliform counts in surface and bottom water samples from Swanbourne, 24 January 2012

Enterococci *spp.*

- The highest offshore surface count of *Enterococci* spp. was 52 MPN/100 mL at sites 35 and 36, located directly above and 151 m east of the diffuser, respectively. The next highest count of *Enterococci* spp. was 20 MPN/100 mL at sites 29 and 38, located 149 m south and 147 m north of the diffuser, respectively. At all other sites, counts of *Enterococci* spp. in surface waters were below the 10 MPN/100 mL detection limit (Figure 4.21).
- The highest bottom count of *Enterococci* spp. was 20 MPN/100 mL at site 35, located directly above the diffuser. At all other sites, counts of *Enterococci* spp. in bottom waters were equal to or below the 10 MPN/100 mL detection limit (Figure 4.21)
- All shoreline sites had counts of *Enterococci* spp. of <10 MPN/100 mL (Figure 4.21).
- The median counts for *Enterococci* spp. recorded at shoreline sites, and in surface and bottom waters at all offshore sites were below the ANZECC/ARMCANZ (2000) guidelines for primary and secondary contact recreation (Table 4.4).
- Spatial patterns in offshore counts of *Enterococci* spp. (Figure 4.22) revealed localised increases above the ANZECC/ARMCANZ (2000) guidelines at surface waters in the immediate vicinity of the diffuser. No other sites had concentrations that exceeded the guidelines.

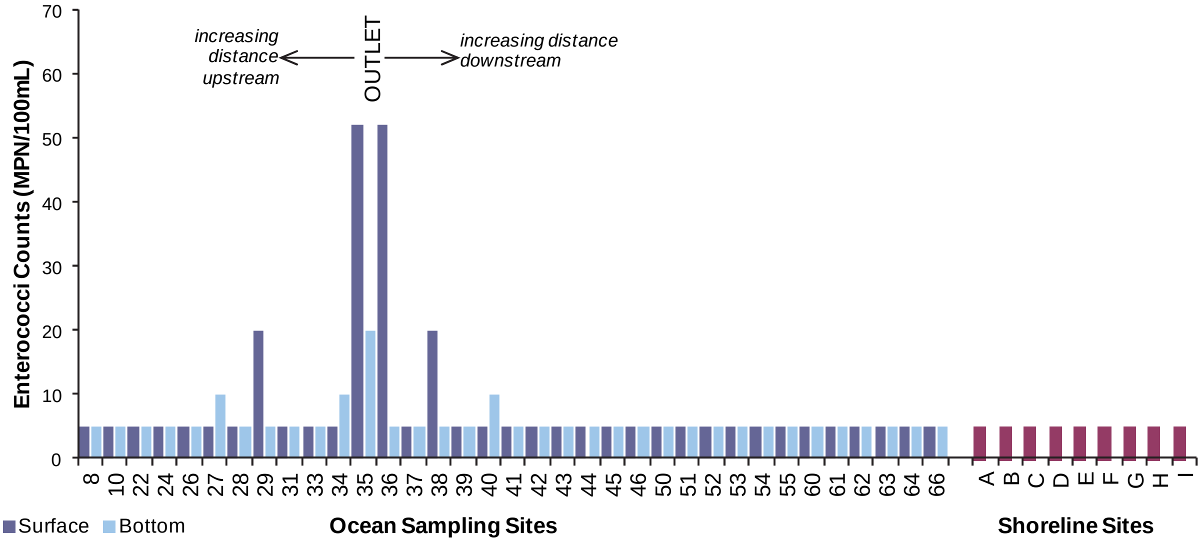
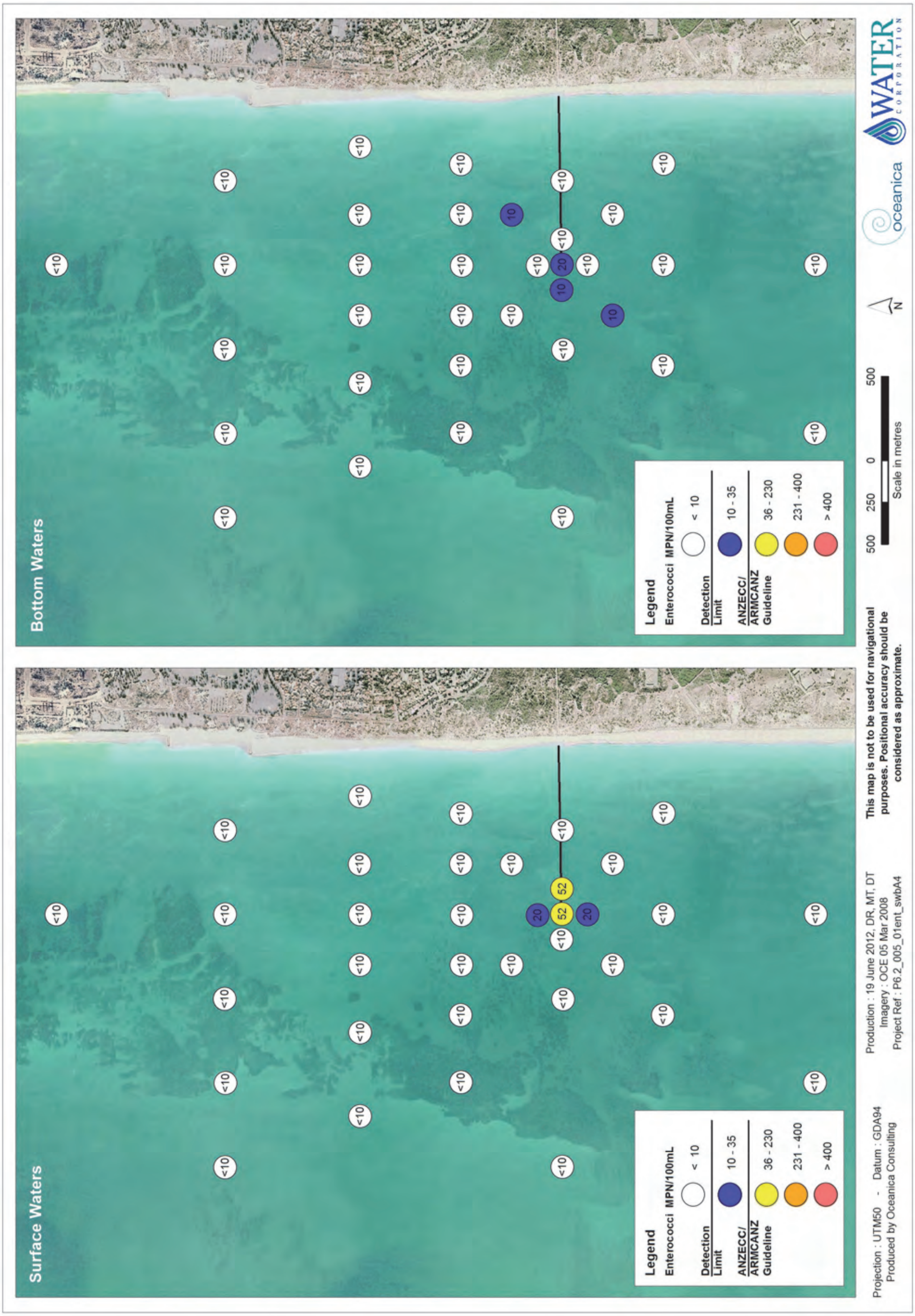


Figure 4.21 **Counts of *Enterococci* spp. at surface, bottom and shoreline samples at Swanbourne, 24 January 2012**

Table 4.4 **Median counts (MPN/100 mL) of *Enterococci* spp. at shoreline sites and in surface and bottom waters at offshore sites <250 m and >250 m from the diffuser at Swanbourne on 24 January 2012**

Sites	Surface	Bottom	ANZECC/ARMCANZ (2000)
<250 m from the diffuser	20	<10(1)	35 faecal coliforms/100 mL (1° contact) 230 faecal coliforms/100 mL (2° contact)
>250 m from the diffuser	<10(1)	10(1)	
Shoreline	<10(1)	-	

Note:
1. 10 MPN/100 mL is the lower assay limit for the parameter.



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 4.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 4.22 Spatial distribution of counts of *Enterococci* spp. in surface and bottom water samples from Swanbourne, 24 January 2012

4.6 Conclusions

During the survey on 24 January 2012 at Swanbourne, the treated wastewater plume was initially buoyant (as indicated by the slightly higher concentrations of nutrients and microbiological indicators in surface waters than in bottom waters) and was advecting in a northwest direction from the outlet.

The survey captured the extent of the elevated nutrient concentrations related to the discharge of treated wastewater into the marine environment at the Swanbourne ocean outlet. Nutrient concentrations were higher at sites closer to the diffuser, than at sites located further from the influence of the outlet.

The summer water quality surveys were not specifically designed to provide information suitable for comparison with ANZECC/ARMCANZ (2000) guidelines or with 80th percentile of reference values. For information only, water quality parameters at sites located <250 m and >250 m from the diffuser were compared with the ANZECC/ARMCANZ (2000) guidelines and 80th percentile of reference values. ANZECC/ARMCANZ (2000) suggests that an exceedance of a trigger value should be regarded as an "early warning" and furthermore, that trigger values are not intended as a means of assessing "compliance".

Median concentrations of phosphate-related nutrients were sometimes above the ANZECC/ARMCANZ (2000) guideline values and 80th percentile of reference values. Specifically, median concentrations of total phosphorus exceeded the ANZECC/ARMCANZ (2000) guideline of >20 µg/L in surface and bottom waters <250 m from the diffuser, and at shoreline sites. Surface waters <250 m from the diffuser also exceeded the 80th percentile of reference values (>33 µg/L). A similar pattern of exceedances was observed for ortho-phosphate concentrations: shoreline sites and surface and bottom waters <250 m from the diffuser exceeded both the ANZECC/ARMCANZ (2000) guideline (>5 µg/L) and 80th percentile of reference values (>6 µg/L). The median concentration of total phosphorus and ortho-phosphate at sites >250 m from the diffuser did not exceed the ANZECC/ARMCANZ (2000) or 80th percentile of reference values.

Median concentrations of nitrogen-related parameters (total nitrogen, ammonium, nitrate+nitrite) did not exceed ANZECC/ARMCANZ (2000) or 80th percentile of reference values in surface or bottom waters >250 m from the diffuser. In surface and bottom waters <250 m from the diffuser, median concentrations of total nitrogen exceeded the 80th reference values, while median concentrations of nitrate+nitrite exceeded both the ANZECC/ARMCANZ (2000) guidelines and the 80th percentile of reference values. Median ammonium and nitrate+nitrite concentrations exceeded 80th percentile of reference values at shoreline sites.

The pattern of exceedances in median chlorophyll *a* concentrations mirrored the exceedances for nitrogen parameters: median chlorophyll *a* concentrations at shoreline sites and sites <250 m from the diffuser exceeded both the ANZECC/ARMCANZ and 80th percentile of reference values. Experience with the PLOOM Program suggests that there is no straightforward mechanism for managing ocean outlets in the open ocean on the basis of establishing guidelines for chlorophyll *a*. General practice has been to manage nutrient impacts by specifying maximum nutrient loads and minimum dilution values. Maximum nutrient loads are based on ecological investigations. Minimum initial dilutions are specified, which determine maximum contaminant concentrations. These measures identify the extent of influence of the outlet. This approach has been adopted throughout the PLOOM and Perth Coastal Waters Studies.

Thermo-tolerant coliform counts exceeded the EGQ and EQS for the maintenance of seafood safe for human consumption in surface waters <250 m from the diffuser (Table 4.3, Table 4.5). However, the guidelines were met at distances >250 m from the diffuser and at shoreline sites. The elevated TTC counts in the immediate vicinity of the diffuser and a decline in counts away from the outlet indicate die-off of the microbes. Counts of *Enterococci* spp. met the guideline for primary contact recreation in all cases (Table 4.4, Table 4.6). Shoreline monitoring found no indication of contamination of any beaches adjacent to the outlets (Table 4.5, Table 4.6).

Table 4.5 Summary comparison of the EPA (2005) EQG with the median concentrations of thermo-tolerant coliforms recorded at shoreline sites and in surface (S) and bottom (B) waters of offshore sites located <250 m and >250 m from the diffuser during the summer water quality survey at Swanbourne on 24 January 2012

Parameter	Environmental Quality Guideline (EPA 2005) [1]				
	<250 m		>250 m		Shoreline
	S	B	S	B	
Thermo-tolerant coliforms	🟥	🟩	🟩	🟩	🟩

Notes:

1. For the maintenance of seafood safe for human consumption
2. 🟥 = median values > EQG;
3. 🟩 = median values ≤ EQG

Table 4.6 Summary comparison of the ANZECC/ARMCANZ (2000) guideline with the median concentrations of *Enterococci* spp. recorded at shoreline sites and in surface (S) and bottom (B) waters of offshore sites located <250 m and >250 m from the diffuser during the summer water quality survey at Swanbourne on 24 January 2012

Parameter	ANZECC/ARMCANZ (2000) [1]				
	<250 m		>250 m		Shoreline
	S	B	S	B	
Enterococci spp. [1]	🟩	🟩	🟩	🟩	🟩

Notes:

1. Results for primary contact recreation.
2. 🟥 = median values > ANZECC/ARMCANZ (2000);
3. 🟩 = median values ≤ ANZECC/ARMCANZ (2000)

The results from the summer water quality survey on 24 January 2012 indicate that the Swanbourne ocean outlet was operating effectively. The plume of treated wastewater rapidly dissipated. Despite elevated levels of water quality parameters at some individual sites outside the immediate zone of influence of the outlet, the water quality conditions required for ecosystem protection and public health criteria were met.

Summer Water Quality Survey

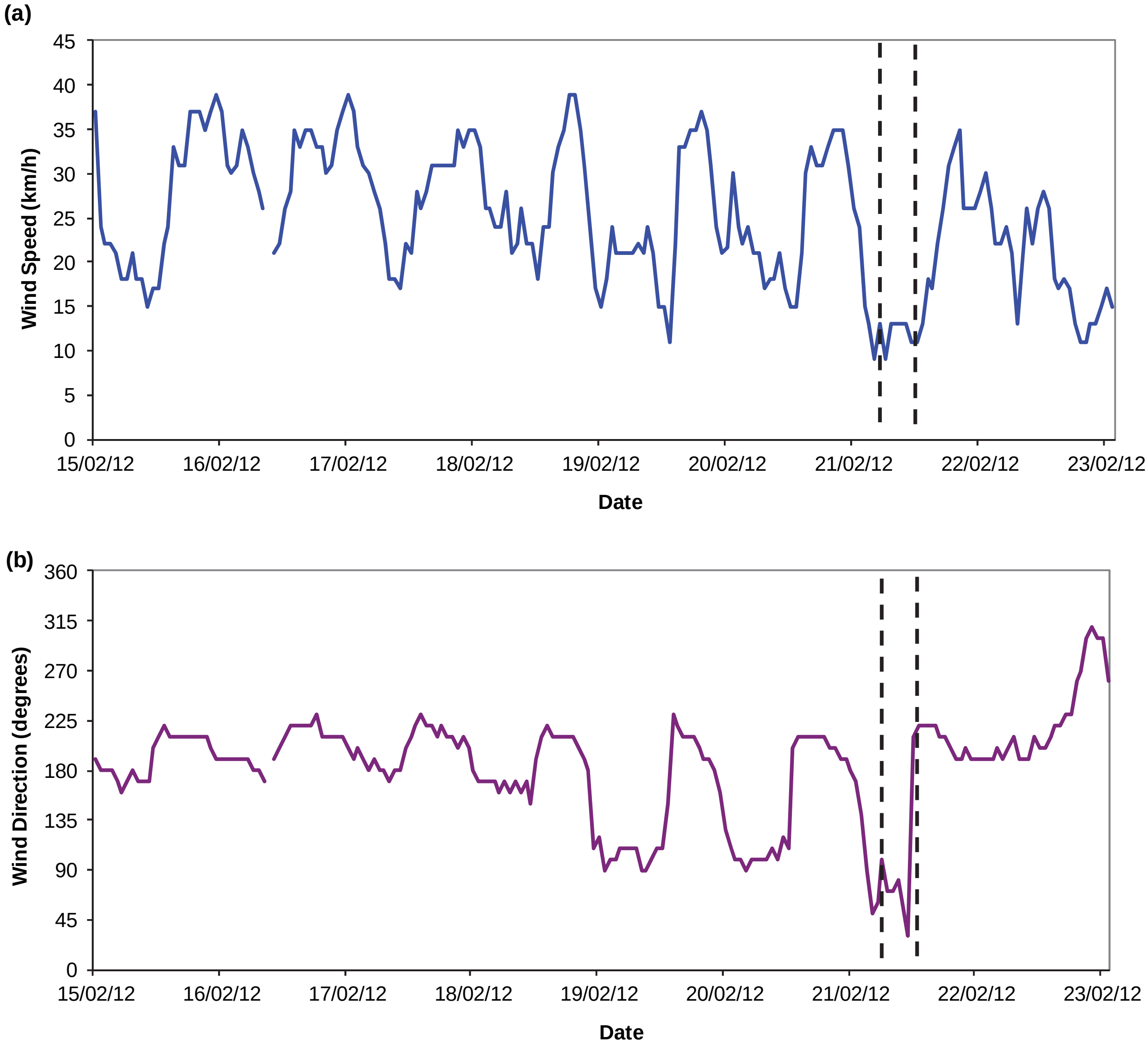
Sepia Depression

21 February 2012

5. Sepia Depression Summer Water Quality Survey – Results and Interpretation

5.1 Wind, wave and tide conditions

The survey at Sepia Depression was undertaken on 21 February 2012. For 24 hours prior to the survey, the winds at Sepia Depression were gentle easterlies (average 17.2 km/h), before changing to southerlies that went from fresh (average 31.5 km/h), to moderate (average 21.6 km/h), before changing back to light easterlies (average 11.0 km/h; Figure 5.1). Conditions during the survey were light easterlies, with an average speed of 12.6 km/h.



Note:
1. Dashed lines (- -) show approximate timing of the summer water quality survey.

Figure 5.1 Hourly averages of (a) wind speed and (b) wind direction, prior to and during the summer water quality survey at Sepia Depression, 21 February 2012

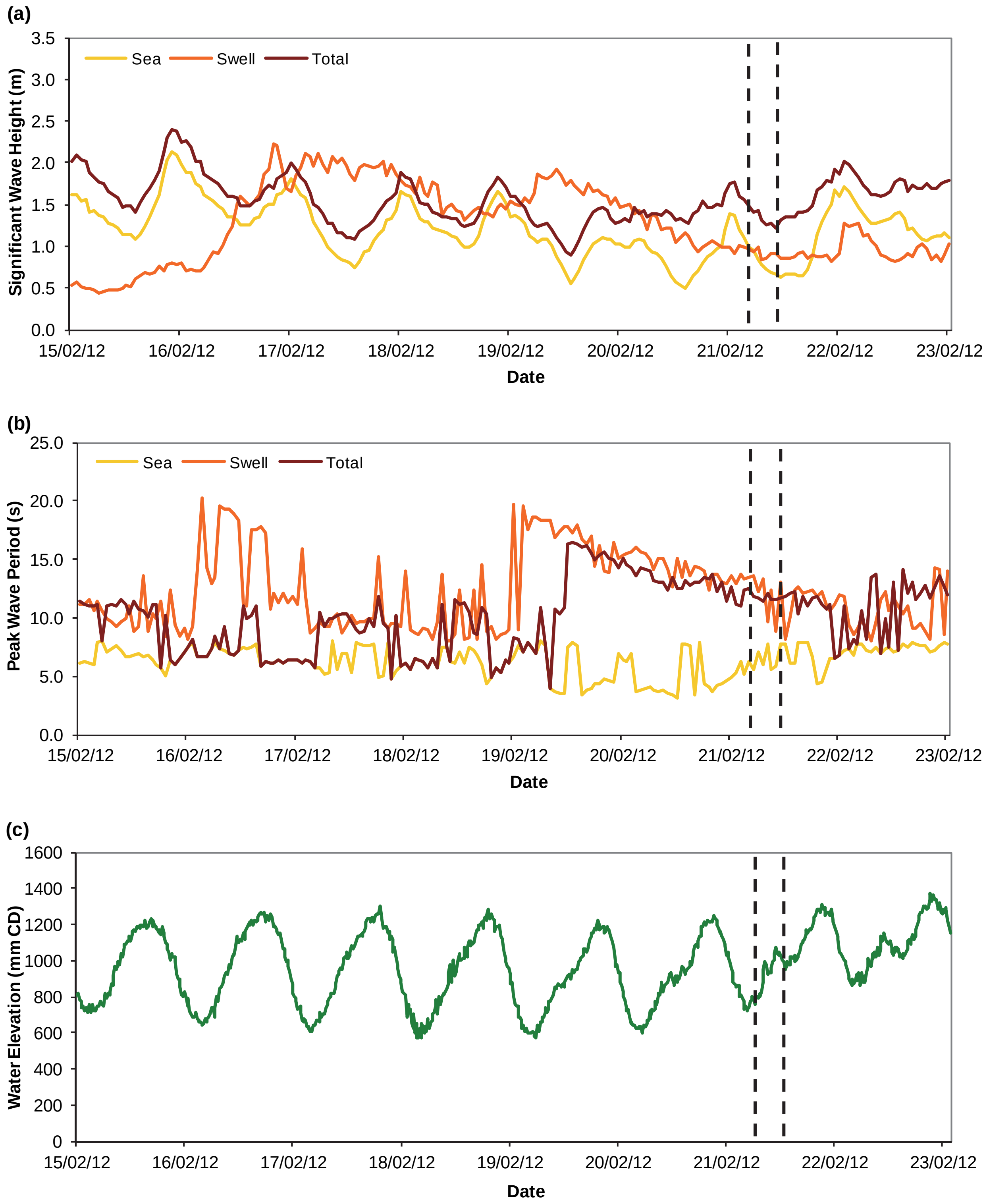
For the 24 hours prior to the survey, the average significant wave height[23] offshore from Rottnest Island was 1.5 m[24], with an average peak wave period[25] of 12.6 s[24] (Figure 5.2a and b). During the survey the average offshore significant wave height

[23] *The significant wave height (in metres) is defined as the average height of the highest one-third of waves recorded (Source: http//www.dpi.wa.gov.au/).*

[24] *All significant wave heights and wave periods presented are for the 'total' wave conditions, that is, the combined sea and swell conditions.*

[25] *The wave period (in seconds) is the time between consecutive wave crests. The peak wave period is the wave period of those waves that are producing the most energy in a wave record.*

decreased to 1.3 m, while the peak wave period decreased to 11.7 s. The survey was conducted during a rising tide (Figure 5.2c).



Note:
1. Dashed lines (- -) show approximate timing of the summer water quality survey.

Figure 5.2 **(a) Significant wave heights (offshore Rottnest Island), (b) peak wave periods (offshore Rottnest Island) and (c) water level elevation (Fremantle Fishing Boat Harbour), prior to and during the summer water quality survey at Sepia Depression, 21 February 2012**

5.2 Discharge from outlet

The characteristics of the treated wastewater from Woodman Point WWTP measured from a 24 hour composite sample collected prior to and during the survey at Sepia Depression on 21 February 2012 are presented in Table 5.1. Samples of primary treated wastewater were not collected at Point Peron and are therefore not presented in the table below[26].

Table 5.1 Characteristics of the secondary treated wastewater from Woodman Point WWTP on 21 February 2012

PARAMETER	CONCENTRATION / COUNTS Woodman Point (21/02/2012)
Total phosphorus	4,900 µg/L
Total nitrogen	23,000 µg/L
Ammonium	15,000 µg/L
Nitrate+nitrite	Not analysed by laboratory
Thermo-tolerant coliforms	>1,000,000 CFU/100 mL
Enterococci spp.	>24,000 MPN/100 mL
Total suspended solids	75 mg/L
Biological oxygen demand	28 mg/L
Total flow	138.3 ML/d

5.3 Surface drogue movement

The surface drogue, released over the centre of the diffuser at the beginning of the survey, drifted in a northerly direction with an average velocity of 0.14 m/s (Figure 5.3). At the time of the survey it was expected that the discharged treated wastewater would be advecting to the north and offshore of the diffuser.

[26] *Samples either not taken or misplaced by laboratory*

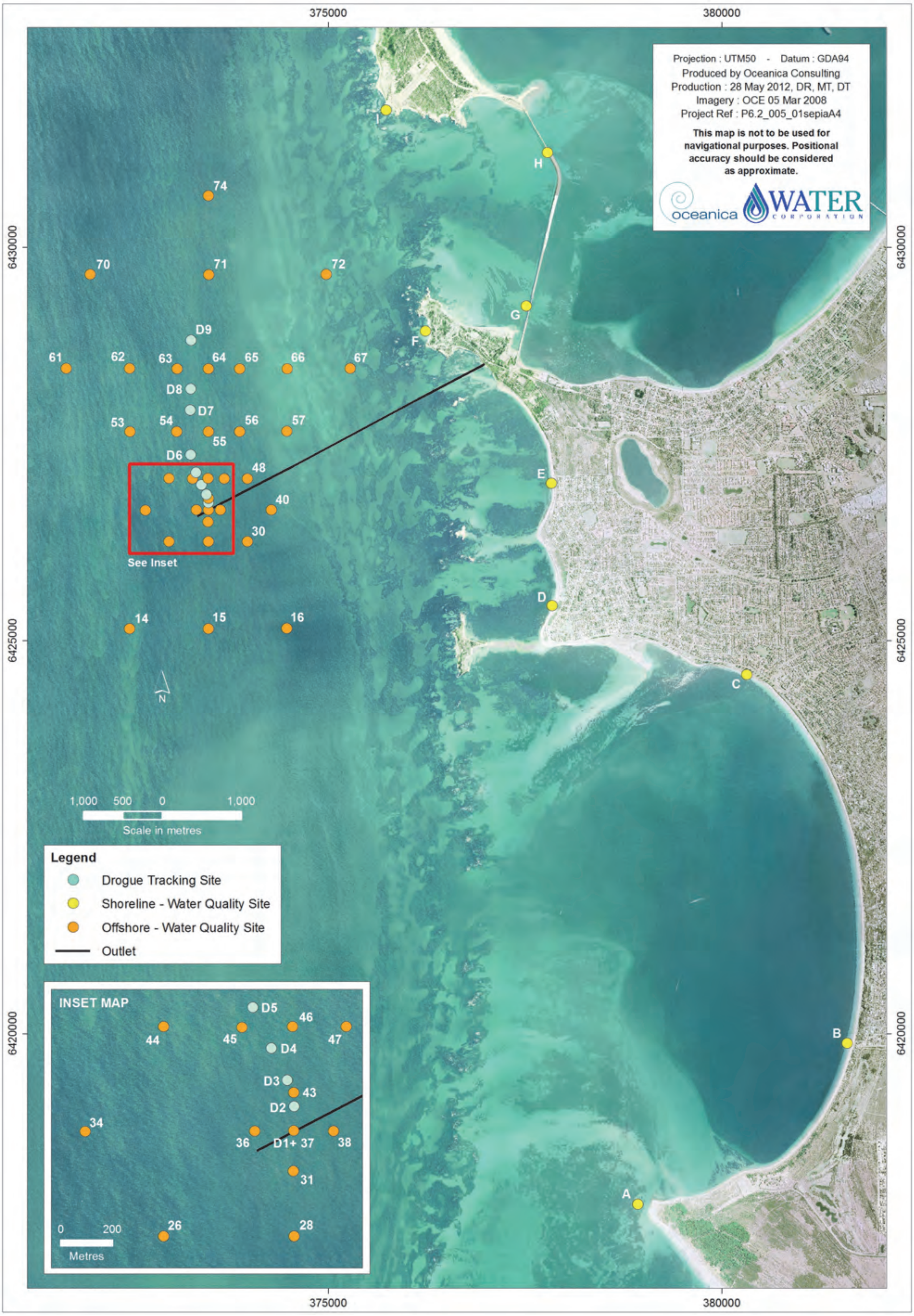


Figure 5.3 **Sepia Depression ocean outlet summer water quality survey sites and drogue tracking sites, 21 February 2012**

5.4 Initial dilution modelling

For the ambient conditions at the time of the summer water quality survey on 21 February 2012, the modelling predicted an average initial dilution of 1:139 and a centreline dilution of 1:86 (Figure 5.4a). The plume was predicted to first reach the surface within approximately 3 m (horizontal distance) from the discharge point (see the ambient boundary[27] of the plume in Figure 5.4b). The full model output is included in Appendix C.

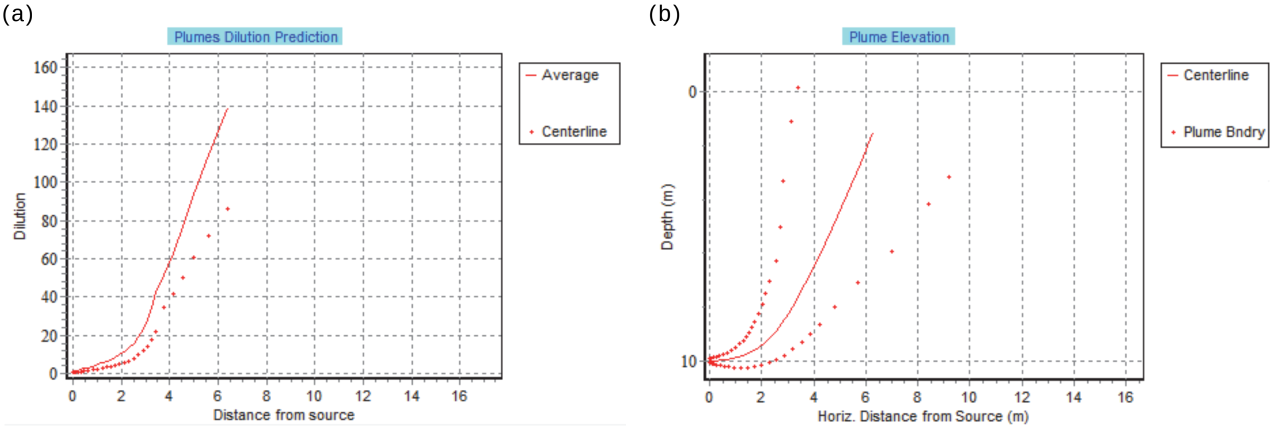


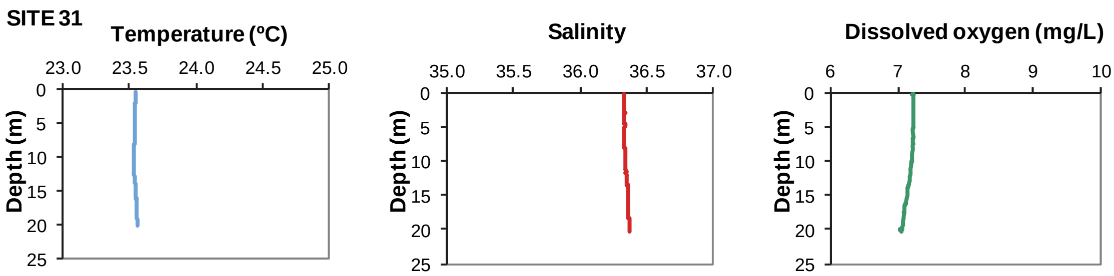
Figure 5.4 **UM3 initial dilution modelling results for (a) predicted average and centreline dilutions and (b) predicted plume elevation trajectory, during the summer water quality survey at Sepia Depression, 21 February 2012**

5.5 Water quality

The grid for northerly flow conditions at Sepia Depression was sampled during the survey on 21 February 2012, as southerly winds prevailed during the survey period (Section 5.1). Water samples were collected from the surface and bottom waters of the 34 offshore sites and from the nine shoreline sites (Figure 5.3). Tables containing the concentrations of all water quality parameters taken during the summer survey are included in Appendix D.

5.5.1 Water column structure

Water column structure was recorded at eight sites (sites 31, 36, 37, 38, 43, 46, 55 and 64). Water temperature varied from 23.5 to 23.8°C, salinity varied from 35.92 to 36.56[28] and dissolved oxygen varied from 6.98 to 7.25 mg/L (equivalent to 102% to 105% saturation) (Figure 5.5). Temperature and dissolved oxygen profiles revealed little change in these parameters with depth at all sites. Salinity profiles showed an moderate increase in salinity with depth of approximately 0.25 at sites 46, 55 and 64. Salinity at site 37 showed the greatest fluctuations with depth, starting at 36.3 at the surface, reaching a low of 36.0 at 17.7 m depth then increasing back to 36.3 at 19.8 m depth.



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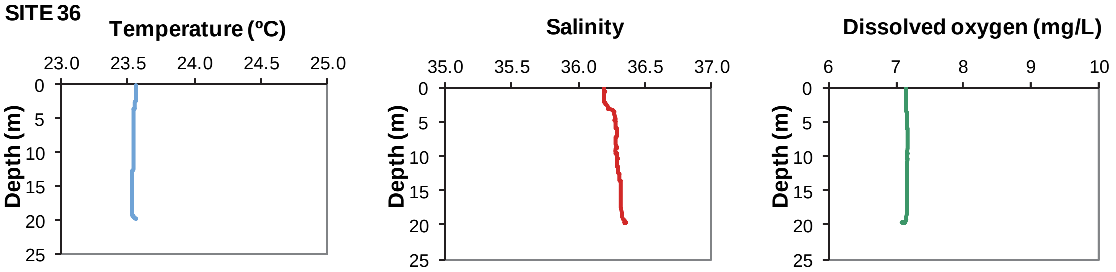
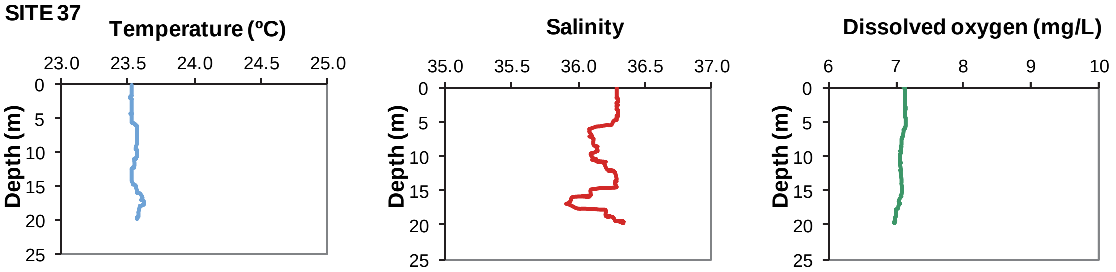
[27] *The ambient boundary corresponds to the plume boundary at which concentrations are estimated to be equal to ambient conditions*

[28] *Salinity throughout this report is referred to without units according to the Practical Salinity Scale. On this scale salinity is defined as the ratio of conductivities and therefore cannot have units. Seawater typically has a salinity in the range of 34-36.*

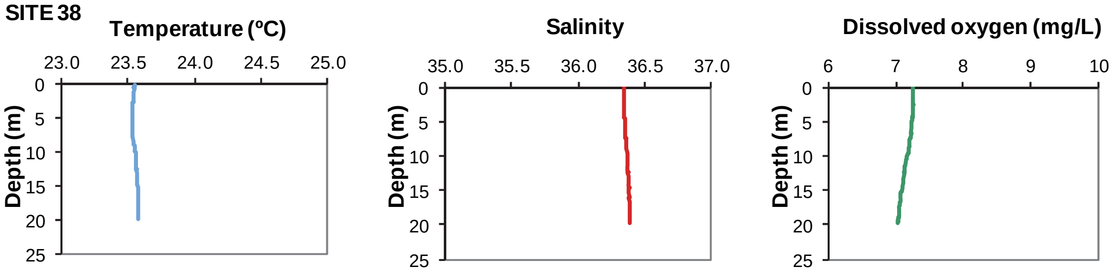
SITE 36



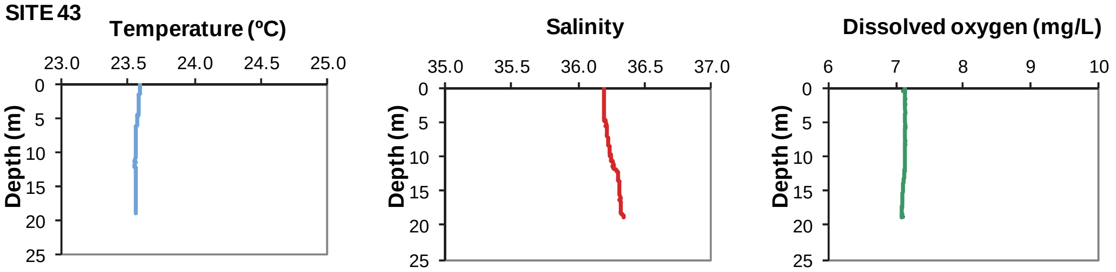
SITE 37



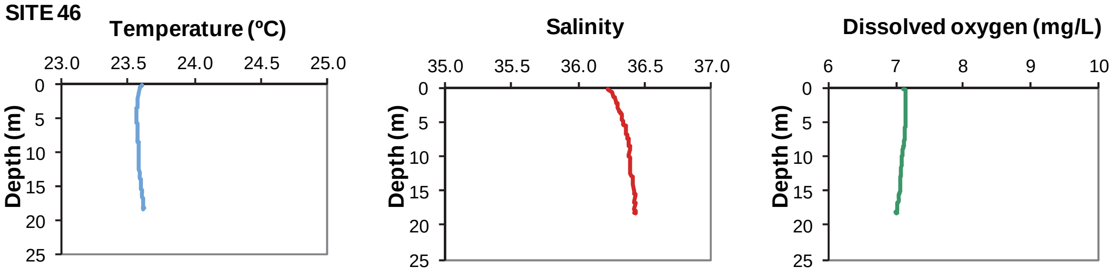
SITE 38



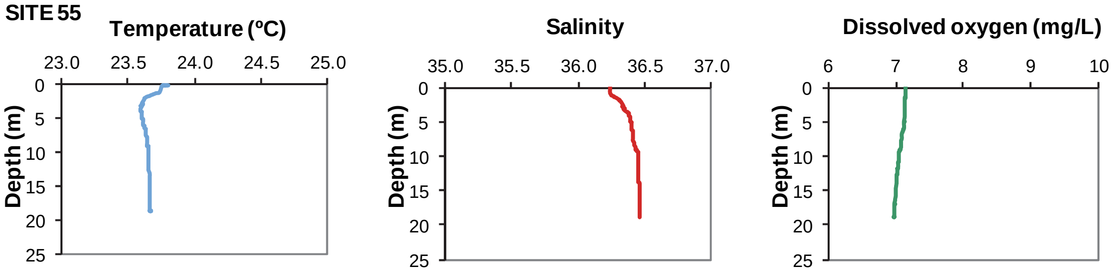
SITE 43



SITE 46



SITE 55



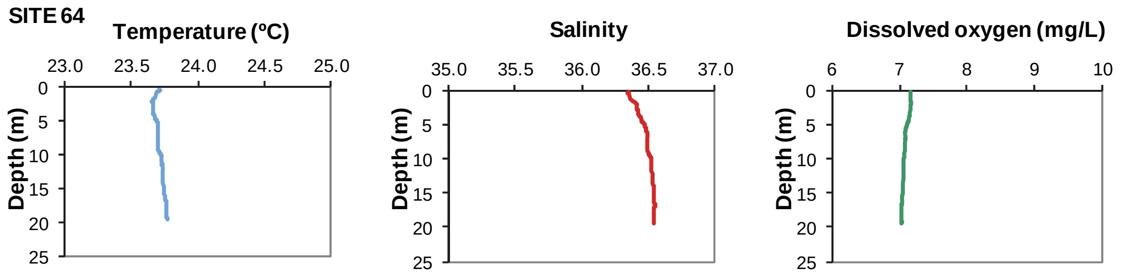


Figure 5.5 **Temperature, salinity and dissolved oxygen vertical profiles at selected sampling sites during the summer water quality survey at Sepia Depression, 21 February 2012**

The effect of the discharged wastewater on the physical structure of the water column is illustrated in Figure 5.6. Note that the colour scales used in this figure range from the minimum to the maximum of each parameter, thus exaggerating small differences in measurements. Water temperature was coolest nearby the outlet to approximately 800 m north. Further north surface and bottom waters were warmer, although a layer of cooler water remained just below the surface (Figure 5.6a). Salinity was lowest in the immediate vicinity of the outlet and in surface waters between approximately 100-200 m north of the outlet. Salinity showed a gradual increase with distance north of the outlet, however a layer of less saline water remained at the surface (Figure 5.6b). Water density showed a similar profile as salinity: density was lowest in the immediate vicinity of the outlet. Density gradually increased with distance north of the outlet, however a layer of less dense water remained at the surface (Figure 5.6c). The profiles of temperature, salinity and density were taken in a south-north direction and therefore may not have captured the full extent of the discharged wastewater plume.

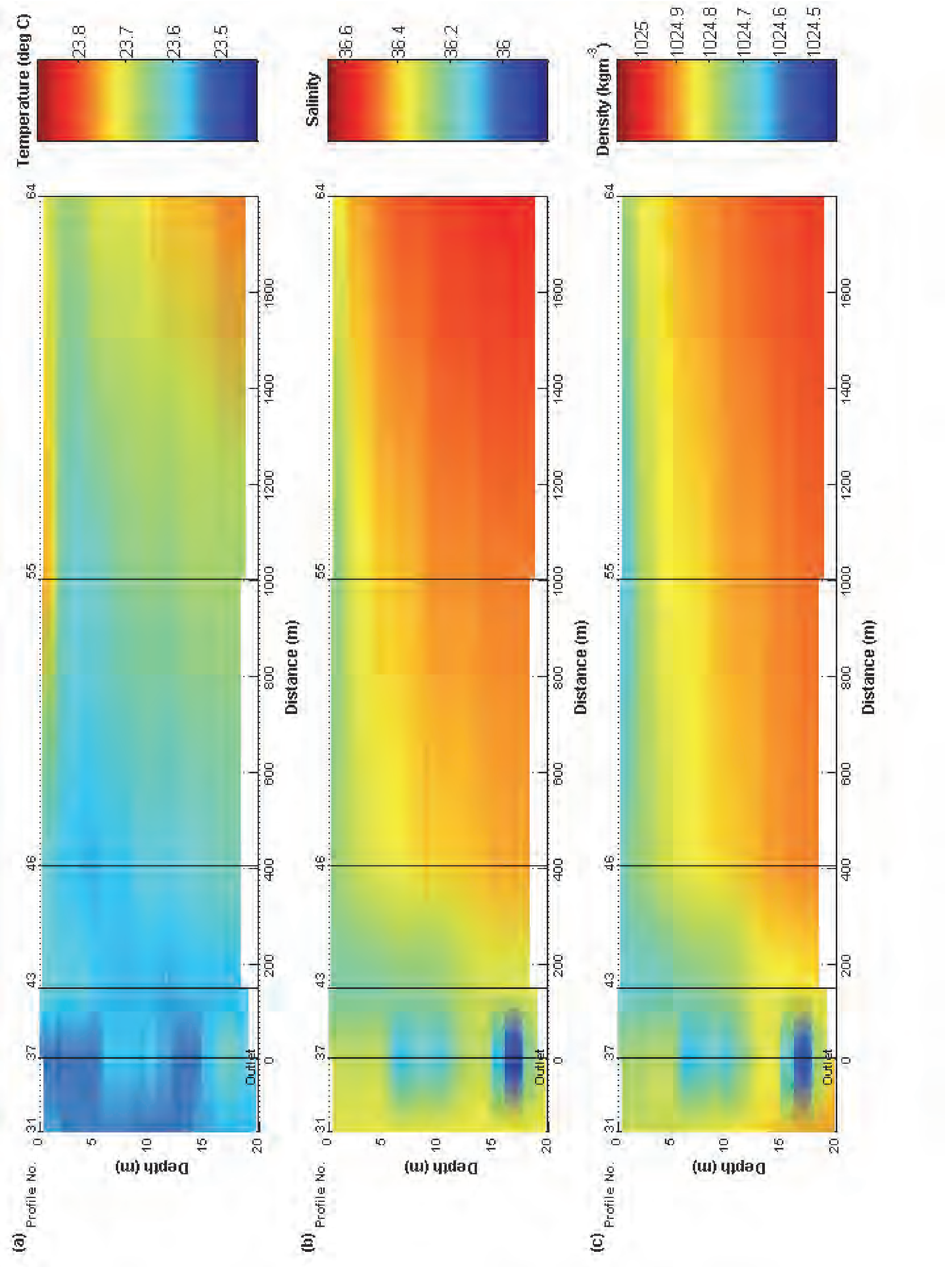


Figure 5.6 **(a) Temperature, (b) salinity and (c) density profiles along a south to north transect during the summer water quality survey at Sepia Depression, 21 February 2012**

5.5.2 Replicate samples

Variance in measurements of water quality parameters may be introduced by small-scale spatial variability in the water column or by variability among laboratory analyses. To examine the range of this variance, three surface samples were collected at site 15 (Table 5.2). The results indicated that in general, the variability amongst replicates was small. The mean value of these replicate samples was used as representative of the water quality parameters at site 15.

Table 5.2 Replicate surface samples from site 15, Sepia Depression, 21 February 2012

Parameter	Ammonia	Ortho-phosphate	Nitrate+nitrite	Total phosphorus	Total nitrogen
Units	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
Reporting limit	**<3**	**<2**	**<2**	**<5**	**<50**
Surface rep 1	1.5	1	1	10	90
Surface rep 2	1.5	1	1	10	80
Surface rep 3	1.5	1	1	9	80
Mean	*1.5*	*1*	*1*	*9.7*	*83.3*
Parameter	**Chlorophyll *a*** *(Flourometery)*	**Chlorophyll *a*** *(Acetone)*	**Phaeophytin**	**Thermal coliforms**	**Entrococci**
Units	**µg/L**	**µg/L**	**µg/L**	**CFU/100mL**	**MPN/100mL**
Reporting limit	**<0.1**	**<0.1**	**<0.2**	**<10**	**<10**
Surface rep 1	0.2	0.3	0.1	5	5
Surface rep 2	0.2	0.2	0.1	5	5
Surface rep 3	0.2			5	5
Mean	*0.2*	*0.3*	*0.1*	*5*	*5*

Notes:
1. Measurements below the reporting limit are listed as half the reporting limit
2. Only two replicate samples were taken for chlorophyll *a* and Phaeophytin

5.5.3 Nutrient concentrations and distribution

Total Nitrogen (TN)

- The highest offshore surface concentration of TN was 180 µg/L at sites 45 and 71, located 447 m and 2997 m north of the diffuser, respectively. The next highest TN concentration was 170 µg/L at sites 47 and 62, located 449 m northeast and 2060 m northwest of the diffuser, respectively (Figure 5.7).
- The highest offshore bottom concentration of TN was 140 µg/L at sites 16, 26, 34 and 53. These sites were located 1802 m southeast, 640 m southwest, 801 m west and 1411 m northwest of the diffuser, respectively (Figure 5.7).
- The concentrations of TN in surface and bottom waters at all sites were below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. TN concentrations in surface waters at 30 sites (88%) and bottom waters at 34 sites (100%) were below the 80th percentile of reference values (>160 µg/L [surface] and >150 µg/L [bottom]).
- TN concentrations at shoreline sites ranged between 120 µg/L (site B) and 240 µg/L (site H). Four shoreline sites (44%) had TN concentrations below the ANZECC/ARMCANZ (2000) guideline of 230 µg/L. The reasons for the elevated TN concentrations at all other shoreline sites is unknown, but may be due to the decay of beach wrack, the locations of stormwater drains or elevated nitrogen levels in groundwater.
- Spatial patterns in TN concentrations (Figure 5.8) revealed that localised increases in surface waters were predominant to the north of the diffuser, whereas localised increases in bottom waters occurred to the west of the diffuser. All surface and bottom sites had TN concentrations that were below the ANZECC/ARMCANZ (2000) guideline.

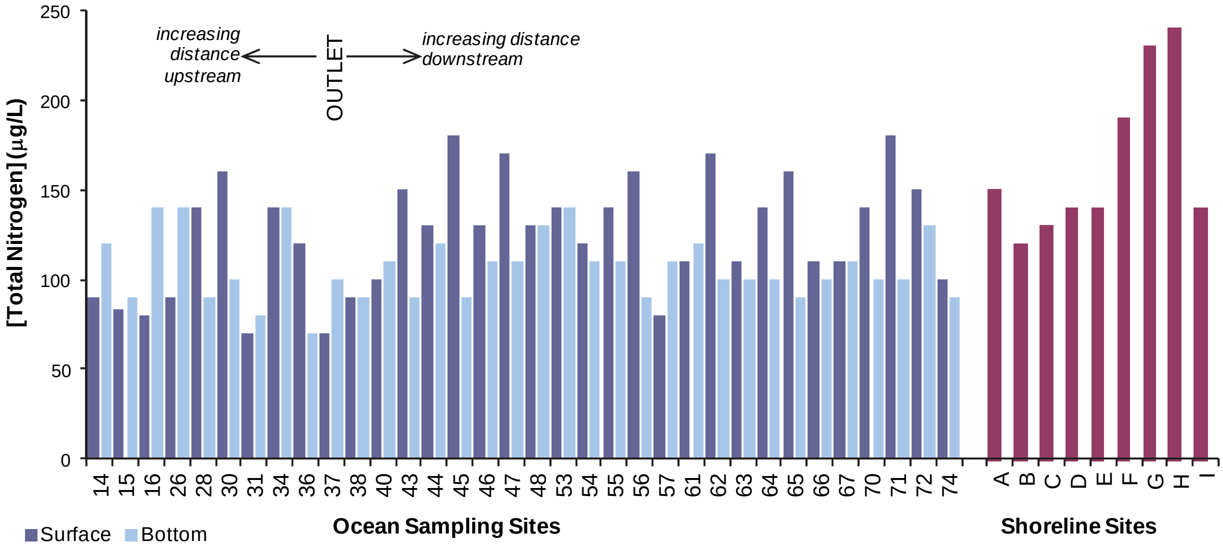
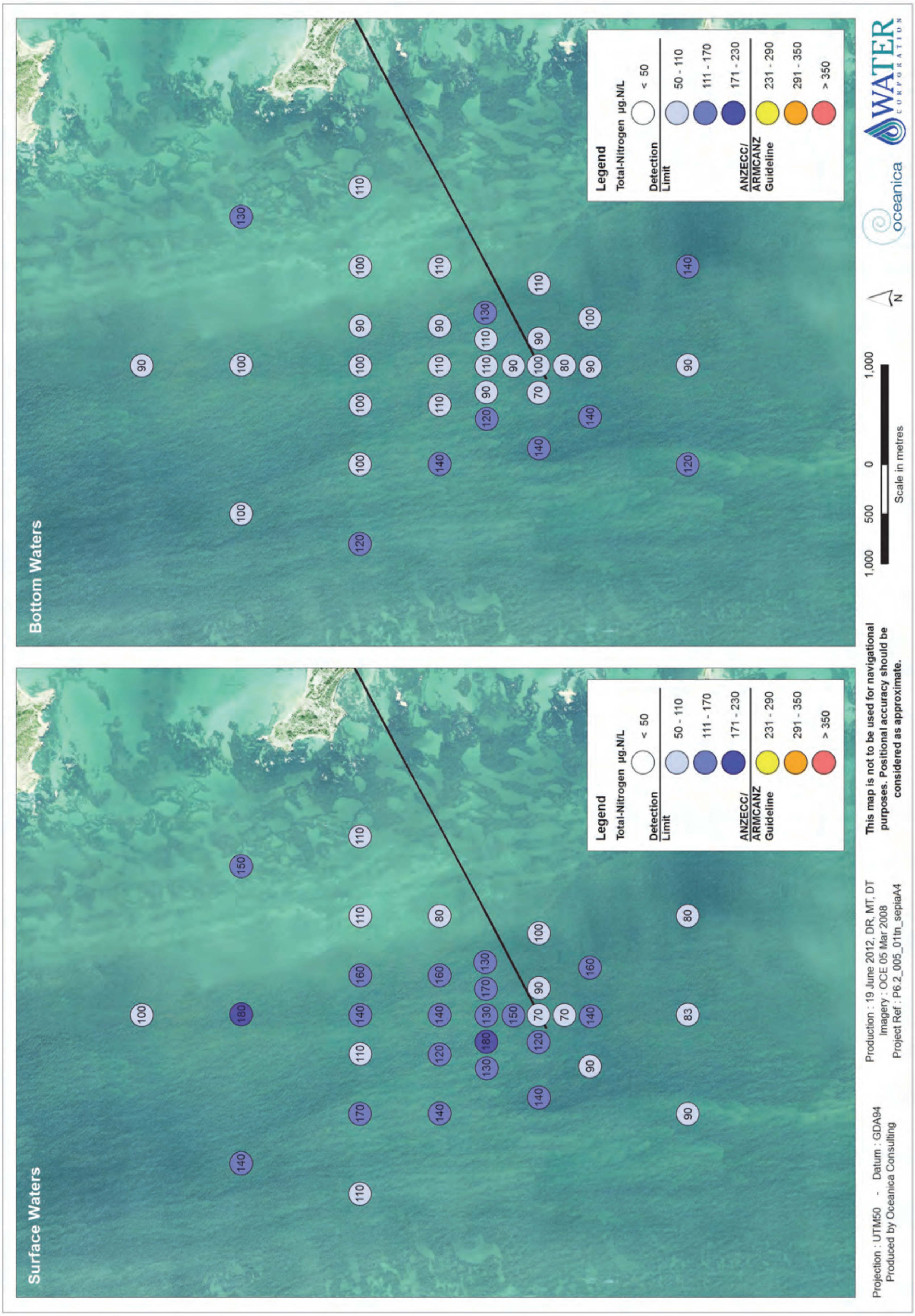


Figure 5.7 Total nitrogen concentrations at surface, bottom and shoreline sites sampled at Sepia Depression, 21 February 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 5.8 Spatial distribution of total nitrogen concentrations in surface and bottom water samples from Sepia Depression, 21 February 2012

Ammonium Nitrogen (NH_4^+)

- The highest offshore surface concentration of NH_4^+ was 31 µg/L at sites 43 and 47, located 149 m and 449 m northeast of the diffuser, respectively (Figure 5.9). The next highest NH_4^+ concentrations were 30 µg/L at site 46 (403 m north of the diffuser) and 28 µg/L at site 48 (641 m northeast of the diffuser
- The highest offshore bottom water NH_4^+ concentrations were 5 µg/L at site 43 (149 m northeast of the diffuser) and 4 µg/L at site 48 (641 m northeast of the diffuser; Figure 5.9). The bottom waters at all other sites had NH_4^+ concentrations equal to or below the detection limit of 3 µg/L.
- The concentration of NH_4^+ at 19 surface sites (56%) and 34 bottom sites (100%) were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Concentrations at 19 surface sites (56%) and 33 bottom sites (97%) were below the 80th percentile of reference values (6 µg/L [surface] and 4 µg/L [bottom]).
- NH_4^+ concentrations at shoreline sites varied between <3 µg/L (site B) to 17 µg/L (site A). Four shoreline sites (44%) had NH_4^+ concentrations which were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L.
- Spatial patterns in NH_4^+ concentrations (Figure 5.10) revealed that localised increases above the ANZECC/ARMCANZ (2000) guideline of 5 µg/L occurred in surface waters to the north of the diffuser. NH_4^+ concentrations in bottom waters at all sites were below the ANZECC/ARMCANZ (2000) guideline.

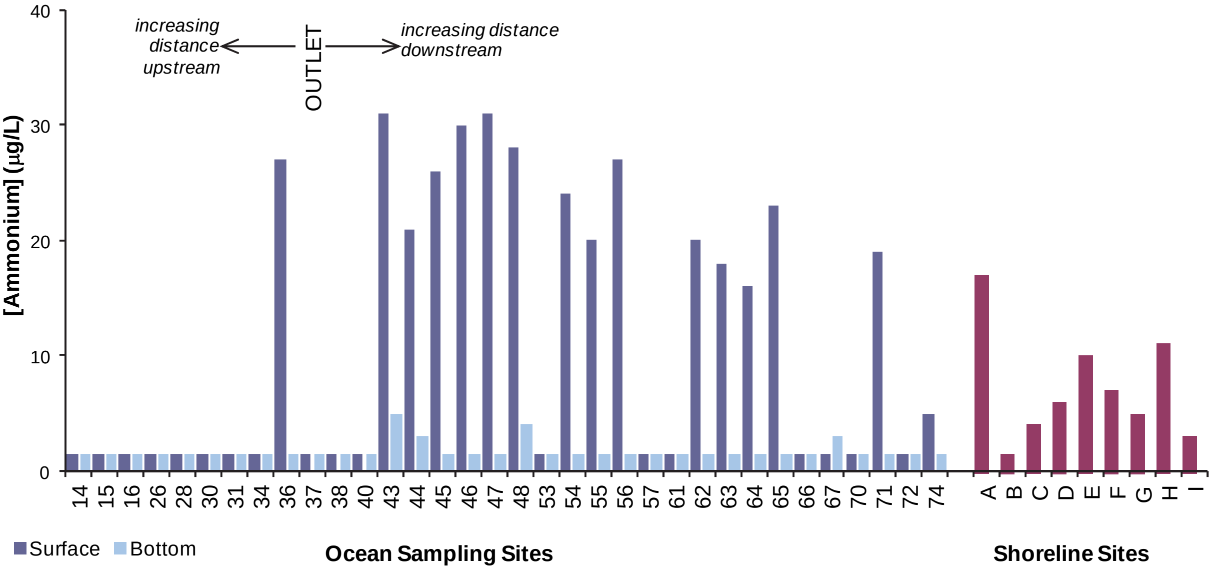
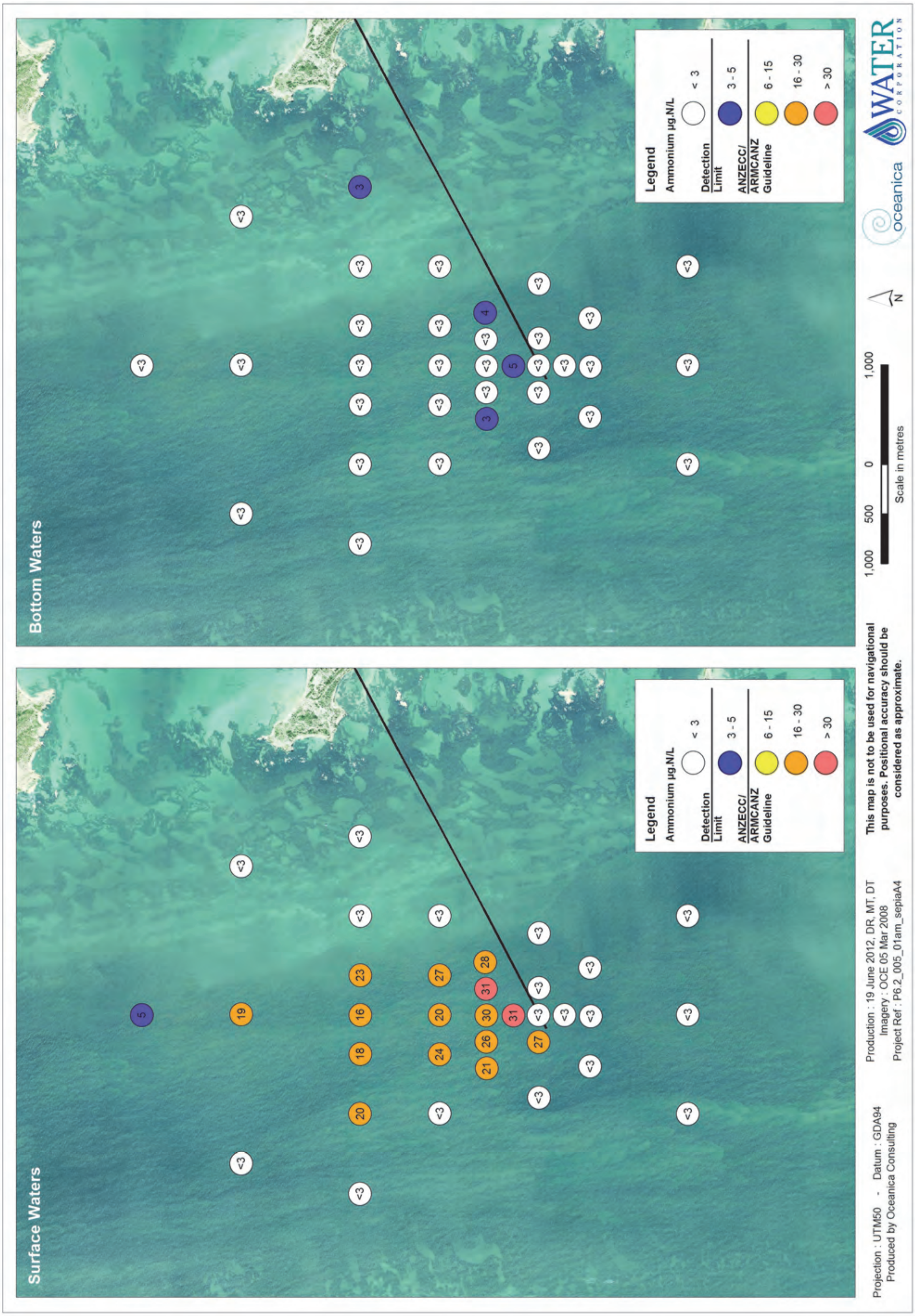


Figure 5.9 Ammonium concentrations at surface, bottom and shoreline sites sampled at Sepia Depression, 21 February 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 5.10 Spatial distribution of ammonium concentrations in surface and bottom water samples from Sepia Depression, 21 February 2012

Nitrate+Nitrite Nitrogen ($NO_2^-+NO_3^-$)

- The highest offshore surface concentration of $NO_2^-+NO_3^-$ was 13 µg/L at sites 54 and 62, located 1077 m north and 1060 m northeast of the diffuser, respectively (Figure 5.11). The next highest $NO_2^-+NO_3^-$ concentration was 12 µg/L at site 56, located 1077 m northeast of the diffuser.
- The highest offshore bottom concentrations of $NO_2^-+NO_3^-$ were 6 µg/L at site 72, 5 µg/L at site 67 and 3 µg/L at site 14 (Figure 5.11). Sites 72, 67 and 14 were located 3354 m northeast, 2548 m northeast and 1804 m southwest of the diffuser, respectively. The bottom waters at all other sites had $NO_2^-+NO_3^-$ concentrations equal to or less than the detection limit of 2 µg/L.
- The concentrations of $NO_2^-+NO_3^-$ at 15 surface sites (44%) and 33 bottom sites (97%) were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Surface concentrations of $NO_2^-+NO_3^-$ at 15 sites (44%) and bottom concentrations at 32 sites (94%) were below the 80th percentile of reference values (4.6 µg/L [surface] and 3.2 µg/L [bottom]).
- The $NO_2^-+NO_3^-$ concentrations at shoreline sites ranged from <2 µg/L (site C) to 10 µg/L (sites G and H). All shoreline sites except sites G and H were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L.
- Spatial patterns in $NO_2^-+NO_3^-$ concentrations (Figure 5.12) revealed that localised increases above the ANZECC/ARMCANZ (2000) guideline of 5 µg/L occurred in surface waters to the north, northeast and northwest of the diffuser. $NO_2^-+NO_3^-$ concentrations in bottom waters at all sites except site 72 were below the ANZECC/ARMCANZ (2000) guideline.

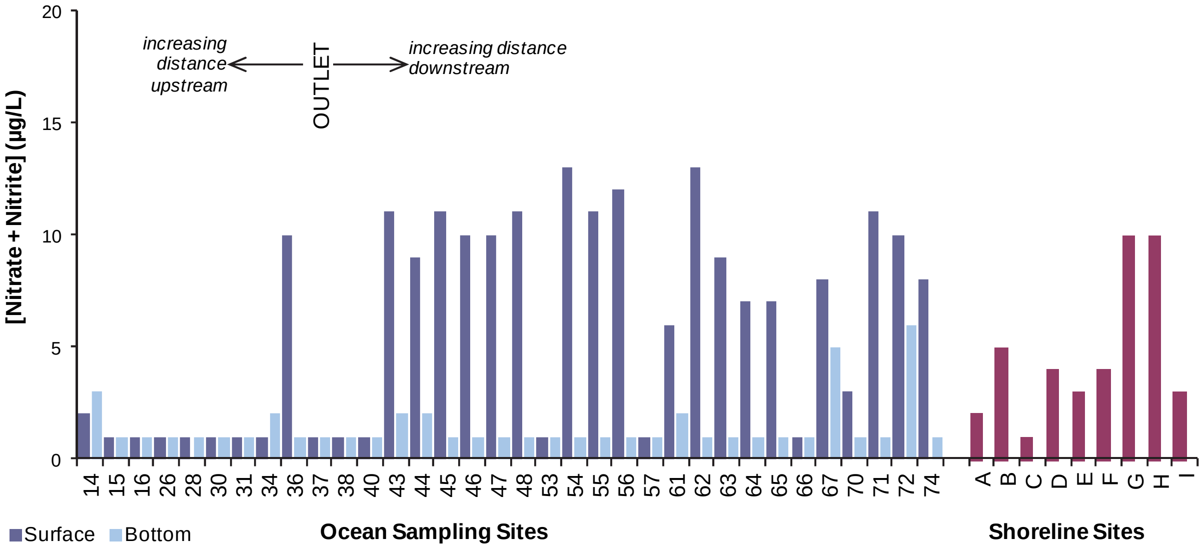
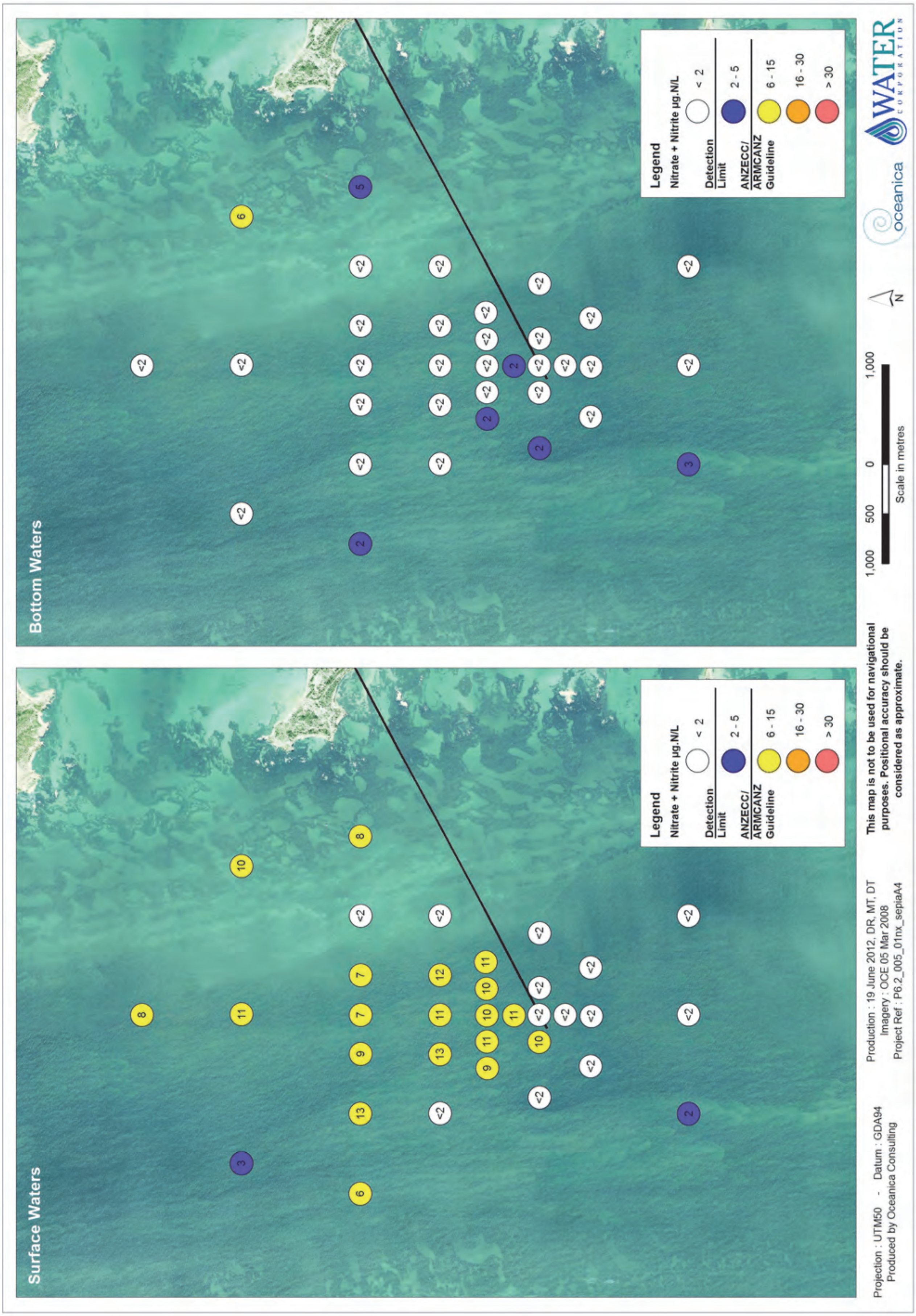


Figure 5.11 **Nitrate+nitrite concentrations at surface, bottom and shoreline sites sampled at Sepia Depression, 21 February 2012**



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 5.12 Spatial distribution of nitrate+nitrite concentrations in surface and bottom water samples from Sepia Depression, 21 February 2012

Total Phosphorus (TP)

- The highest offshore surface concentration of TP was 21 µg/L at sites 46, 47 and 48, located 403 m north, 449 m northeast, and 641 m northeast or the diffuser, respectively (Figure 5.13).
- The highest offshore bottom concentration of TP was 14 µg/L at site 44, located 642 m northwest of the diffuser. The next highest concentration of TP was 12 µg/L at sites 34, 43, 46, 47, 48, 56, 64, and 72, which were located at varying distances upstream and downstream of the diffuser (Figure 5.13).
- The concentrations of TP at 31 surface sites (91%) and 34 bottom sites (100%) were below the ANZECC/ARMCANZ (2000) guideline of 20 µg/L. Surface and bottom concentrations of TP at all surface and bottom sites were within the range of the 80th percentile of reference values of 32 µg/L.
- The concentrations of TP at all shoreline sites ranged from 11 µg/L at site C to 21 µg/L at sites G and H. TP concentrations at 7 shoreline sites (78%) were below the ANZECC/ARMCANZ (2000) guideline of 20 µg/L; the exceptions were sites G and H.
- Spatial patterns of TP concentrations (Figure 5.14) revealed that concentrations above the ANZECC/ARMCANZ (2000) guideline occurred in surface waters nearby to the northeast of the diffuser. TP concentrations in the bottom waters at all sites were below the ANZECC/ARMCANZ (2000) guideline.

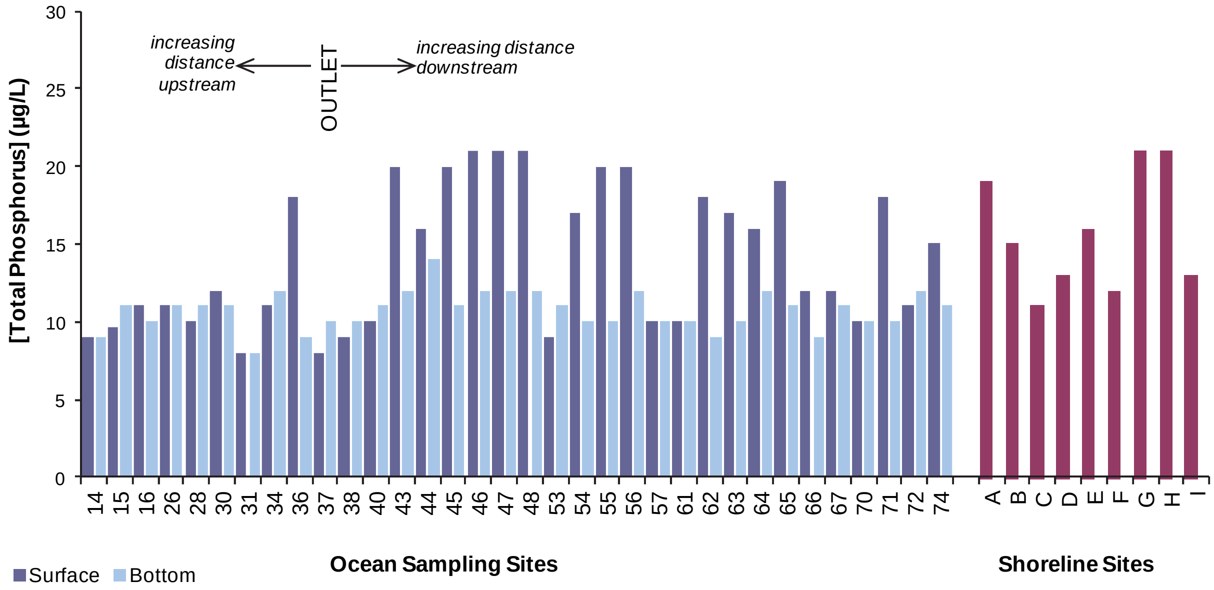
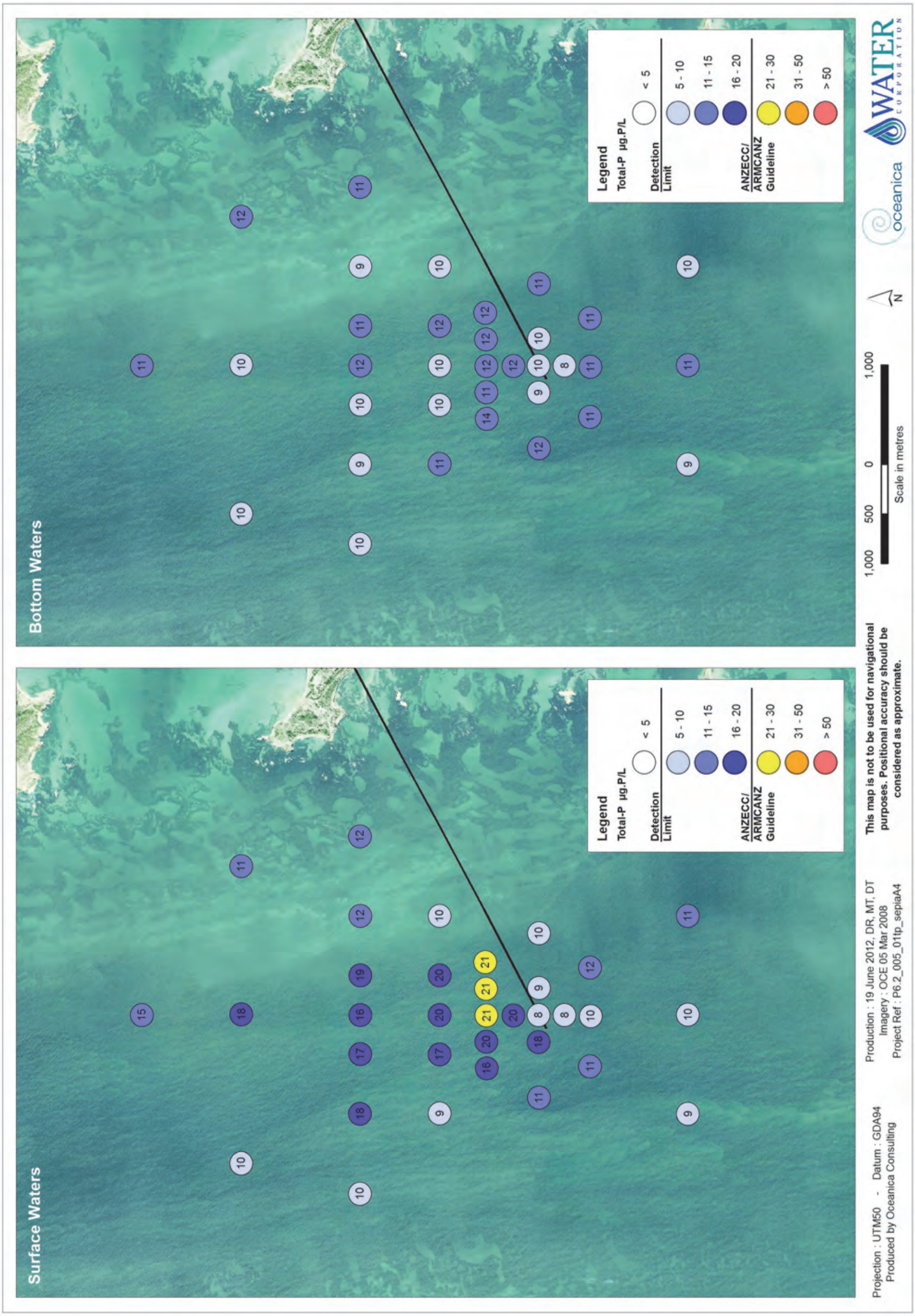


Figure 5.13 Total phosphorus concentrations at surface, bottom and shoreline sites sampled at Sepia Depression, 21 February 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 5.14 Spatial distribution of total phosphorus concentrations in surface and bottom water samples from Sepia Depression, 21 February 2012

Ortho-phosphate

- The highest offshore surface concentration of ortho-phosphate was 10 µg/L at sites 43, 46 and 47, located 149 m northeast, 403 m north and 449 m northeast of the diffuser, respectively (Figure 5.15).
- The highest offshore bottom concentrations of ortho-phosphate were 3 µg/L at site 43 and 2 µg/L at sites 56 and 72 (Figure 5.15). Sites 43, 56 and 72 were located 149 m, 1077 m and 3354 m northeast of the diffuser, respectively.
- The concentrations of ortho-phosphate at 19 surface sites (56%) and 34 bottom sites (100%) were below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L. Surface concentrations of ortho-phosphate at 20 sites (59%) and bottom concentrations at 34 sites (100%) were within the range of the 80th percentile of reference values, 6 µg/L (surface and bottom).
- Concentrations of ortho-phosphate at shoreline sites ranged from 2 µg/L (sites C, D, G) to 6 µg/L (site A). All shoreline sites except site A had ortho-phosphate concentrations below the ANZECC/ARMCANZ (2000) guideline of 5 µg/L.
- Spatial patterns in ortho-phosphate concentrations (Figure 5.16) revealed that concentrations above the ANZECC/ARMCANZ (2000) guideline occurred in surface waters to the north of the diffuser. The ortho-phosphate concentrations in bottom waters at all sites were below the ANZECC/ARMCANZ (2000) guideline.

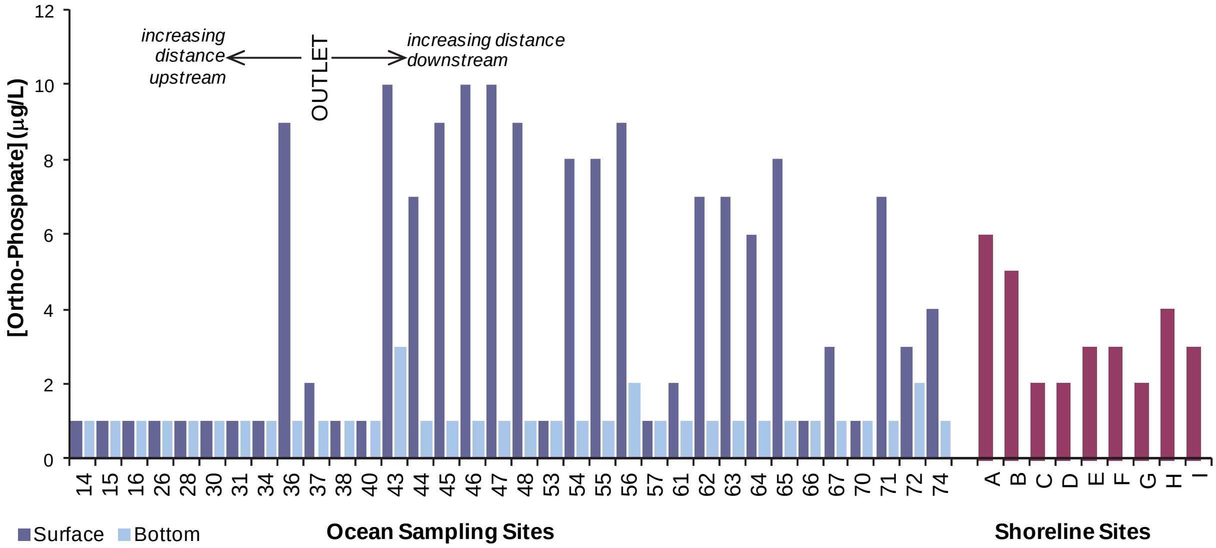
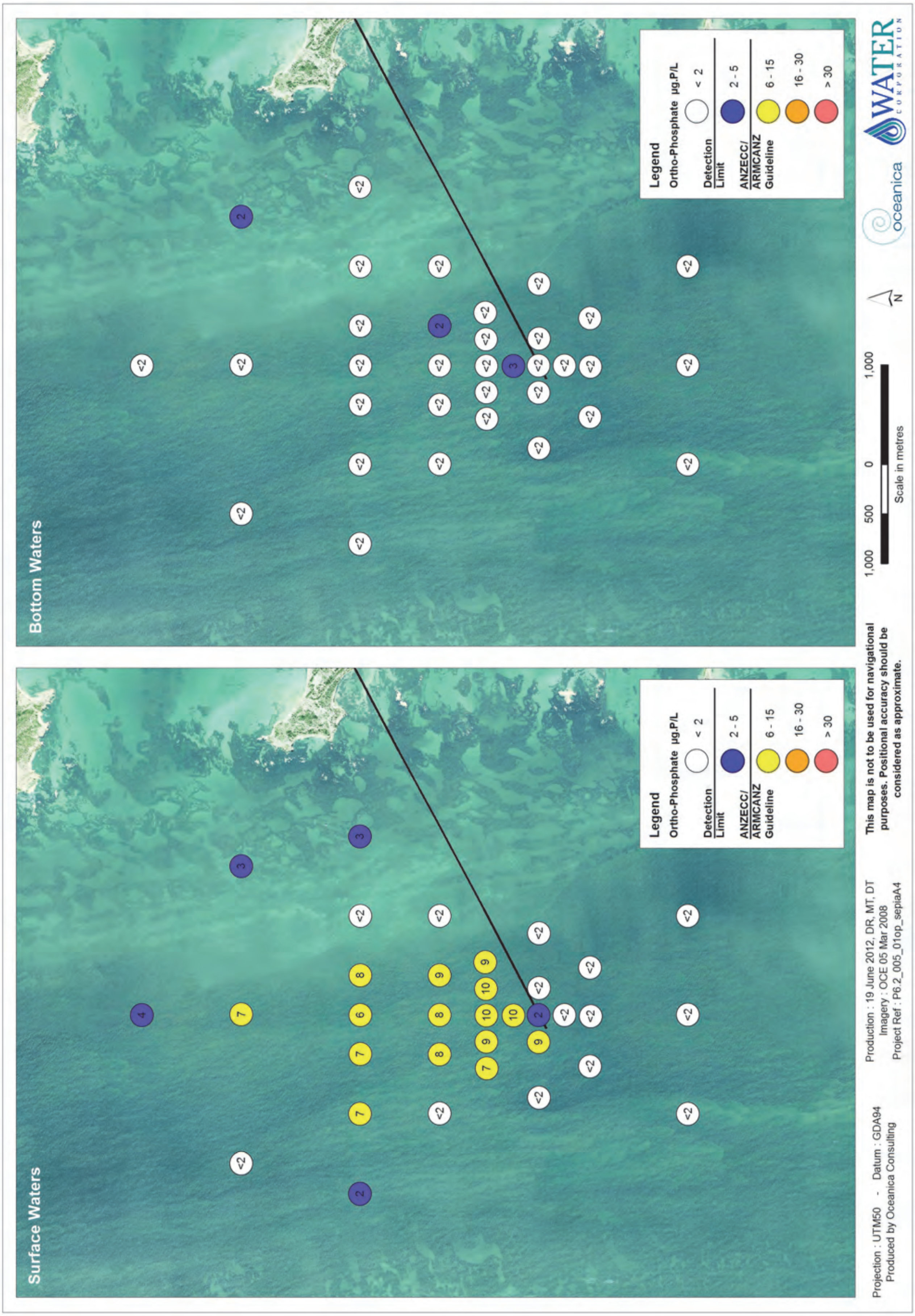


Figure 5.15 Ortho-phosphate concentrations at surface, bottom and shoreline sites sampled at Sepia Depression, 21 February 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 5.16 Spatial distribution of ortho-phosphate concentrations in surface and bottom water samples from Sepia Depression, 21 February 2012

5.5.4 Phytoplankton biomass and distribution

Phaeophytin

- Phaeophytin concentrations were measured at five offshore surface sites (15, 61, 67, 72 and 74) and one bottom site (15). Concentrations at all sites were below the 0.2 µg/L detection limit.
- Phaeophytin concentrations were measured at nine shoreline sites. Concentrations ranged from <0.2 µg/L (sites C, D, E, I) to 0.4 µg/L (sites F, G, H).

Chlorophyll a

- *Note: Chlorophyll* a *concentrations at surface and bottom offshore sites were determined in-situ using a fluorometer. The chlorophyll* a *concentration at shoreline sites were analysed using acetone extraction methods.*
- The highest offshore surface concentrations of chlorophyll a were 0.6 µg/L at site 67 and 0.5 µg/L at sites 30 and 63 (Figure 5.17). Sites 67, 30 and 63 were located 2548 m northeast, 638 m east, and 1841 m north of the diffuser, respectively
- The highest offshore bottom concentration of chlorophyll *a* was 0.5 µg/L at sites 54, 61, 63, 64 and 72 (Figure 5.17). Sites 54, 61, 63, 64 and 72 were located 1077 m north, 2549 m northwest, 1841 m north, 1799 m north, and 3354 m northeast of the diffuser, respectively.
- The concentrations of chlorophyll *a* at all surface and bottom sites were below the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L. Concentrations of chlorophyll *a* at 33 surface sites (97%) and 34 bottom site (100%) were below the 80th percentile of reference values (0.5 µg/L [surface] and 0.6 µg/L [bottom]).
- Chlorophyll *a* concentrations at shoreline sites varied from 0.3 µg/L (site F) to 1.4 µg/L (site H). Four shoreline sites (44%) had chlorophyll *a* concentrations below the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L.
- Spatial patterns in chlorophyll *a* concentrations (Figure 5.18) revealed localised increases in surface and bottom waters to the north, northeast, and northwest of the diffuser. However, these localised increases were below the ANZECC/ARMCANZ (2000) guideline of 0.7 µg/L.

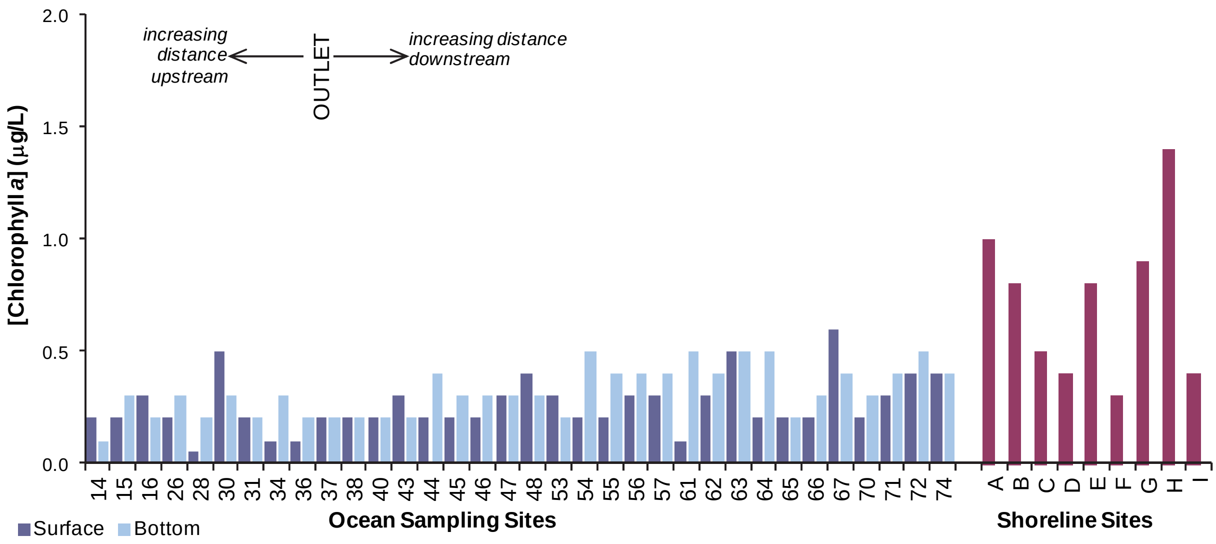
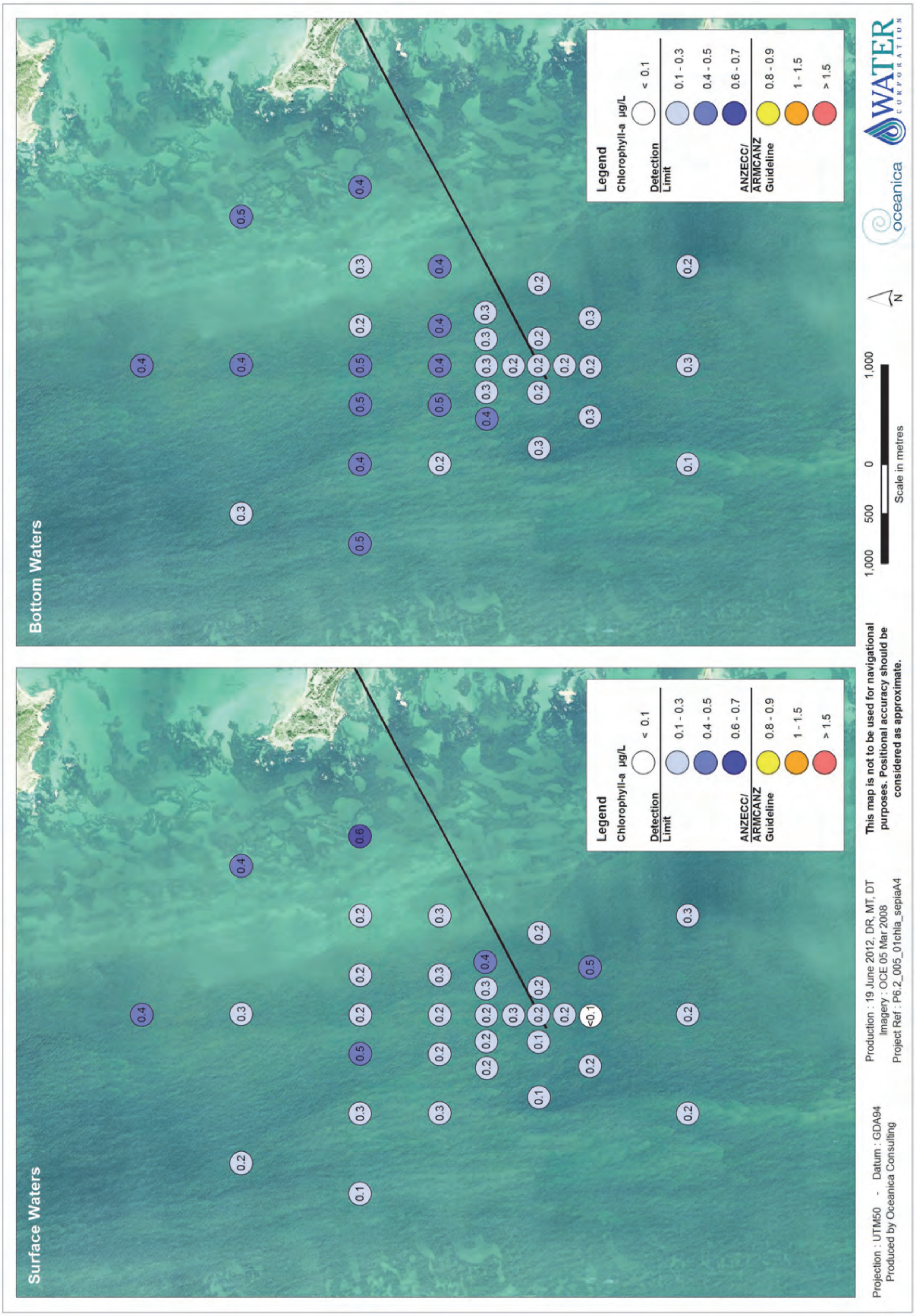


Figure 5.17 Chlorophyll *a* concentrations at surface, bottom and shoreline sites sampled at Sepia Depression, 21 February 2012



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 5.18 Spatial distribution of chlorophyll *a* concentrations in surface and bottom water samples from Sepia Depression, 21 February 2012

5.5.5 Bacterial counts and distribution

Thermo-tolerant coliforms (TTC)

- The three highest offshore surface counts of TTC were 8200 CFU/100 mL at site 36 (located 150 m west of the diffuser), 7000 CFU/100 mL at site 43 (149 m north of the diffuser) and 5600 CFU/100 mL at site 46 (403 m north of the diffuser; Figure 5.19).
- The three highest offshore bottom counts of TTC were 800 CFU/100 mL at site 43 (located 149 m north of the diffuser), 130 CFU/100 mL at site 37 (located directly above the diffuser) and 80 CFU/100 mL at site 44 (located 642 m northwest of the diffuser; Figure 5.19).
- All shoreline counts of TTC were equal to or below the 10 CFU/100 mL detection limit.

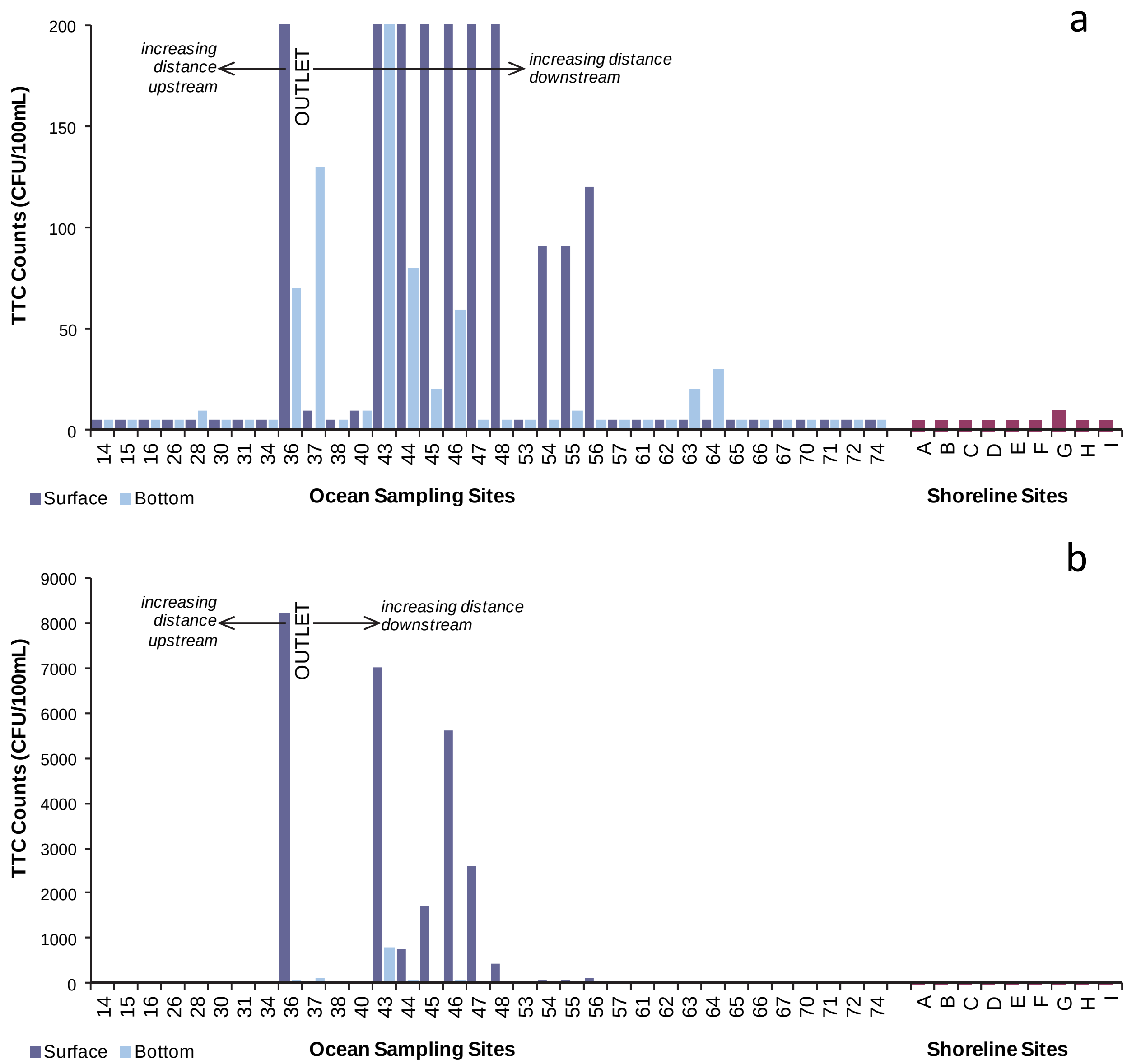


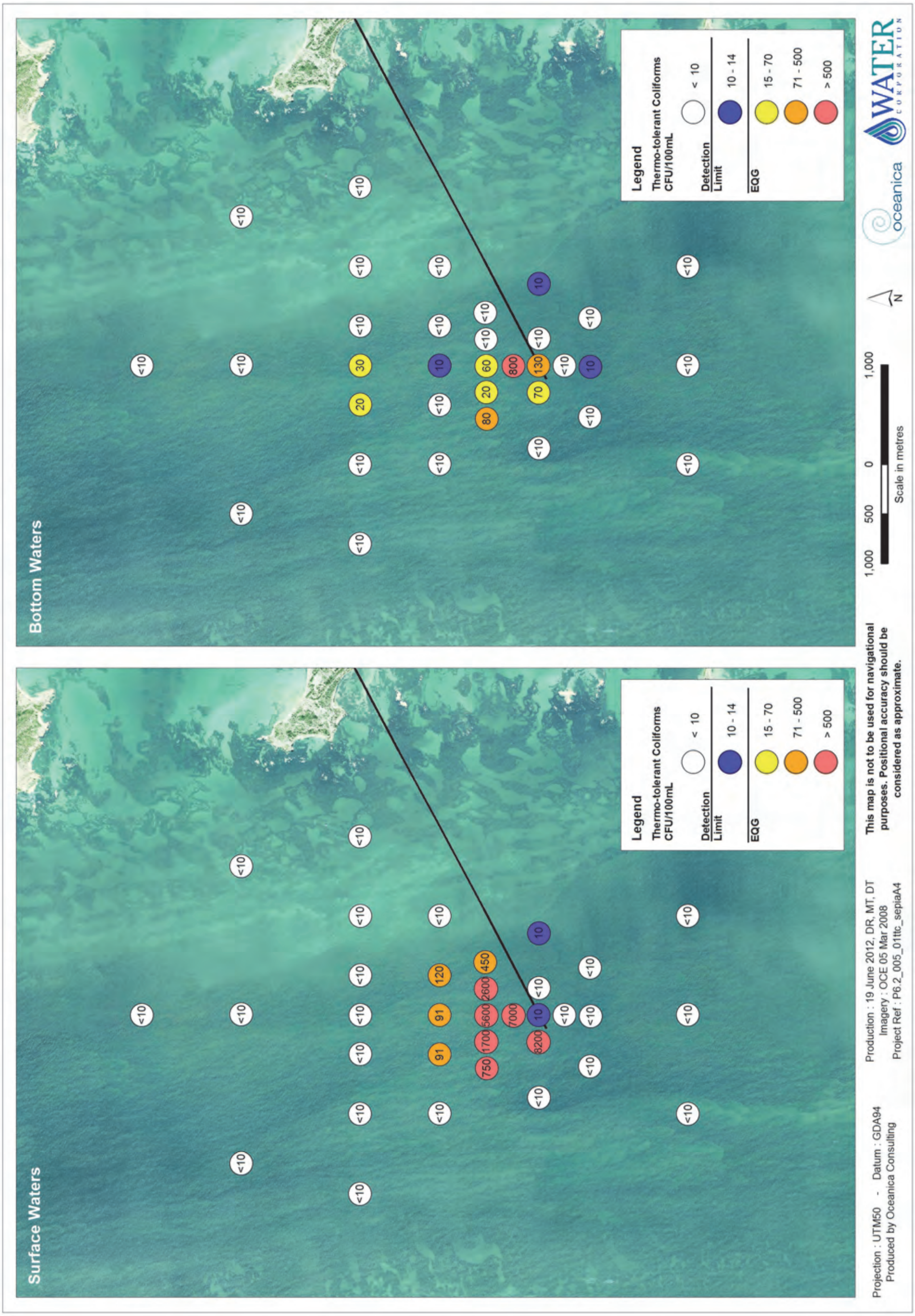
Figure 5.19 Thermo-tolerant coliform counts at surface, bottom and shoreline sites sampled at Sepia Depression, 21 February 2012. (a) axis scaled to show low range counts; (b) axis scaled to show high range counts

- The median surface counts of TTC at sites <250 m from the diffuser did not exceed either the EQG and the EQS for the maintenance of seafood safe for human consumption (Table 5.3). The median TTC counts in bottom waters at sites <250 m from the diffuser exceeded the EQG but were equal to the EQS. The median TTC counts in surface and bottom waters at sites >250 m, and shoreline sites, were below the EQG.
- Spatial patterns in TTC counts (Figure 5.20) revealed that localised increases above the ANZECC/ARMCANZ guideline and the EQG occurred in surface and bottom waters nearby and to the north of the diffuser.

Table 5.3 Median counts (CFU/100 mL) of thermo-tolerant coliforms at shoreline sites and in surface and bottom waters at offshore sites <250 m and >250 m from the diffuser at Sepia Depression on 21 February 2012

Sites	Surface	Bottom	EQC (EPA 2005)
<250 m from the diffuser	10	70	14 CFU/100 mL (EQG) 70 CFU/100 mL (EQS)
>250 m from the diffuser	<10 (1)	<10 (1)	
Shoreline	<10 (1)	-	

Note:
1. 10 CFU/100 mL is the lower assay limit for the parameter.



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3
2. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or EQG

Figure 5.20 Spatial distribution of thermo-tolerant coliform counts in surface and bottom water samples from Sepia Depression, 21 February 2012

Enterococci *spp.*

- The three highest offshore surface counts of *Enterococci* spp. were 630 MPN/100 mL at site 43 (149 m north of the diffuser), 520 MPN/100 mL at site 36 (150 m west of the diffuser) and 400 MPN/100 mL at sites 46 and 47 (403 m north and 449 m northeast of the diffuser, respectively; Figure 5.21).
- The highest offshore bottom count of *Enterococci* spp. was 84 MPN/100 mL at site 43, located 149 m north of the diffuser. All other sites had counts of *Enterococci* spp.equal to or below the 10 MPN/100 mL detection limit.
- The highest shoreline count of *Enterococci* spp. was 20 MPN/100 mL at site G; all other shoreline sites had counts of *Enterococci* spp. below the 10 MPN 100/mL detection limit.

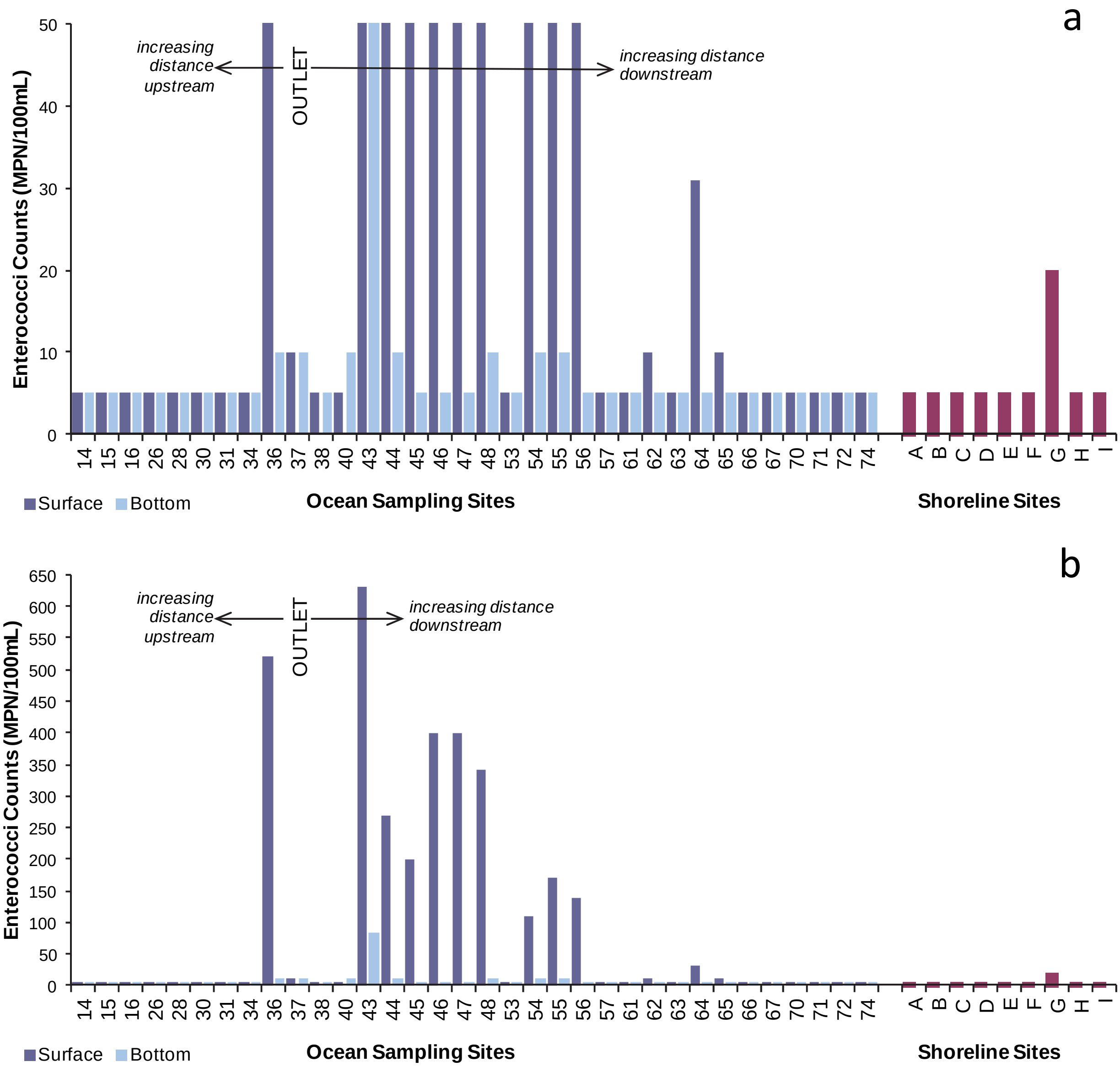


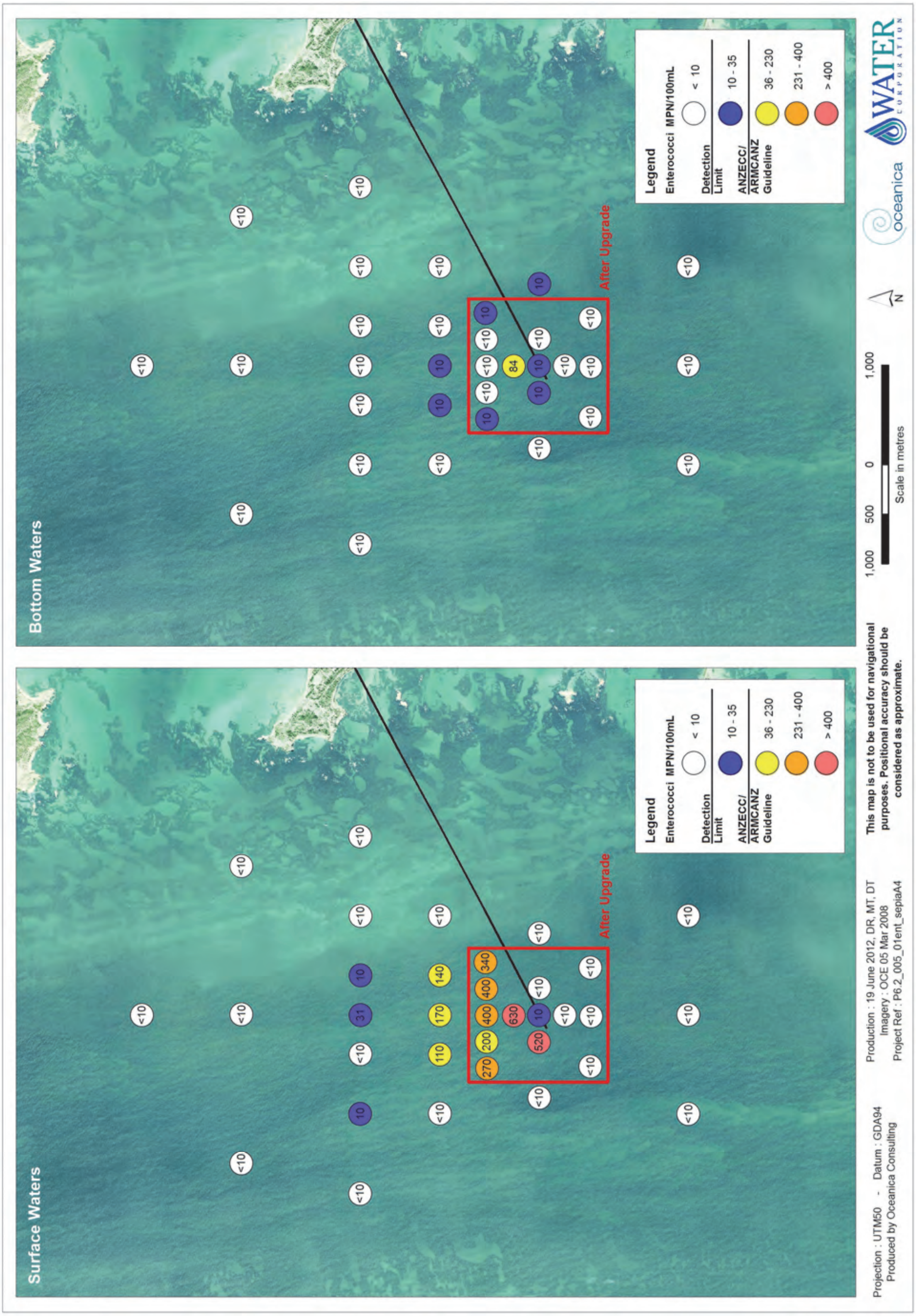
Figure 5.21 **Counts of *Enterococci* spp. at surface, bottom and shoreline sites sampled at Sepia Depression, 21 February 2012. (a) axis scaled to show low range counts; (b) axis scaled to show high range counts**

- The median count of *Enterococci* spp. at surface sites within the post-upgrade boundary were above the ANZECC/ARMCANZ (2000) guideline for primary contact, but below the guideline for secondary contact. The median count of *Enterococci* spp. counts at bottom sites within the post-upgrade boundary, and at surface and bottom sites outside the post-upgrade boundary, were below the ANZECC/ARMCANZ (2000) guidelines for both primary and secondary contact.
- Spatial patterns of counts of *Enterococci* spp. (Figure 5.22) revealed that localised increases above the ANZECC/ARMCANZ (2000) guideline occurred in surface waters nearby and to the north of the diffuser, and in bottom waters at one site just north of the diffuser.

Table 5.4 Median counts (MPN/100 mL) of *Enterococci* spp. at shoreline sites and in surface and bottom waters at offshore sites within and outside the post-upgrade boundary at Sepia Depression on 21 February 2012

Sites	Surface	Bottom	ANZECC/ARMCANZ (2000)
Inside the post-upgrade boundary	200	<10[1]	35 faecal coliforms/100 mL (1° contact) 230 faecal coliforms/100 mL (2° contact)
Outside the post-upgrade boundary	<10[1]	<10[1]	
Shoreline	<10[1]	-	

Note:
1. 10 MPN/100 mL is the lower assay limit for the parameter.



Notes:

1. Site locations have been exaggerated for visual clarity. Precise site locations are given in Figure 5.3
2. The scale of the 'After Upgrade' boundary has been exaggerated to clarify which sites are located inside or outside the boundary
3. Breaks in the legend (solid lines) indicate concentrations above or below the detection limit or ANZECC/ARMCANZ (2000) guideline

Figure 5.22 Spatial distribution of counts of *Enterococci* spp. in surface and bottom water samples from Sepia Depression, 21 February 2012

5.6 Conclusions

During the survey on 21 February 2012 at Sepia Depression, the treated wastewater plume was advecting in a northerly direction away from the outlet. The survey captured the extent of the elevated nutrient concentrations related to the discharge of treated wastewater into the marine environment. Nutrient concentrations were higher at sites closer to the diffuser and in the downstream plume, than at sites located further from the influence of the outlet.

The summer water quality surveys were not specifically designed to provide information suitable for comparison with ANZECC/ARMCANZ (2000) guidelines or with 80th percentile of reference values. For information only, comparison of water quality parameters at sites located <250 m of the diffuser and >250 m from the diffuser with the ANZECC/ARMCANZ (2000) guidelines and 80th percentile of reference values were made. ANZECC/ARMCANZ (2000) suggests that an exceedance of a trigger value should be regarded as an “early warning” and furthermore, that trigger values are not intended as a means of assessing “compliance”.

Median concentrations of ammonia and total nitrogen in surface and bottom waters at all offshore sites were below the ANZECC/ARMCANZ (2000) guidelines and the 80th percentile of reference values. Median concentrations of nitrate+nitrite exceeded the ANZECC/ARMCANZ (2000) guideline and 80th percentile of reference values at sites >250 m from the diffuser. However, median nitrate+nitrite concentrations were not in exceedance in bottom waters >250 m from the diffuser, nor in surface and bottom waters <250 m of the diffuser. At shoreline sites, median ammonia concentrations exceeded the ANZECC/ARMCANZ (2000) guideline, while nitrate+nitrite and total nitrogen did not. Phosphate-related parameters did not exceed ANZECC/ARMCANZ (2000) guidelines or 80th percentile of reference values at any sites.

Median concentrations of chlorophyll *a* at <250 m and >250 m from the diffuser at surface and bottom sites, were below the ANZECC/ARMCANZ (2000) guideline values and the 80th percentile of reference values. The median concentration of chlorophyll *a* at shoreline sites was above the ANZECC/ARMCANZ (2000) guideline values. Increases in phytoplankton biomass (measured as an increase in chlorophyll *a* concentration) in response to increased nutrient concentrations are not instantaneous. Elevations in phytoplankton biomass are likely to occur downstream from the immediate outlet-mixing environment in a manner that will vary with flow conditions, rather than in the immediate vicinity of the discharge point. Experience with the PLOOM Program suggests that there is no straightforward mechanism for managing ocean outlets in the open ocean on the basis of establishing guidelines for chlorophyll *a*. General practice has been to manage nutrient impacts by specifying maximum nutrient loads and minimum dilution values. Maximum nutrient loads are based on ecological investigations. Minimum initial dilutions are specified, which determine maximum contaminant concentrations. These measures identify the extent of influence of the outlet. This approach has been adopted throughout the PLOOM and Perth Coastal Waters Studies.

The microbiological indicators showed elevated counts in the immediate vicinity of the diffuser and a decline in counts away from the outlet, indicating die-off of the microbes. Thermo-tolerant coliform counts were above the EQG and EQS for the maintenance of seafood safe for human consumption in bottom waters in the vicinity of the outlet (<250 m). However, the guidelines were met in surface waters in the vicinity of the outlet, at distances >250 m from the diffuser and at shoreline sites (Table 5.3, Table 5.5).

Human health concerns relating to seafood are not considered to be an issue at Sepia Depression as there is no harvesting of seafood or aquaculture undertaken in the waters 1–2 km offshore. Median counts of *Enterococci* spp. were above the ANZECC/ARMCANZ (2000) guideline for primary contact in surface waters inside the post-upgrade boundary. However median counts of *Enterococci* spp. were below the ANZECC/ARMCANZ (2000) guideline in bottom waters inside the post-upgrade boundary, and in surface and bottom waters outside the post-upgrade boundary, and at shoreline sites (Table 5.4, Table 5.6). Public health concerns relating to primary (whole-body) contact recreation are not considered to be an issue at Sepia Depression because there is no primary contact recreational use of the waters 1–2 km offshore. Furthermore, the Environmental Protection Authority (2005) notes in the Manual of Standard Operating Procedures for Environmental Monitoring Against the Cockburn

Sound Environmental Quality Criteria (2003–2004) that the Environmental Quality Criteria for primary and secondary contact recreation are only appropriate for evaluation of data collected from waters at recreational beaches, as they protect regular users of beaches.

Table 5.5 Summary comparison of the EPA (2005) EQG with the median concentrations of thermo-tolerant coliforms recorded at shoreline sites and in surface (S) and bottom (B) waters of offshore sites located <250 m and >250 m from the diffuser during the summer water quality survey at Sepia Depression on 08 March 2011

Parameter	Environmental Quality Guideline (EPA 2005) [1]				
	<250 m		>250 m		Shoreline
	S	B	S	B	
Thermo-tolerant coliforms	🟩	🟥	🟩	🟩	🟩

Notes:
1. For the maintenance of seafood safe for human consumption
2. 🟥 = median values > EQG;
3. 🟩 = median values ≤ EQG

Table 5.6 Summary comparison of the ANZECC/ARMCANZ (2000) guideline with the median concentrations of *Enterococci* spp. recorded at shoreline sites and in surface (S) and bottom (B) waters located inside and outside the post-upgrade boundary during the summer water quality survey at Sepia Depression on 08 March 2011

Parameter	ANZECC/ARMCANZ (2000) [1]				
	Inside post-upgrade boundary		Outside post-upgrade boundary >		Shoreline
	S	B	S	B	
Enterococci spp. [1]	🟥	🟩	🟩	🟩	🟩

Notes:
1. Results for primary contact recreation
2. 🟥 = median values > ANZECC/ARMCANZ (2000) guideline
3. 🟩 = median values ≤ ANZECC/ARMCANZ (2000) guideline

The results from the summer water quality survey on 21 February 2012 indicate that the Sepia Depression ocean outlet was operating effectively. The plume of treated wastewater rapidly dissipated. Despite elevated levels of water quality parameters at some individual sites outside the immediate zone of influence of the outlet, the water quality conditions required for ecosystem protection and public health criteria were met.

6. Acknowledgements

The summer water quality surveys were coordinated by **Mark Nener** (Water Corporation). The nutrient analyses were conducted by the Marine and Freshwater Research Laboratory, Murdoch University. The microbiological assays were conducted by the PathCentre. The wind data were provided by the Bureau of Meteorology and the wave and tide data were supplied by Department of Transport. The following people assisted in data preparation and analysis and figure preparation: **Rochelle Desmond**, **Sarah Marshman,** and **Katherine Cox**.

This report was prepared by **David Rivers** (Oceanica Consulting) and reviewed by **Glenn Shiell** and **Martin Lourey** (Oceanica Consulting) and **Mark Nener** (Water Corporation). GIS and preparation of figures for this report was completed by **Dinesh Tuladhar**, **William An** and **Manoj Tuladhar** (Oceanica Consulting). The report was formatted by **Dennis Bothur** and **Rachael Hillman** (Oceanica Consulting).

7. References

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Oceanica (2006) Perth Long-term Ocean Outlet Monitoring (PLOOM) Program -2006 Summer Water Quality Monitoring Surveys: Ocean Reef, 31 January 2006; Swanbourne, 17 January 2006; Sepia Depression, 14 February 2006. Prepared for Water Corporation of Western Australia by Oceanica Consulting Pty Ltd, Report No. 479/1, Perth, Western Australia, July 2005

Oceanica (2007) Perth Long-term Ocean Outlet Monitoring (PLOOM) Program - 2007 Summer Water Quality Survey Compliance Report: Ocean Reef 30 January 2007; Swanbourne 16 January 2007; Sepia Depression 6 February 2008. Prepared for Water Corporation of Western Australia by Oceanica Consulting Pty Ltd, Report No. 538/1, Perth, Western Australia, June 2007

Oceanica (2008) Perth Long-term Ocean Outlet Monitoring (PLOOM) Program - 2008 Summer Water Quality Survey Compliance Report - Ocean Reef: 29 January 2008, Swanbourne: 15 January 2008, Sepia Depression: 12 February 2008. Prepared for Water Corporation of Western Australia by Oceanica Consulting Pty Ltd, Report No. 527_009/1, Perth, Western Australia, July 2008.

Oceanica (2009) Perth Long-term Ocean Outlet Monitoring (PLOOM) Program - 2009 Summer Water Quality Survey Compliance Report - Ocean Reef: 3 February 2009, Swanbourne: 20 January 2009, Sepia Depression: 17 February 2009. Prepared for Water Corporation of Western Australia by Oceanica Consulting Pty Ltd, Report No. 628_005/1, Perth, Western Australia, July 2009

Oceanica (2010) Perth Long-term Ocean Outlet Monitoring (PLOOM) Program - 2010 Summer Water Quality Survey Compliance Report: Ocean Reef: 23 February 2010, Swanbourne: 9 February 2010, Sepia Depression: 9 March 2010. Prepared for Water Corporation of Western Australia by Oceanica Consulting Pty Ltd, Report No. 788_005/1, Perth, Western Australia, June 2010

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Appendix A

Wastewater Treatment Plant Licence Conditions

Beenyup Wastewater Treatment Plant Licence

Department of
Environment and Conservation

Your ref: DEC625-02
Our ref: L7882/1991/13
Enquiries: Tanya Gilders
Phone: 9333 7527
Fax: 9333 7550
Email: Tanya.Gilders@dec.wa.gov.au

Mr Guy Watson
Environmental Branch
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

Dear Mr Watson

ENVIRONMENTAL PROTECTION ACT 1986 – LICENCE

Premises: Beenyup Wastewater Treatment Plant
Location: Lot 8278 on Plan 30778, Ocean Reef Road, Craigie WA 6025
Licence: L7882/1991/13

You are advised that your application for a licence to operate the works prescribed under the *Environmental Protection Act 1986* at the above-mentioned location has been approved subject to the attached conditions. Enclosed is your licence number **L7882/1991/13**.

If any aspect of the conditions of licence aggrieves you, you may lodge an appeal, accompanied by the $50.00 fee, with the Minister for the Environment within 21 days from the date on which this licence is received. Members of the public may also appeal conditions. Please contact the Appeals Registrar at the Office of the Appeals Convenor on 9221 8711 after the closing date of appeals to check whether any appeals were received.

Under Section 58 of the *Environmental Protection Act 1986*, it is an offence to contravene a licence condition. This offence carries a penalty of up to $125,000, with a daily penalty of up to $25,000. The Department considers that a breach of this section, or any other section, of the *Environmental Protection Act 1986* to be extremely serious.

If you have any questions relating to the licence or licence conditions, please do not hesitate to contact Tanya Gilders on 9333 7527 for clarification or discussion of any grievances you have.

Yours faithfully

Paul Byrnes

Paul Byrnes
A/ Principal Environmental Officer

31 October 2008

encl: Environmental Protection ACT 1986 – Licence L7882/1991/13
copy to: Local Government Authority: City of Joondalup

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT AND CONSERVATION

Environmental Protection Act 1986

ISSUED LICENCE

LICENCE NUMBER: L7882/1991/13 **FILE NUMBER: DEC625-02**

LICENSEE AND OCCUPIER:
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

NAME AND LOCATION OF PREMISES:
Beenyup Wastewater Treatment Plant
Lot 8278 on Plan 30778, Ocean Reef Road
Craigie WA 6025

Environmental Protection Regulations 1987
CLASSIFICATION(S) OF PREMISES:

Category: 61 Liquid waste facility;
Category: 54 Sewage facility

COMMENCEMENT DATE OF LICENCE: 1 November 2008

EXPIRY DATE OF LICENCE: 31 October 2011

CONDITIONS OF LICENCE:
As described and attached:

DEFINITION(S)
GENERAL CONDITION(S): 3
AIR CONTROL CONDITION(S): 3
WATER CONTROL CONDITION(S): 6
SOLID WASTE CONTROL CONDITION(S): 1
ATTACHMENT(S): 4

Paul Byrnes
....

Officer delegated under Section 20
of the *Environmental Protection Act 1986*

Date of Issue: Friday, 31 October 2008

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT & CONSERVATION

Environmental Protection Act 1986

LICENCE NUMBER: L7882/1991/13 **FILE NUMBER: DEC625-02**

PREAMBLE

The following statements in this Preamble either reflect important sections of the Environmental Protection Act 1986 or provide relevant background information for the licensee. They should not be regarded as conditions of licence.

Applicability

This licence is issued to the Water Corporation for the Beenyup Wastewater Treatment Plant (WWTP) located at Lot 8278 on Plan 30778, Ocean Reef Road, Craigie (Attachment 1), which is a prescribed premises within Schedule 1 of the *Environmental Protection Regulations 1987* as outlined in Table 1.

Table 1: Categories under which Beenyup WWTP at Lot 8278 on Plan 30778 Ocean Reef Road, Craigie is prescribed.

Category number	*Category name*	*Description*
54	Sewage facility	Premises on which sewage is treated (excluding septic tanks); or from which treated sewage is discharged onto land or into waters.
61	Liquid waste facility	Premises on which liquid waste produced on other premises (other than sewerage waste) is stored, reprocessed, treated or irrigated.

Under the *Environmental Protection (Controlled Waste) Regulations 2004*, the licensee is only permitted to accept the following tankered controlled wastes at the premises:
(i) biological wastes (categories 1.02 and 1.05).

Nominal Rated Throughput

The nominal rated throughput of the premises covered by this licence is as follows:

- Quantity of wastewater treated: 120 megalitres per day
- Quantity of liquid waste accepted: 50 000 tonnes per year

Ministerial Conditions

This premises is also bound by Ministerial Conditions for its operation, which should be considered in conjunction with this licence. The Ministerial Conditions were amended in July 2001 to allow the load of phosphorus discharged at the ocean outlet to be greater, and this change has been incorporated into these conditions of licence. The increase was approved because it has been demonstrated that nitrogen is the limiting factor in algal growth in the particular body of water subject to the discharge.

Odour Control

The licensee should manage and operate the premises such that odours emanating from the premises do not unreasonably interfere with the health, welfare, convenience, comfort or amenity of any person at an odour sensitive premises.

This licence recognises that residential encroachment has generated a situation whereby odours generated by the WWTP may impact upon nearby residences. However, this does not override the requirements of the paragraph above, and the Water Corporation is expected to adopt continuous improvement with respect to odour control.

Emergency, Accident or Malfunction
The licensee should inform the Director as soon as practicable of the identification of any discharge of waste which has occurred as a result of an emergency, accident or malfunction, or extreme weather conditions, otherwise than in accordance with any condition of this licence and has caused or is likely to cause pollution.

Alteration to Premises
Prior to making any significant alterations to the premises which may affect the air, water or noise emissions from the premises the licensee must submit a proposal to the Director accompanied by supporting information and plans which allow the environmental impact of that change to be assessed.

General Requirements
The following statements reflect important sections of the *Environmental Protection Act 1986* and are included for the information of the licensee:

- The licensee should take all reasonable and practicable measures to prevent pollution of the environment.
- Noise emissions from operations on site are required to comply with the *Environmental Protection (Noise) Regulations 1997.*
- The licensee should take all reasonable and practicable measures to prevent or minimise the discharge of waste and the emission of noise, odours or electromagnetic radiation from the premises.
- The licensee should inform the Director at least 24 hours prior to the commencement of any planned non-standard operations, which may have the potential to cause pollution.

CONDITIONS OF LICENCE

DEFINITIONS

'APHA-AWWA-WEF' means American Public Health Association; American Water Works Association; Water Environment Federation.

'biological wastes category 1.02 and 1.05' means biological wastes under category 1.02 and 1.05 within Appendix A – Controlled Waste Categories and Descriptions of the *Environmental Protection (Controlled Waste) Regulations 2004.*

'Director' means Director, or other delegated officer, Environmental Regulation Division of the Department of Environment & Conservation for and on behalf of the Chief Executive Officer as delegated under Section 20 of the *Environmental Protection Act 1986*;

'Director' or 'Department of Environment & Conservation' for the purpose of correspondence means-

Program Manager, Industry Regulation
Swan Region
Department of Environment & Conservation
Locked Bag 104
Bentley Delivery Centre WA 6983
Address:
181-205 Davy Street
Booragoon WA 6154

Telephone: (08) 9333 7510
Facsimile: (08) 9333 7550

'inform' means inform by telephone or facsimile;

'licensed' means licensed or registered under the *Environmental Protection Act 1986* unless otherwise specified.

'mg/L' means milligram per litre;

'mL' means millilitre;

'μg/L' means micrograms per litre;

'mg/m^3' means milligram per cubic metre;

'NATA' means National Association of Testing Authorities.

'odour sensitive premises' means any land or building that is used as a residence, guest house, hotel, motel, caravan park, school, church, hospital, or as an office or consulting rooms, where such office or consulting rooms are not located in an industrial area.

'premises' means Beenyup Wastewater Treatment Plant located at Lot 8278 on Plan 30778, Ocean Reef Road, Craigie, as shown in Attachment 1.

'routine maintenance' means the servicing of the pre-treatment or primary treatment areas of the plant.

'STP' means standard temperature and pressure.

GENERAL CONDITIONS

ANNUAL MONITORING REPORT

G1(a) The licensee shall provide to the Director, by **1 September each year**, an Annual Monitoring Report containing data collected over the previous financial year (**1 July to 30 June**). The report shall contain but not be limited to:

(i) monitoring data or other collected data required by any condition of this licence;
(ii) an assessment of the data against any limits set or other environmental guidelines or policies referred to in this licence and data from previous years' monitoring;
(iii) a summary of any data exceeding those limits, guidelines or policies including information on why the exceedence occurred (if known) and action taken by the licensee to prevent recurrence of such exceedences.
(iv) a summary of the number and type of complaints received;
(v) any changes to site boundaries, surface drainage channels and on-site or off-site impacts or pollution; and
(vi) a list of any monitoring methods used to collect and analyse data required by any condition of this licence to demonstrate they comply with the methods specified in this licence.

G1(b) The licensee shall use the following units in reports required by part (a) of this condition:

Parameter	Unit
Monthly cumulative volume discharged	Cubic metres per day (monthly average)

pH	pH units
E. coli	Colony forming units per 100 ml
Faecal enterococci	Most probable number per 100 ml
All other parameters (treated wastewater)	mg/L
All other parameters (marine)	µg/L
Nitrogen and phosphorus load	kilograms per day (monthly average)

COMPLAINTS

G2 The licensee shall keep a written record of complaints received regarding emissions from the premises. For each such complaint the following information shall be recorded (if known or provided):

(i) name and address of complainant(s);
(ii) date and time of complaint;
(iii) a general description of the nature of complaint;
(iv) any on-site activities (if any) that may have led to the emission;
(v) wind direction, wind speed and temperature at the time of the complaint;
(vi) likely source of the reported problem; and
(vii) action taken in response to the complaint.

G3 ANNUAL AUDIT COMPLIANCE REPORT

The licensee shall by 1 September in each year, provide to the CEO an annual audit compliance report in the form in attachment 4 to this licence, signed and certified in the manner required by Section C of the form, indicating the extent to which the licensee has complied with the conditions of this licence, and any previous licence issued under Part V of the Act for the Premises, during the period beginning 1 July the previous year and ending on 30 June in that year.

AIR POLLUTION CONTROL CONDITIONS

COVERING OF PRE TREATMENT, PRIMARY TREATMENT AND SECONDARY TREATMENT AREAS

A1(a) The licensee shall maintain covers over the pre-treatment, primary treatment and secondary treatment areas of the plant, except for routine maintenance or emergency situations.

A1(b) The licensee shall maintain a chemical scrubbing system for the removal of odorous compounds from the pre-treatment, primary treatment and secondary treatment areas, prior to their emission through the scrubber stack except for routine maintenance or emergency situations.

STACK MONITORING

A2(a) The licensee shall monitor and record each of the following parameters, at the frequency stated using the method specified, in the exit gases emitted from the scrubber stack as specified on Attachment 2:

Parameter to be monitored	Monitoring frequency	Units	Monitoring method
Hydrogen	Monthly	mg/m^3 at STP,	VicEPA method

sulphide		dry	B18
Volumetric flow rate	Monthly	m^3/sec	USEPA method 2
Stack exit temperature	Monthly	°Celsius	n/a

A2(b) The licensee shall ensure that all hydrogen sulphide samples referred to in condition A2(a) are analysed in a laboratory holding NATA accreditation for that parameter.

ODOUR CONTROL LIMIT

A3 The licensee shall ensure that the emissions from the scrubber stack, monitored as per condition A2, do not exceed the following limits:

Emission	Concentration limit	Mass emission rate limit
Hydrogen sulphide	5 mg/m^3 at STP, dry	140 mg/sec at STP, dry

WATER POLLUTION CONTROL CONDITIONS

DISCHARGE AND SAMPLING POINT

W1(a) The licensee shall discharge treated wastewater from the premises to the environment through the Ocean Reef ocean outlet or to reuse schemes.

W1(b) The licensee shall maintain a sampling point in the outlet channel from the treatment plant so that representative water samples can be easily taken there from.

FLOW MONITORING

W2(a) The licensee shall monitor and record the cumulative monthly volumes of treated wastewater being discharged to the Ocean Reef ocean outlet and re-use schemes.

W2(b) The monthly flow results shall be recorded and presented in the next annual monitoring report in a tabular form.

WATER MONITORING AND REPORTING

W3(a) The licensee shall, at the frequencies stated, take representative water samples from the following monitoring sites, and have them analysed for the parameters listed:

Monitoring Sites	Sampling Frequency	Parameters to be sampled
Outlet channel	Monthly	pH, Total Suspended Solids, (filtered) 5-Day Biochemical Oxygen Demand, Total Nitrogen, Ammonium-nitrogen, Nitrate+Nitrite-nitrogen, Total Phosphorus
Outlet channel	3-monthly	*E.coli*, Oil and Grease, arsenic, cadmium,

		copper, chromium, lead, mercury, nickel, zinc
Ocean monitoring sites depicted in Attachment 3 (depending on ocean current)	Annually every summer	Total Nitrogen, Nitrate + Nitrite-nitrogen, Ammonium-nitrogen, Total Phosphorus, Filterable Reactive Phosphorus, Chlorophyll 'a', *E.coli*, Faecal enterococci

W3(b) The licensee shall collect, handle and preserve all water samples in accordance with the relevant part(s) of Australian Standard 5667:1998. With respect to marine sampling, it is accepted that the licensee (or its contractor) does not need to collect, container and transport blanks or field spikes in accordance with the above standard.

W3(c) The licensee shall analyse all water samples in its own quality assured laboratory, or ensure that samples are analysed in a laboratory holding NATA accreditation for the analyses specified. If the licensee uses its own laboratory, then at least one set of samples per year shall also be submitted to a laboratory holding NATA accreditation for the analysis specified in condition W3(a). The licensee shall report these duplicate results to the Director in the following annual monitoring report, specifying the laboratory in which each analysis was performed.

W3(d) The licensee shall keep the original laboratory analysis reports (or copies thereof) on record for the duration of this licence.

CALCULATION OF CONTAMINANT LOAD

W4 The licensee shall determine the monthly load of each contaminant in the treated wastewater discharged from the premises (except pH and bacteria) using flow-weighted data. The loads shall be based on the treated wastewater discharge rate and the concentration as measured in accordance with conditions W2 and W3. Monthly and annual average loads of the contaminants shall be reported in the Annual Monitoring Report in kilograms per day.

TOTAL PHOSPHORUS AND NITROGEN LOAD LIMIT

W5(a) The licensee shall ensure that the load for total phosphorus in treated wastewater discharged from the Beenyup WWTP to the ocean through the Ocean Reef ocean outlet does not exceed an annual average of 1500 kilograms per day recorded over the financial year.

W5(b) The licensee shall ensure that the load for total nitrogen in treated wastewater discharged from the Beenyup WWTP to the ocean through the Ocean Reef ocean outlet does not exceed an annual average of 3600 kilograms per day recorded over the financial year.

TANKERED WASTE

W6 The licensee may accept biological wastes category 1.02 and 1.05 (from other Water Corporation assets) tankered into the premises at the pre-treatment works of the sewage treatment plant. The waste shall be delivered to the plant via an enclosed pipeline.

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT & CONSERVATION

Environmental Protection Act 1986

LICENCE NUMBER: L7882/1991/13 **FILE NUMBER: DEC625-02**

SOLID WASTE CONTROL CONDITIONS

SOLIDS DISPOSAL

S1(a) The licensee shall dispose of collected grit and screenings from the pre-treatment area to a licensed landfill.

S1(b) The licensee shall either tanker sludges to another Water Corporation asset for treatment or dispose of sludge and biosolids in accordance with the document *Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products*, Department of Environmental Protection, Water and Rivers Commission and Department of Health (February, 2002).

Paul Byrnes

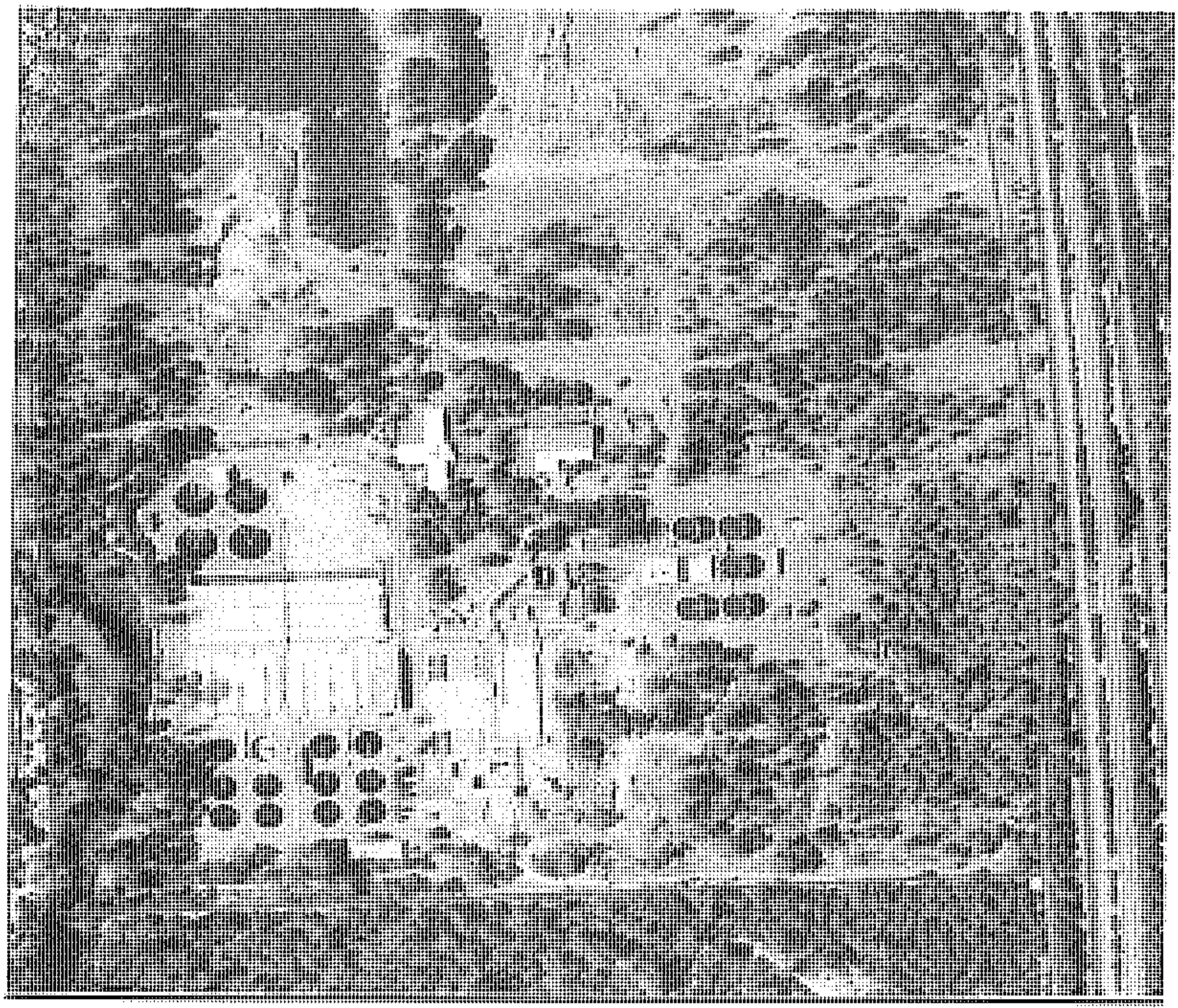
....

Officer delegated under Section 20
of the *Environmental Protection Act 1986*

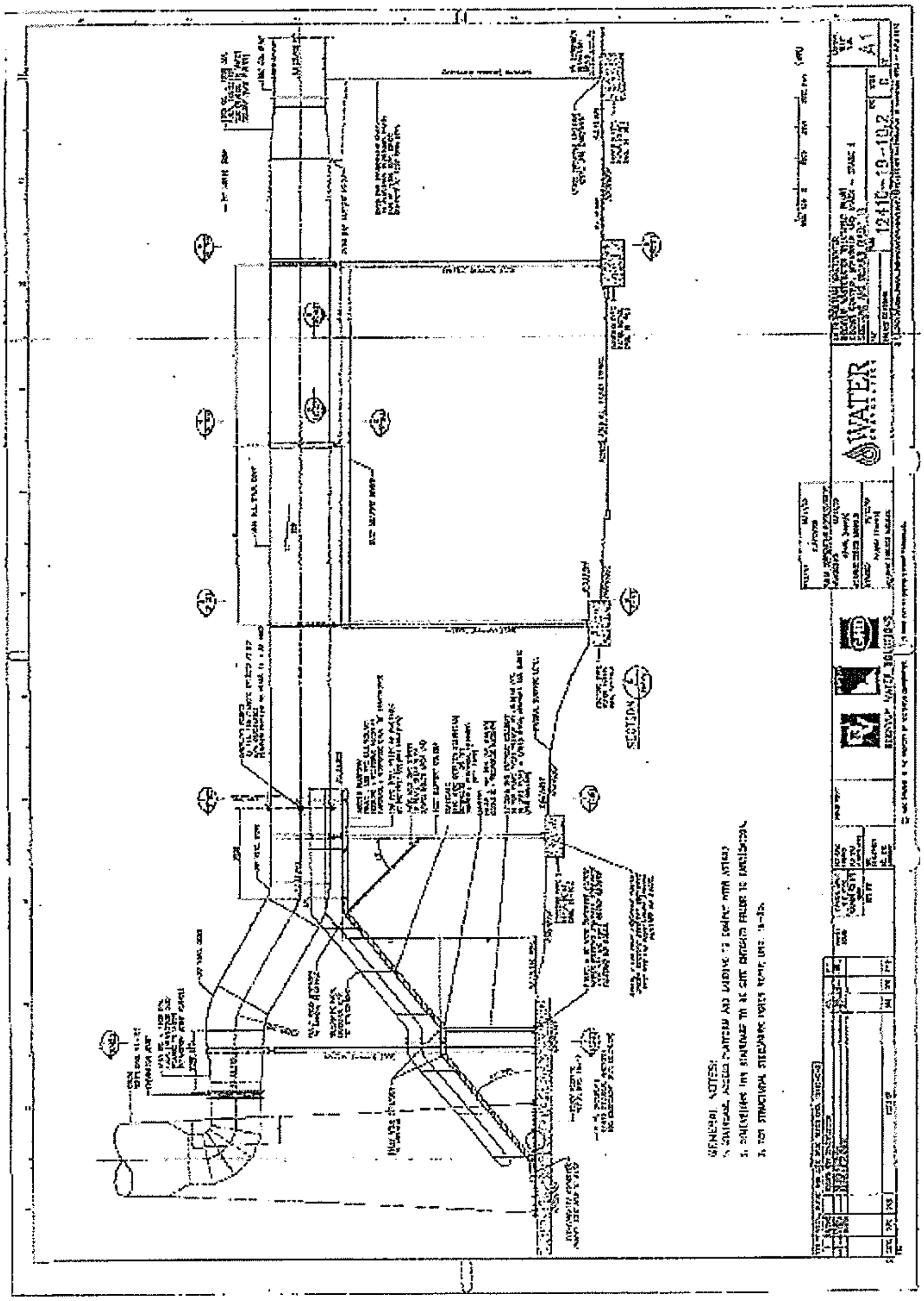
Date of Issue: 31 October 2008

ATTACHMENT 1

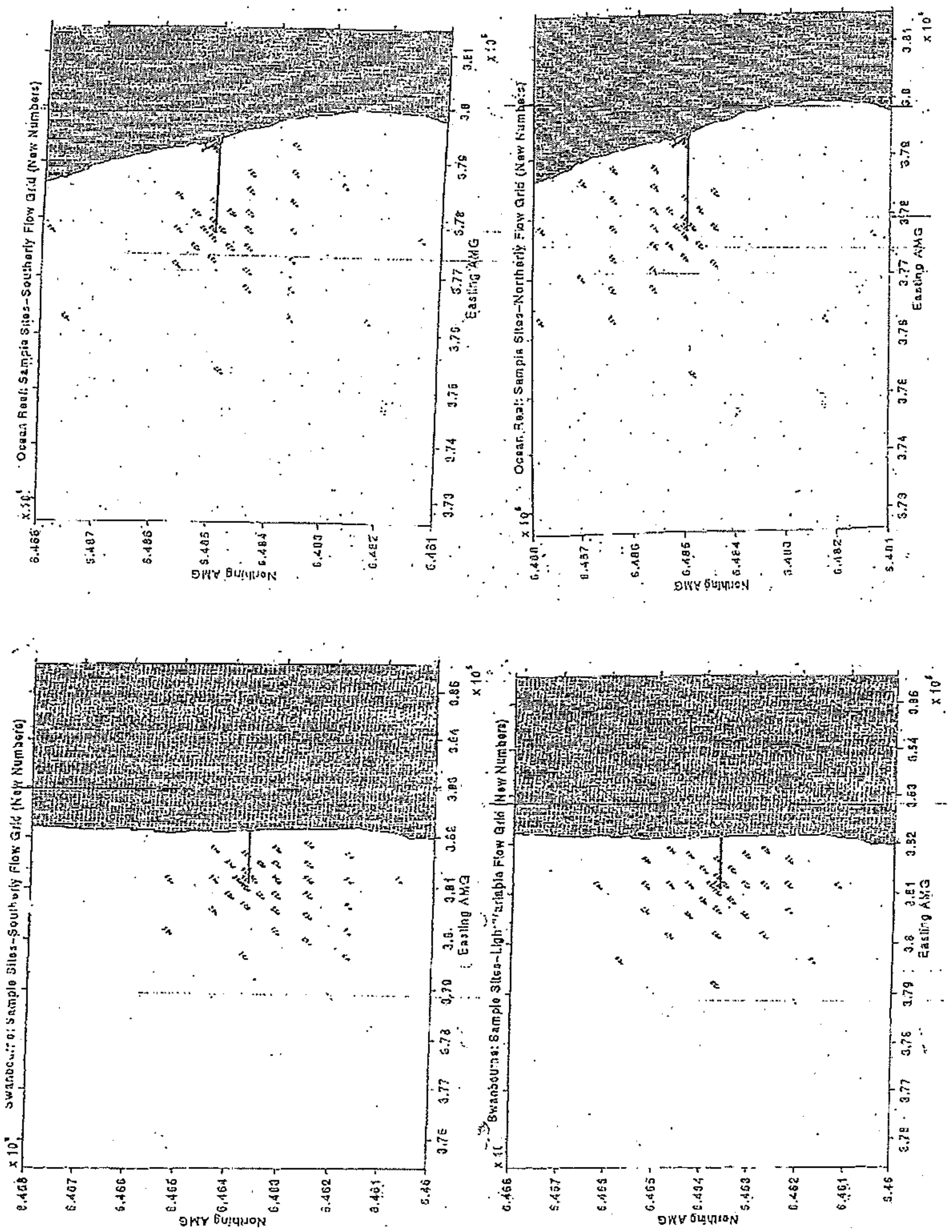
Lot 8278 on Plan 30778 Ocean Reef Road
Craigie WA 6025



ATTACHMENT 2



ATTACHMENT 3



ATTACHMENT 4

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT & CONSERVATION

Environmental Protection Act 1986

LICENCE NUMBER: L7882/1991/13 **FILE NUMBER: DEC625-02**

SECTION A

LICENCE DETAILS

Licence Number:	Licence File Number:
Company Name: Trading as:	ABN:
Reporting period: ________________ to ________________	

STATEMENT OF COMPLIANCE WITH LICENCE CONDITIONS

1. Were all conditions of licence complied with within the reporting period? (please tick the appropriate box)

Yes ☐ Please proceed to Section C

No ☐ Please proceed to Section B

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:______________

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT & CONSERVATION

Environmental Protection Act 1986

LICENCE NUMBER: L7882/1991/13 **FILE NUMBER: DEC625-02**

SECTION B
DETAILS OF NON-COMPLIANCE WITH LICENCE CONDITION.

Please use a separate page for each licence condition that was not complied with.

a) Licence condition not complied with?	
b) Date(s) when the non compliance occurred, if applicable?	
c) Was this non compliance reported to DEC?	
☐ Yes ☐ Reported to DEC verbally Date ___________ ☐ Reported to DEC in writing Date ___________	☐ No
d) Has DEC taken, or finalised any action in relation to the non compliance?	
e) Summary of particulars of non compliance, and what was the environmental impact?	
f) If relevant, the precise location where the non compliance occurred (attach map or diagram)	
g) Cause of non compliance	
h) Action taken or that will be taken to mitigate any adverse effects of the non compliance	
i) Action taken or that will be taken to prevent recurrence of the non compliance	

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:___________

SECTION C
SIGNATURE AND CERTIFICATION

This Annual Audit Compliance Report may only be signed by a person(s) with legal authority to sign it. The ways in which the Annual Audit Compliance Report must be signed and certified, and the people who may sign the statement, are set out below.

Please tick the box next to the category that describes how this Annual Audit Compliance Report is being signed. If you are uncertain about who is entitled to sign or which category to tick, please contact the licensing officer for your premises.

If the licence holder is		The Annual Audit Compliance Report must be signed and certified:
an individual	☐	by the individual licence holder, or
	☐	by a person approved in writing by the Chief Executive Officer of the Department of Environment and Conservation to sign on the licensee's behalf.
A firm or other unincorporated company	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
A corporation	☐	by affixing the common seal of the licensee in accordance with the Corporations Act 2001; or
	☐	by two directors of the licensee; or
	☐	by a director and a company secretary of the licensee, or
	☐	if the licensee is a proprietary company that has a sole director who is also the sole company secretary – by that director, or
	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
A public authority (other than a local government)	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
a local government	☐	by the chief executive officer of the licensee; or
	☐	by affixing the seal of the local government.

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT & CONSERVATION

Environmental Protection Act 1986

LICENCE NUMBER: L7882/1991/13 **FILE NUMBER: DEC625-02**

It is an offence under section 112 of the Environmental Protection Act 1986 *for a person to give information on this form that to their knowledge is false or misleading in a material particular. There is a maximum penalty of $50,000 for an individual or body corporate.*

I/We declare that the information in this annual audit compliance report is correct and not false or misleading in a material particular.

SIGNATURE: ______________________ SIGNATURE: ______________________

NAME:(printed) __________________________ NAME:(printed) __________________________

POSITION: ________________________ POSITION: ________________________

DATE: _____/______/______________ DATE: _____/______/______________

SEAL (if signing under seal)

Subiaco Wastewater Treatment Plant Licence

Department of
Environment and Conservation

Your ref: DEC794-02
Our ref: L4726/1991/13
Enquiries: Tanya Gilders
Phone: 9333 7527
Fax: 9333 7550
Email: Tanya.Gilders@dec.wa.gov.au

Mr Guy Watson
Environmental Branch
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

Dear Mr Watson

ENVIRONMENTAL PROTECTION ACT 1986 – LICENCE

Premises: Subiaco Wastewater Treatment Plant
Location: Lot 3150 on Plan 149501, Lot 5286 on Plan 162620 and Lot 6815 on Plan 166929 Lemnos Street, Shenton Park WA 6008
Licence: L4726/1991/13

You are advised that your application for a licence to operate the works prescribed under the *Environmental Protection Act 1986* at the above-mentioned location has been approved subject to the attached conditions. Enclosed is your licence number **L4726/1991/13**.

If any aspect of the conditions of licence aggrieves you, you may lodge an appeal, accompanied by the $50.00 fee, with the Minister for the Environment within 21 days from the date on which this licence is received. Members of the public may also appeal conditions. Please contact the Appeals Registrar at the Office of the Appeals Convenor on 9221 8711 after the closing date of appeals to check whether any appeals were received.

Under Section 58 of the *Environmental Protection Act 1986*, it is an offence to contravene a licence condition. This offence carries a penalty of up to $125,000, with a daily penalty of up to $25,000. The Department considers that a breach of this section, or any other section, of the *Environmental Protection Act 1986* to be extremely serious.

If you have any questions relating to the licence or licence conditions, please do not hesitate to contact Tanya Gilders on 9333 7527 for clarification or discussion of any grievances you have.

Yours faithfully

Paul Byrnes
A/ Principal Environmental Officer

31 October 2008

encl: Environmental Protection ACT 1986 – Licence L4726/1991/13
copy to: Local Government Authority: City of Nedlands

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT AND CONSERVATION

Environmental Protection Act 1986

ISSUED LICENCE

LICENCE NUMBER: L4726/1991/13 **FILE NUMBER: DEC794-02**

LICENSEE AND OCCUPIER:
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

NAME AND LOCATION OF PREMISES:
Subiaco Wastewater Treatment Plant
Lot 3150 on Plan 149501, Lot 5286 on Plan 162620 and Lot 6815 on Plan 166929 Lemnos Street
Shenton Park WA 6008

Environmental Protection Regulations 1987
CLASSIFICATION(S) OF PREMISES:

Category: 61 Liquid waste facility;
Category: 54 Sewage facility

COMMENCEMENT DATE OF LICENCE: 1 November 2008

EXPIRY DATE OF LICENCE: 31 October 2011

CONDITIONS OF LICENCE:
As described and attached:

DEFINITION(S)
REPORTING REQUIREMENT(S): 3
MONITORING REQUIREMENT(S): 4
EMISSION TOAIR CONDITION(S): 1
WATER CONTROL CONDITION(S): 2
ATTACHMENT(S): 5

....

Officer delegated under Section 20
of the *Environmental Protection Act 1986*

Date of Issue: Friday, 31 October 2008

WESTERN AUSTRALIA

DEPARTMENT OF ENVIRONMENT & CONSERVATION

Environmental Protection Act 1986

LICENCE NUMBER: L4726/1991/13 **FILE NUMBER: DEC794_2**

DEFINITIONS

"APHA-AWWA-WEF" means American Public Health Association; American Water Works Association; Water Environment Federation.

"Biological wastes category 1.02 and 1.05" means biological wastes under category 1.02 and 1.05 within Appendix A – Controlled Waste Categories and Descriptions of the *Environmental Protection (Controlled Waste) Regulations 2004*

"Director" means Director, or other delegated officer, Environmental Regulation Division of the Department of Environment & Conservation for and on behalf of the Chief Executive Officer as delegated under Section 20 of the *Environmental Protection Act 1986*;

"Director" or 'Department of Environment & Conservation' for the purpose of correspondence means;

Program Manager, Environmental Regulation Unit
Swan Region
Department of Environment and Conservation
Locked Bag 104
Bentley Delivery Centre WA 6983

Address:
181-205 Davy Street
Booragoon WA 6154

Telephone: 9333 7510
Facsimile: 9333 7550

"Chemical scrubbing system" means a chemical scrubbing system for the removal of odorous compounds.

"Continuous monitor" means a monitor that measures the instantaneous concentration of exit gas every fifteen minute.

"Covers" means metallic or non-metallic covers used to cover the pre-treatment, primary treatment and secondary aeration areas of the treatment plant.

"Histogram" means a chart, graph or table showing the results of specified monitoring over a specified interval.

"Inspector" means person appointed to be an inspector under section 88 of the *Environmental Protection Act 1986*.

"Licensed" means licensed or registered under the *Environmental Protection Act 1986* unless otherwise specified.

"Monitoring period" means 1 July to 30 June.

"NATA" means National Association of Testing Authorities.

"Odour boundary" means the outer boundary of odour modelled at 5 OU at 99.9 percentile 1 hour averaging (as referred to in Attachment 4)..

"Scrubber stack" means the stack from the chemical scrubbing system as depicted on Attachment 2.

"Sewage treatment" means the activity under which the premises is prescribed, and includes the treatment of sewage and the discharge of treated wastewater onto land or into waters.

"STP, dry" means standard temperature and pressure (0°C and 101.325 kilopascals).

"Swanbourne Ocean Outlet" means Swanbourne Ocean Outlet extending 1.1 kilometres off the shore shown in Attachment 3.

"USEPA" means United States Environmental Protection Agency.

"Victorian EPA" means Victorian Environmental Protection Authority.

"Subiaco Main Drain" means Subiaco Main Drain Outlet extending approximately 50 metres off the shore as shown in Attachment 3.

REPORTING REQUIREMENTS

ANNUAL MONITORING REPORT

R1 The licensee shall submit to the Director, by **1 September** each year, an annual monitoring report providing the following information obtained during the monitoring period from 1 July to 30 June:

(i) A histogram showing the monthly recorded average flow rate, temperature and concentration of hydrogen sulphide being emitted through the scrubber stack, measured in accordance with condition M1.

(ii) A histogram showing the daily maximum and daily average concentrations of hydrogen sulphide emitted through the scrubber stack, as measured in accordance with condition M2.

(iii) A histogram showing the reliability of the continuous monitor against the bench marks of 90% of the time in a calendar month and 95% of the time over monitoring period of a year.

(iv) A histogram showing the volumes of treated wastewater discharged each month through the Swanbourne Ocean Outlet and approved re-use schemes.

(v) A histogram showing the date and volume of treated wastewater discharged to the Subiaco Main Drain.

(vi) A histogram showing the monthly average loadings for total phosphorus and total nitrogen in treated wastewater discharged to the ocean from Subiaco WWTP through the Swanbourne Ocean Outlet in kg/day.

(vii) A histogram showing the results of treated wastewater monitoring as per condition M3 (b) including duplicate NATA accredited laboratory results.

(viii) A histogram showing the number of complaints received by the licensee over the reporting period.

(ix) The daily average concentration of hydrogen sulphide emitted through the scrubber stack, as determined from the hydrogen sulphide concentrations recorded as per condition M2 and an estimate of the air flow rate.

(x) Monitoring data reliability against the bench marks of 90% of the time in a calendar month and 95% of the time over the monitoring period.

ACCESS TO DATA

R2 The licensee shall make available complaint data, calibration or monitoring data, results of analytical data or any other information collected under any condition of this licence to an Inspector, on request.

ANNUAL AUDIT COMPLIANCE REPORT

R3 The licensee shall by 1 September in each year, provide to the Director an annual audit compliance report in the form in Attachment 5 to this licence, signed and certified in the manner required by Section C of the form, indicating the extent to which the licensee has complied with the conditions of this licence, and any previous licence issued under Part V of the Act for the Premises, during the period beginning 1 July the previous year and ending on 30 June in that year.

MONITORING REQUIREMENTS

STACK MONITORING

M1 (a) The licensee shall monitor and record each of the following parameters, at the frequency stated using the method specified, in the exit gases emitted from the scrubber stack as specified on Attachment 2:

Parameter to be monitored	**Monitoring frequency**	**Units**	**Monitoring method**
Hydrogen sulphide	March, June, September and December	mg/m^3 at STP, dry	Vic EPA method B18
Volumetric flow rate	March, June, September and December	m^3/sec	USEPA method 2
Stack exit temperature	March, June, September and December	°Celsius	n/a

M1 (b) The licensee shall ensure that all hydrogen sulphide samples referred to in condition M1 (a) are analysed in a laboratory holding NATA accreditation for that parameter.

OPERATIONAL EMISSION MONITORING

M2 The licensee shall operate and maintain a continuous hydrogen sulphide monitor in accordance with the manufacturer's instructions to measure and record hydrogen sulphide emitted from the scrubber.

MONITORING OF DISCHARGED TREATED WASTEWATER

M3 (a) The licensee shall monitor and record the cumulative monthly volumes of treated wastewater being discharged to the Swanbourne Ocean Outlet and re-use schemes.

M3(b) The licensee shall monitor and record the concentration of the following parameters, at the frequencies stated, in treated wastewater being discharged from the Subiaco WWTP to the ocean through the Swanbourne Ocean Outlet as shown in Attachment 3 at the treated wastewater sampling point depicted on Attachment 1:

Parameter to be monitored	Monitoring frequency	Units
Total Nitrogen, Total Phosphorus	Monthly	mg/L
Total suspended solids, 5-Day Biochemical Oxygen Demand (filtered), Oil and Grease, Arsenic, Cadmium, Copper, Chromium, Lead, Mercury, Nickel and Zinc	6 Monthly	

M3(c) The licensee shall ensure that all water samples are collected, handled and preserved in accordance with the relevant parts of the Australian Standard 5667 - 1998.

M3 (d) The licensee shall ensure that all water samples are analysed in accordance with the current "Standard Methods for Examination of Water and Wastewater," APHA-AWWA-WEF.

M3 (e) The licensee shall analyse all water samples in its own laboratory, or ensure that samples are analysed in a laboratory holding NATA accreditation for the analyses specified. If the licensee uses its own laboratory, then at least one set of samples per year shall also be submitted to a laboratory holding NATA accreditation for the analysis specified in condition M3(b).

RECORDING OF COMPLAINTS

M4 The licensee shall maintain a written register of complaints received regarding alleged emissions from the premises. For each such complaint the following information shall be recorded (if known or provided):

(i) the name and address of the complainant;
(ii) the date and time of the complaint;
(iii) a general description of the complaint;
(iv) any on-site activities (if any) that may have led to the complaint;
(v) wind direction, wind speed and temperature at the time of the complaint;
(vi) likely source of the reported problem; and
(vii) action taken in response to the complaint.

EMISSION TO AIR

ODOUR CONTROL LIMIT

A1 The licensee shall ensure that the emissions from the scrubber stack, monitored as per condition M1, do not exceed the following limits:

Emission	Concentration limit	Mass emission rate limit
Hydrogen sulphide	5mg/m³ at STP, dry	140mg/sec at STP, dry

DISCHARGE TO WATER

OCEAN DISCHARGE LOADING LIMITS

W2(a) The licensee shall ensure that the load for total phosphorus in treated wastewater discharged from the Subiaco WWTP to the ocean through the Swanbourne Ocean Outlet does not exceed an annual average of 1000 kilograms per day. The annual average shall be calculated over the monitoring period.

W2(b) The licensee shall ensure that the load for total nitrogen in treated wastewater discharged from the Subiaco WWTP to the ocean through the Swanbourne Ocean Outlet does not exceed an annual average of 3300 kilograms per day. The annual average shall be calculated over the monitoring period.

OTHER EMISSIONS MANAGEMENT CONDITIONS

ODOUR CONTROL

X1 The licensee shall ensure that odour generated at the premises as detected by the unaided nose of an Inspector beyond the odour boundary shown in Attachment 4 shall not be offensive at any time.

MANAGEMENT OF ODOUR CONTROL SYSTEM

X2(a) The licensee shall ensure that the covers on the pre-treatment and secondary aeration areas of the plant, as indicated on Attachment 1, are kept in place at all times except when removal is required for maintenance operations or during emergency situations.

X2(b) The licensee shall operate and maintain the chemical scrubbing system in accordance with the design/manufacturers specification and instructions or own standard operating procedures. As a minimum manufacturer's specification and instructions shall be complied with.

MANAGEMENT OF PROCESS SOLID WASTES

X3(a) The licensee shall dispose of collected grit and screenings from the pre-treatment area to a licensed or registered landfill.

X3(b) The licensee shall dispose of sludge and biosolids in accordance with the document *Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products*, Department of Environmental Protection, Water and Rivers Commission and Department of Health (February, 2002) (as amended).

SECONDARY TREATED WASTEWATER CONTROL

X4(a) The licensee may, during unforeseen treated wastewater pump station failures, discharge treated wastewater from the premises to the emergency overflow basin and then into the Subiaco Main Drain.

X4(b) The licensee shall report all discharges of treated wastewater to the Subiaco Main Drain to the Director within 24 hours of becoming aware of such discharges.

TANKERED WASTE

X5 The licensee may accept up to 20,000 tonnes per annum of biological wastes category 1.02 and 1.05 (from other Water Corporation assets) into the premises for treatment. This waste shall be delivered to the treatment plant via a closed pipeline.

Paul Byrne

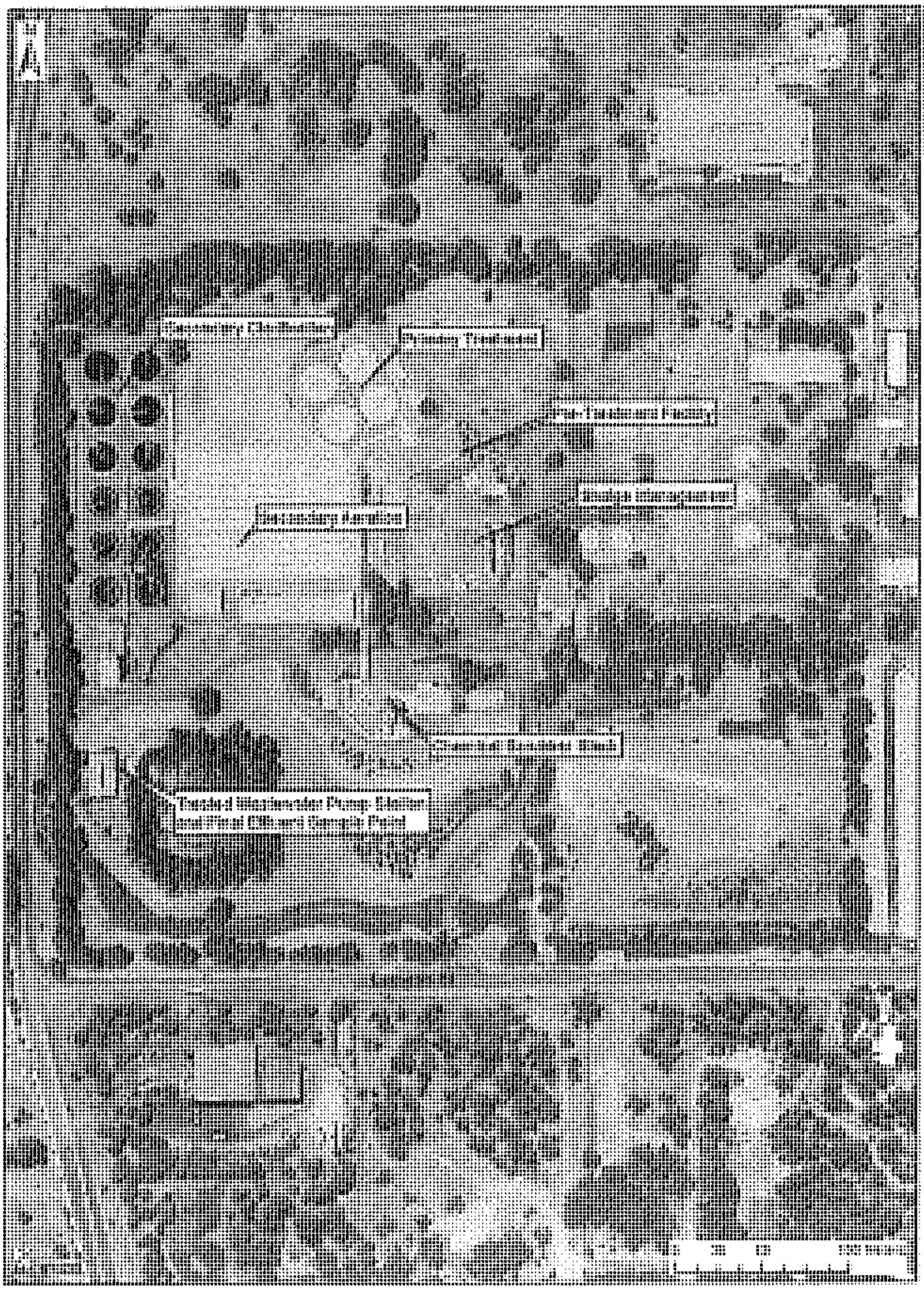
....

Officer delegated under Section 20
of the *Environmental Protection Act 1986*

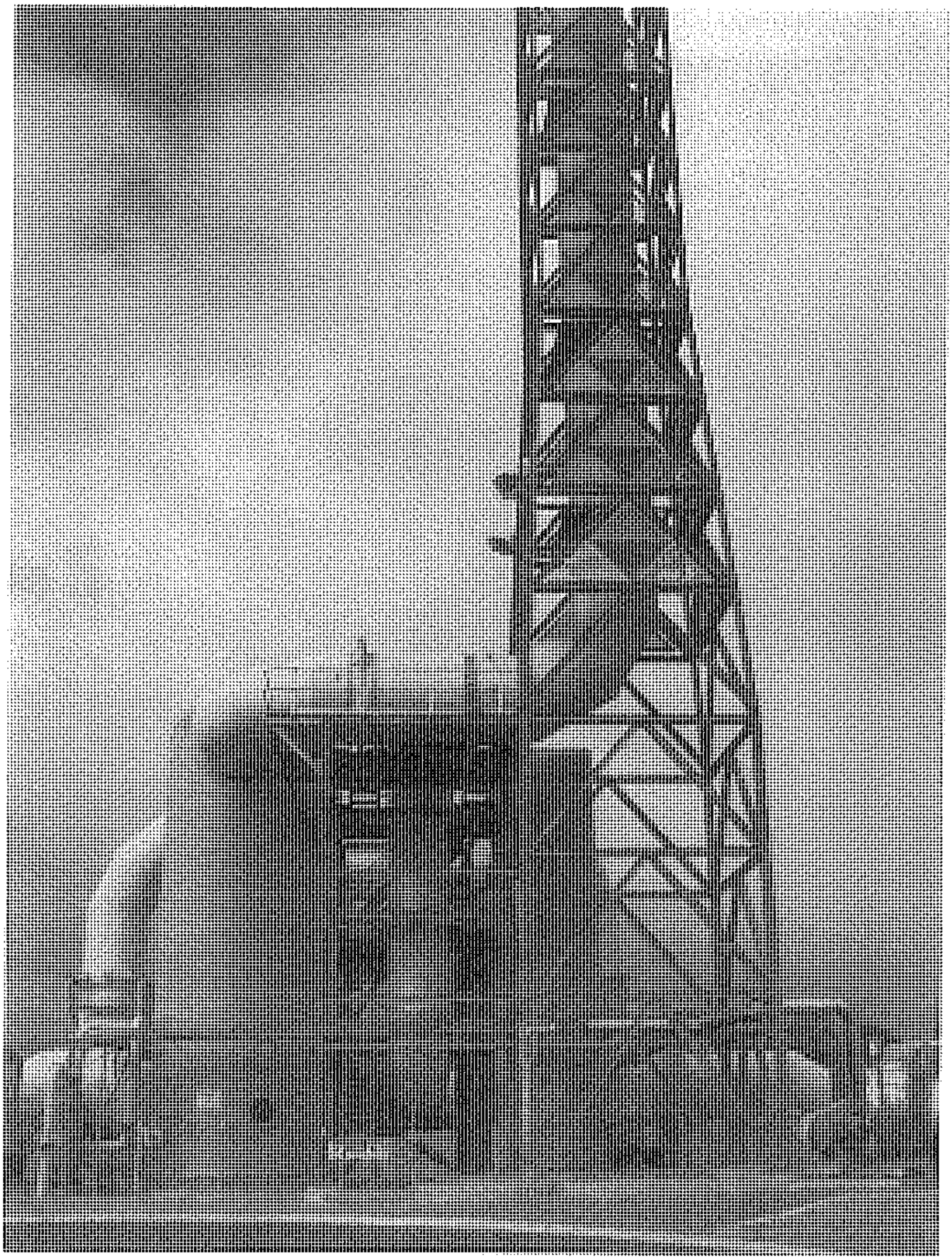
Date of Issue: 31 October 2008

ATTACHMENT 1

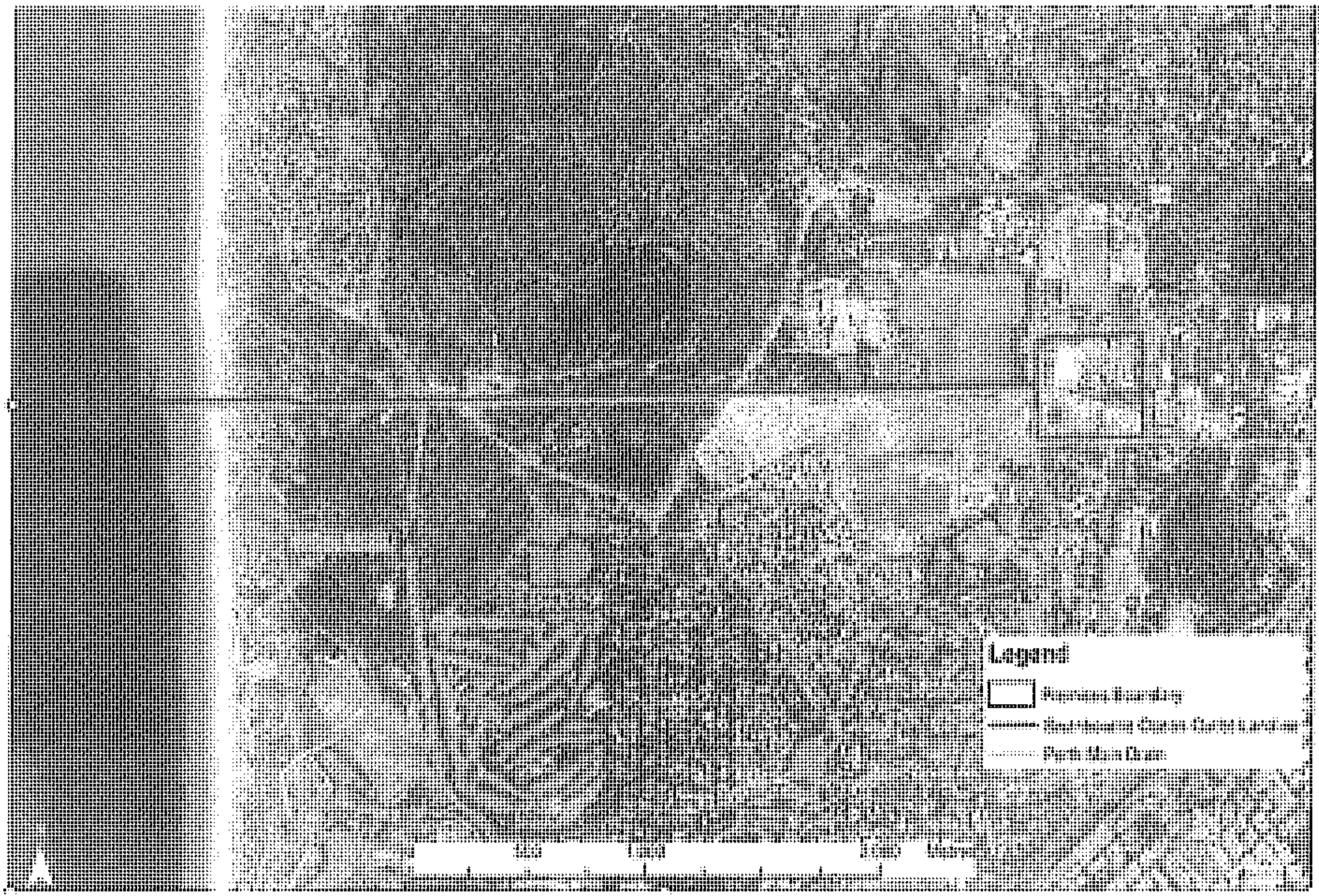
Subiaco WWTP



ATTACHMENT 2

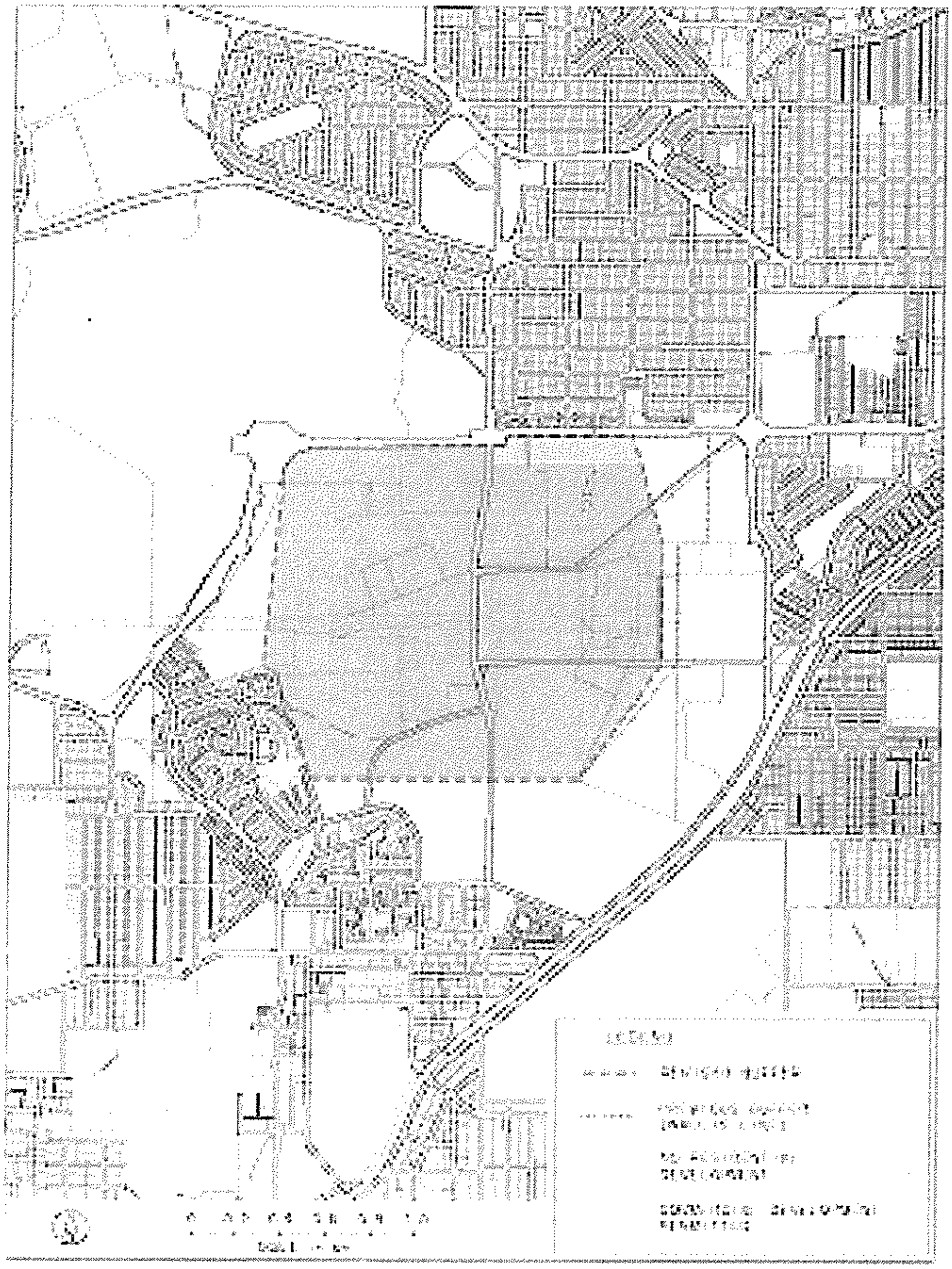


ATTACHMENT 3



ATTACHMENT 4

REVISED BUFFER ZONE
FOR SUBIACO WASTEWATER TREATMENT PLANT



ATTACHMENT 5

SECTION A

LICENCE DETAILS

Licence Number:	Licence File Number:
Company Name: Trading as:	ABN:
Reporting period: _______________ to _______________	

STATEMENT OF COMPLIANCE WITH LICENCE CONDITIONS

1. Were all conditions of licence complied with within the reporting period? (please tick the appropriate box)

Yes ☐ Please proceed to Section C

No ☐ Please proceed to Section B

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:_______________

SECTION B

DETAILS OF NON-COMPLIANCE WITH LICENCE CONDITION.

Please use a separate page for each licence condition that was not complied with.

a) Licence condition not complied with?	
b) Date(s) when the non compliance oceurred, if applicable?	
c) Was this non compliance reported to DEC?	
☐ Yes ☐ Reported to DEC verbally Date ___________ ☐ Reported to DEC in writing Date ___________	☐ No
d) Has DEC taken, or finalised any action in relation to the non compliance?	
e) Summary of particulars of non compliance, and what was the environmental impact?	
f) If relevant, the precise location where the non compliance occurred (attach map or diagram)	
g) Cause of non compliance	
h) Action taken or that will be taken to mitigate any adverse effects of the non compliance	
i) Action taken or that will be taken to prevent recurrence of the non compliance	

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:___________

SECTION C

SIGNATURE AND CERTIFICATION

This Annual Audit Compliance Report may only be signed by a person(s) with legal authority to sign it. The ways in which the Annual Audit Compliance Report must be signed and certified, and the people who may sign the statement, are set out below.

Please tick the box next to the category that describes how this Annual Audit Compliance Report is being signed. If you are uncertain about who is entitled to sign or which category to tick, please contact the licensing officer for your premises.

If the licence holder is		The Annual Audit Compliance Report must be signed and certified:
an individual	☐	by the individual licence holder, or
	☐	by a person approved in writing by the Chief Executive Officer of the Department of Environment and Conservation to sign on the licensee's behalf.
A firm or other unincorporated company	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
A corporation	☐	by affixing the common seal of the licensee in accordance with the Corporations Act 2001; or
	☐	by two directors of the licensee; or
	☐	by a director and a company secretary of the licensee, or
	☐	if the licensee is a proprietary company that has a sole director who is also the sole company secretary – by that director, or
	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
A public authority (other than a local government)	☐	by the principal executive officer of the licensee; or
	☐	by a person with authority to sign on the licensee's behalf who is approved in writing by the Director of the Department of Environment and Conservation.
a local government	☐	by the chief executive officer of the licensee; or
	☐	by affixing the seal of the local government.

It is an offence under section 112 of the *Environmental Protection Act 1986* for a person to give information on this form that to their knowledge is false or misleading in a material particular. There is a maximum penalty of $50,000 for an individual or body corporate.

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:___________

I/We declare that the information in this annual audit compliance report is correct and not false or misleading in a material particular.

SIGNATURE: ______________________	SIGNATURE: ______________________
NAME: (printed) ______________________	NAME: (printed) ______________________
POSITION: ______________________	POSITION: ______________________
DATE: _____/_____/______________	DATE: _____/_____/______________

SEAL (if signing under seal)

Woodman Point Wastewater Treatment Plant Licence

Government of **Western Australia**
Department of **Environment and Conservation**

Your ref:	L4201/1991/11
Our ref:	DEC1658
Enquiries:	Chris Malley
Phone:	9411 1706
Fax:	94195897
Email:	

Chief Executive Officer
Water Corporation
PO Box 100
LEEDERVILLE WA 6902

Dear Sir/Madam

Environmental Protection Act 1986
Licence: L4201/1991/11
Occupier: Water Corporation
Premises: Woodman Point Wastewater Treatment Plant

You are hereby advised that a licence under the *Environmental Protection Act 1986* (the Act) has been granted for the above premises. The Department of Environment and Conservation will advertise the issuing of this licence in the public notices section of The West Australian newspaper.

The licence is subject to the attached conditions. Under section 58 of the Act, it is an offence to contravene a licence condition. This offence carries a penalty of up to $125,000, with a daily penalty of up to $25,000.

In accordance with section 102(1)(c) of the Act, you are afforded 21 days to appeal the conditions of the licence. Under section 102(3)(a) of the Act, any other person may also appeal the conditions of the licence.

To make an appeal or check if any appeals have been made, contact the Office of the Appeals Convenor on 6467 5190. Please direct all other inquiries to the Licensing Officer above.

Yours faithfully,

Peter Vasel
Manager, Works Approval & Emissions Licensing Section

Thursday, 28 October 2010

enc: Licence L4201/1991/11
copy to: Local Government Authority: City of Cockburn

Government of Western Australia
Department of Environment and Conservation

LICENCE FOR PRESCRIBED PREMISES
Environmental Protection Act 1986

LICENCE NUMBER: L4201/1991/11 **FILE NUMBER:** DEC1658

LICENSEE AND OCCUPIER OF PREMISES
Water Corporation
PO BOX 100
LEEDERVILLE WA 6902

NAME AND LOCATION OF PREMISES
Woodman Point Wastewater Treatment Plant
Lot 9 on Diagram 31097 Cockburn Road
Munster, W.A. 6166
(as depicted on Attachment 1)

PRESCRIBED PREMISES CATEGORY
Schedule 1 of the *Environmental Protection Regulations 1987*

CATEGORY	DESCRIPTION	CAPACITY
54	Sewage facility: premises on which sewage is treated (excluding septic tanks); or from which treated sewage is discharged onto land or into waters	160,000 cubic metres per day
61	Liquid waste facility: premises on which liquid waste produced on other premises (other than sewage waste) is stored, reprocessed, treated or irrigated.	50,000 tonnes per year

CONDITIONS OF LICENCE
Subject to the conditions of licence set out in the attached pages.

Officer delegated under Section 20
of the *Environmental Protection Act 1986*

ISSUE DATE:	Thursday, 28 october 2010
COMMENCEMENT DATE:	Monday, 1 November 2010
EXPIRY DATE:	Saturday, 31 October 2015

CONDITIONS OF LICENCE
Environmental Protection Act 1986

DEFINITIONS

In these conditions of licence, unless inconsistent with the text or subject matter:

"Bi-annual" for the purposes of sampling means twice per year with at least three months between each sampling event;

"Biological Waste," "Inorganic Chemicals" and "Low Strength Wastewater" with respect to the acceptance of controlled waste, means those waste categories specified and described in Table 7 of Attachment 7;

"Chemical Scrubber Outlet" means after the chemical scrubber but prior to entering the Odour Control Facility Discharge Stack;

"Director" means Director, or other delegated officer, Environmental Regulation Division of the Department of Environment and Conservation for and on behalf of the Chief Executive Officer as delegated under Section 20 of the *Environmental Protection Act 1986*;

"Director" for the purpose of correspondence means-

Manager, Industry Regulation, Swan Region
Department of Environment and Conservation
PO Box 454
KWINANA WA 6966

Telephone: (08) 9411 1777
Facsimile: (08) 9419 5897;

"g/s" means grams per second;

"Jervoise Bay Ocean Outlet", "Sepia Depression Ocean Outlet" and "Woodman Point Ocean Outlet" mean the marine discharge points labelled and depicted in Attachment 2;

"m^3/hr" means cubic metres per hour;

"mg/l" means milligrams per litre;

"ml" means millilitre;

"mg/m^3" means milligrams per cubic metre;

"m^3/s" means cubic metres per second;

"NATA" means National Association of Testing Authorities;

"Normal Operating Conditions" means operation of the wastewater treatment plant excluding start up, shutdown and upset conditions such as Routine Maintenance or Emergency Situations in relation to stack sampling or monitoring;

"Odour Control Facility" and "Odour Control Facility Discharge Stack" means those structures labelled and depicted in Attachment 1;

"OU" means odour units;

"STP" means standard temperature and pressure (0^{o}Celsius and 101.325 kilopascals respectively);

'Tanker Receival Facility" and "Tanker Receival Facility Discharge Stack" means those structures labelled and depicted in Attachment 1;

"Usual Business Day" means the days Monday to Friday inclusive, excluding public holidays;

"°Celsius" means degrees celsius; and

"µg/l" means micrograms per litre.

CONDITIONS OF LICENCE
Environmental Protection Act 1986

LICENCE NUMBER: L4201/1991/11 **FILE NUMBER:** DEC1658

GENERAL CONDITIONS

REPORTING

G1(a) The licensee shall provide to the Director, by **1 September each year**, an Annual Monitoring Report containing data collected **during the period beginning 1 July the previous year and ending on 30 June in that year** and shall contain but not be limited to:

(i) A histogram(s) showing the daily maximum and daily average concentrations of hydrogen sulphide and the volumetric flow measured in accordance with condition A3(a) of this licence;
(ii) Tabulated results of continuous monitor availability for each calendar month as specified in condition A3(c) of this licence;
(iii) Results of Odour Control Facility stack sampling undertaken in accordance with condition A4 of this licence;
(iv) Results of Tanker Receival Facility stack sampling undertaken in accordance with condition A10 of this licence;
(v) A graphical comparison of data presented in conditions G1(a)(iii) and (iv) of this licence against historical data obtained from 16 October 2009 onwards;
(vi) a summary of any data exceeding limits or targets specified in this licence including information on why the exceedence occurred (if known) and action taken by the licensee to prevent recurrence of such exceedences;
(vii) a tabular representation of nitrogen and phosphorus loads, concentrations and volumes discharged through the Sepia Depression Ocean Outlet Landline from the various inputs (if known);
(viii) a summary of complaints received about emissions from the premises including the date, time, the complaints address (street name and suburb only), a description of the complaint and the likely cause and findings of any investigations; and
(ix) the findings of an annual audit of the operational aspects of the existing odour control devices at the premises.

G1(b) The licensee shall use the units specified in column 2 of Table 1 for the corresponding parameters specified in column 1 of Table 1, in Annual Monitoring Reports required by condition G1(a) of this licence;

Table 1: Parameter units for reporting in the Annual Monitoring Report

Column 1	Column 2
Parameter	**Unit**
Monthly cumulative volume discharged	Cubic metres per day (monthly average)
pH	pH units
E. Coli	Most probable number per 100 ml
Other parameters (treated wastewater)	mg/l
Other parameters (marine)	µg/l
Nitrogen load	Kilograms per day (monthly average)

G2 The licensee shall by **1 September** in each year, provide to the Director an Annual Audit Compliance Report in the form in Attachment 3 to this licence, signed and certified in the manner required by Section C of the form, indicating the extent to which the licensee has complied with the conditions of this licence, and any previous licence issued under Part V of the Act for the premises, **during the period beginning 1 July the previous year and ending on 30 June in that year.**

AIR POLLUTION CONTROL CONDITIONS

PRE AND PRIMARY TREATMENT AREAS

A1 The licensee shall maintain covers over the pre-treatment and primary treatment areas of the plant, except during Routine Maintenance or Emergency Situations.

ODOUR CONTROL FACILITY

A2 The licensee shall operate and maintain odour scrubbing equipment on the Odour Control Facility in accordance with manufacturer's specifications for the Facility.

ODOUR CONTROL FACILITY – CONTINUOUS MONITORING

A3(a) The licensee shall continuously monitor the parameters specified in column 1 of Table 2 at the locations specified in column 2 of Table 2 and in the units specified in column 3 of Table 2.

Table 2: Continuous monitoring requirements in the Odour Control Facility

Column 1	Column 2	Column 3
Parameters	**Monitor Location**	**Units**
Hydrogen sulphide	Chemical scrubber inlet	ppm
	Chemical Scrubber Outlet (prior to entering the discharge stack)	ppm
Volumetric flow	Odour Control Facility Discharge Stack	m^3/hr

A3(b) The licensee shall ensure that the continuous monitors referred to in condition A3(a) of this licence are maintained and calibrated in accordance with the manufacturer's specifications.

A3(c) The licensee shall ensure that the continuous monitors referred to in condition A3(a) of this licence are operated to achieve at least a 90% availability per calendar month.

ODOUR CONTROL FACILITY – STACK SAMPLING

A4 The licensee shall implement a manual stack monitoring program for the location specified in column 1 of Table 3 which measures the parameters specified in column 2 of Table 3 at the frequency specified in column 3 of Table 3, using the sampling methods specified in column 4 of Table 3 and in the units specified in column 5 of Table 3 during Normal Operating Conditions.

Table 3: Odour Control Facility manual stack monitoring.

Column 1	Column 2	Column 3	Column 4	Column 5
Location	**Parameter to be measured**	**Frequency**	**Sampling Method**	**Units**
Exit gases from the Odour Control Facility Discharge Stack	Hydrogen sulphide	Bi-annual	NATA accredited method for the measurement and analysis of hydrogen sulphide emissions from stationary sources	mg/m^3 at STP, dry
	Volumetric flow rate		USEPA method 2	m^3/sec
	Stack exit temperature		n/a	°Celsius
	Odour Units	Annual	AS 4323.3:2001 for Dynamic Olfactometry	OU

ODOUR CONTROL FACILITY - TARGETS

A5(a) The licensee shall operate the Odour Control Facility to achieve a hydrogen sulphide **emission target of less than 1.5 ppm** at the Chemical Scrubber Outlet as monitored in accordance with condition A3(a) of this licence.

A5(b) The licensee shall take corrective action as soon as practicable to reduce hydrogen sulphide emissions upon becoming aware of any confirmed measurement which indicates that the emission target specified in condition A5(a) of this licence has been exceeded.

A6(a) The licensee shall notify the Director before 5pm on the next Usual Business Day after becoming aware of any confirmed measurement which indicates that the emission target specified in condition A5(a) of this licence has been exceeded.

A6(b) The licensee shall follow the notification referred to in condition A6(a) of this licence with a written report to the Director within five (5) working days of receiving the confirmed measurement and shall include, but not be limited to:
- (i) the date and time of the exceedance;
- (ii) results of continuous monitoring required by condition A3(a) of this licence at the time of the exceedance;
- (iii) the cause of the exceedance;
- (iv) the extent of the exceedance; and
- (v) corrective actions taken in accordance with A5(b) and planned corrective actions to prevent a recurrence of the exceedance.

ODOUR CONTROL FACILITY – LIMITS

A7 The licensee shall operate the Odour Control Facility so that hydrogen sulphide emissions from the Odour Control Facility Discharge Stack do not exceed the limits specified in column 2 and column 3 of Table 4, monitored as required by condition A4 of this licence.

Table 4: Odour Control Facility Emission Limits

Column 1	Column 2	Column 3
Emission	**Concentration Limit**	**Emission Rate Limit**
Hydrogen sulphide	5 mg/m^3 at STP, dry	0.25 g/s at STP, dry

A8 The licensee shall notify the Director, in writing, before 5pm on the next Usual Business Day after becoming aware of any confirmed measurement which indicates that an emission limit specified in condition A7 of this licence has been exceeded and the notification shall include:

- (i) the date and time of the exceedance;
- (ii) production rate at time of exceedance;
- (iii) route cause of the exceedance;
- (iv) an estimate of the period over which the limit was or is likely to be exceeded;
- (v) an indication of known or potential environmental impacts;
- (vi) corrective actions taken or planned to mitigate adverse environmental consequences resulting from the exceedance; and
- (vii) corrective action taken or planned to prevent a recurrence of the exceedance.

TANKER RECEIVAL FACILITY

A9(a) The licensee shall maintain covers on equipment where odour can be emitted to the atmosphere from the Tanker Receival Facility, except during Routine Maintenance or Emergency Situations.

A9(b) The licensee shall operate and maintain a chemical scrubbing system for the removal of odorous compounds from the Tanker Receival Facility, prior to their emission through the Tanker Receival Facility Discharge Stack.

TANKER RECEIVAL FACILITY – STACK SAMPLING

A10 The licensee shall implement a manual stack monitoring program for the location specified in column 1 of Table 5 which measures the parameters specified in column 2 of Table 5 at the frequency specified in column 3 of Table 5, using the sampling methods specified in column 4 of Table 5 and in the units specified in column 5 of Table 5 during Normal Operating Conditions.

Table 5: Tanker Receival Facility manual stack monitoring.

Column 1	Column 2	Column 3	Column 4	Column 5
Location	**Parameter to be measured**	**Frequency**	**Sampling method**	**Units**
Exit gases from the Tanker Receival Facility Discharge Stack	Hydrogen sulphide	Bi-annual	NATA accredited method for the measurement and analysis of hydrogen sulphide emissions from stationary sources	mg/m³ at STP, dry
	Volumetric flow rate	Bi-annual	USEPA method 2	m³/s
	Stack exit temperature	Bi-annual	n/a	°Celsius
	Odour Units	Annual	AS 4323.3:2001 for Dynamic Olfactometry	OU/s

STACK SAMPLING REQUIREMENTS

A11(a) The licensee shall ensure that sampling required under conditions A4 and A10 of this licence are undertaken in accordance with AS4323.1-1995 *Stationary Source Emissions Method 1: Selection of sampling positions.*

A11(b) The licensee shall ensure that all stack monitoring required by condition A4 and A10 of this licence are conducted by companies and laboratories with current NATA accreditation for the methods and analyses specified.

WATER POLLUTION CONTROL CONDITIONS

DISCHARGE POINTS

W1(a) Subject to condition W1(b) of this licence, the licensee shall discharge treated wastewater from the premises to the environment through the Sepia Depression Ocean Outlet.

W1(b) Pursuant to condition W1(a) of this licence, the licensee may, during Routine Maintenance or Emergency Situations, discharge treated wastewater from the premises to the environment:
(i) firstly through the Woodman Point Ocean Outlet; and
(ii) secondly through the Jervoise Bay Ocean Outlet.

W1(c) The licensee shall advise the Director prior to intended maintenance works on the Sepia Depression Ocean Outlet, which will require use of the Woodman Point Ocean Outlet or Jervoise Bay Ocean Outlet.

SAMPLING POINTS AND FLOW MONITORING

W2(a) The licensee shall maintain a treated wastewater sampling point in the channel from the Sequencing Batch Reactor to the Flow Balancing Dam (as depicted in Attachment 1) so that treated wastewater samples can be easily taken.

W2(b) The licensee shall maintain a Groundwater Abstraction Sampling Point on the pipeline leading to the treated wastewater wet well so that recovered groundwater samples can be easily taken (as depicted in Attachment 1).

W2(c) The licensee shall monitor and record the cumulative monthly volumes of wastewater treated at the premises (using the Munster Pump Station No. 3 Magnetic flow meters).

W2(d) The licensee shall monitor and record the cumulative monthly volumes of groundwater recovered from bores on the western side of the premises and directed to the Sepia Depression Ocean Outlet.

WATER MONITORING AND REPORTING

W3(a) The licensee shall take representative water samples from the sites specified in column 1 of Table 6, at the frequencies specified in column 2 of Table 6, for the parameters specified in column 3 of Table 6 and have them analysed.

Table 6: Water Monitoring Program

Column 1	**Column 2**	**Column 3**
Monitoring Sites	**Sampling Frequency**	**Parameters to be sampled**
Outlet Channel from the Sequencing Batch Reactor (as depicted in Attachment 1).	Monthly	pH, Total Suspended Solids, (filtered) 5-Day Biochemical Oxygen Demand, Total Nitrogen, Ammonium-nitrogen, Nitrate+Nitrite-nitrogen, Total Phosphorus
	3-monthly	*E. Coli*, Oil and Grease, arsenic, cadmium, copper, chromium, lead, mercury, nickel, zinc
Recovered Groundwater Abstraction Point (as depicted in Attachment 1).	3-monthly	Total Nitrogen
Ocean monitoring sites (as depicted in Attachments 3, 4 and 5 (depending on ocean current)	Annually every summer	Total Nitrogen, Nitrate + Nitrite-nitrogen, Ammonium-nitrogen, Total Phosphorus, Filterable Reactive Phosphorus, Chlorophyll 'a', *E. Coli*
Shoreline monitoring sites (as depicted in Attachment 6).		*E. Coli*

W3(b) The licensee shall collect, handle and preserve all water samples in accordance with the relevant part(s) of Australian Standard 5667:1998 and with respect to marine sampling, it is accepted that the licensee (or its contractor) does not need to collect, container and transport blanks or field spikes in accordance with the above standard.

W3(c) The licensee shall analyse all water samples in its own quality assured laboratory, or ensure that samples are analysed in a laboratory holding NATA accreditation for the analyses specified.

W3(d) If the licensee uses its own laboratory for analysis as noted in condition W3(c) of this licence, then at least one set of samples per year shall also be submitted to a laboratory holding NATA accreditation for the analysis specified in condition W3(a) of this licence and the licensee shall report these duplicate results to the Director in the annual monitoring report, as required in condition G1(a) of this licence, specifying the laboratory in which each analysis was performed.

CALCULATION OF CONTAMINANT LOAD

W4(a) The licensee shall determine the monthly load of each contaminant in the treated wastewater discharged from the premises (where applicable) using flow-weighted data. The loads shall be based on the treated wastewater discharge rate and the concentration as measured in accordance with conditions W2 and W3 of this licence. Monthly and annual average loads of the contaminants shall be reported in the Annual Monitoring Report in kilograms per day.

W4(b) The licensee shall determine the annual load of Total Nitrogen in the recovered groundwater discharged from the premises using flow-weighted data. The loads shall be based on the groundwater discharge rate and the concentration as measured in accordance with conditions W2 and W3 of this licence. Monthly and annual average Total Nitrogen loads shall be reported in the Annual Monitoring Report in kilograms per day.

TOTAL NITROGEN DISCHARGE LIMIT

W5 The licensee shall ensure that the load of total nitrogen discharged through the Sepia Depression Ocean Outlet does not exceed **1,778 tonnes per year** in any consecutive 12 month period.

TANKERED WASTE

W6(a) The licensee shall only accept third party liquid wastes tankered into the premises:
- (i) at the Tanker Receival Facility, or
- (ii) at the pre-treatment works of the sewage treatment plant if there is a breakdown of the tanker receival facility or a delay of more than 60 minutes to unload waste at the Tanker Receival Facility.

W6(b) The licensee shall only accept controlled waste in Biological Waste category 1.02 and category 1.05 (from other Water Corporation assets) tankered into the premises:
- (i) at the pre-treatment works of the sewage treatment plant; or
- (ii) at the Tanker Receival Facility where it is impractical to use the pre-treatment works.

W6(c) The licensee shall only accept third party tankered controlled waste at the premises if the licensee has undertaken a pH, conductivity and visual assessment of the characteristics of the waste and the licensee considers that the waste meets one of the following waste categories:
(i) Biological Wastes - categories 1.01, 1.02, 1.03, 1.04 and 1.05;
(ii) Inorganic chemicals - category 13.15; or
(iii) Low Strength Wastewater - categories 14.01, 14.02, 14.03, 14.04.

W6(d) The licensee shall record the cumulative monthly volume and type of tankered waste accepted at either the Tanker Receival Facility or the pre-treatment works of the sewage treatment plant, with this data presented in a tabular form in the next Annual Monitoring Report, as required by condition G1(a) of this licence.

W6(e) The licensee shall record the date and time when tankered third party waste was accepted at the pre-treatment works of the sewage treatment plant, with this data being presented in a tabular form referencing the tracking form number in the next Annual Monitoring Report as required by condition G1(a) of this licence.

W6(f) The licensee shall direct waste streams from the Tanker Receival Facility to the following locations:
(i) collected grit and screenings to a licensed landfill;
(ii) sludges and biosolids to the on-site sludge treatment and de-watering facilities; and
(iii) wastewater to the pre-treatment area of the sewage treatment plant.

BUNDING AND CONTAINMENT

W7 The licensee shall store environmentally hazardous chemicals including sodium hydroxide and hypochlorite (where the total volume of each substance stored on the premises exceeds 250 litres) within bunded areas in accordance with Australian Standard 3780-2008.

SOLID WASTE CONTROL CONDITIONS

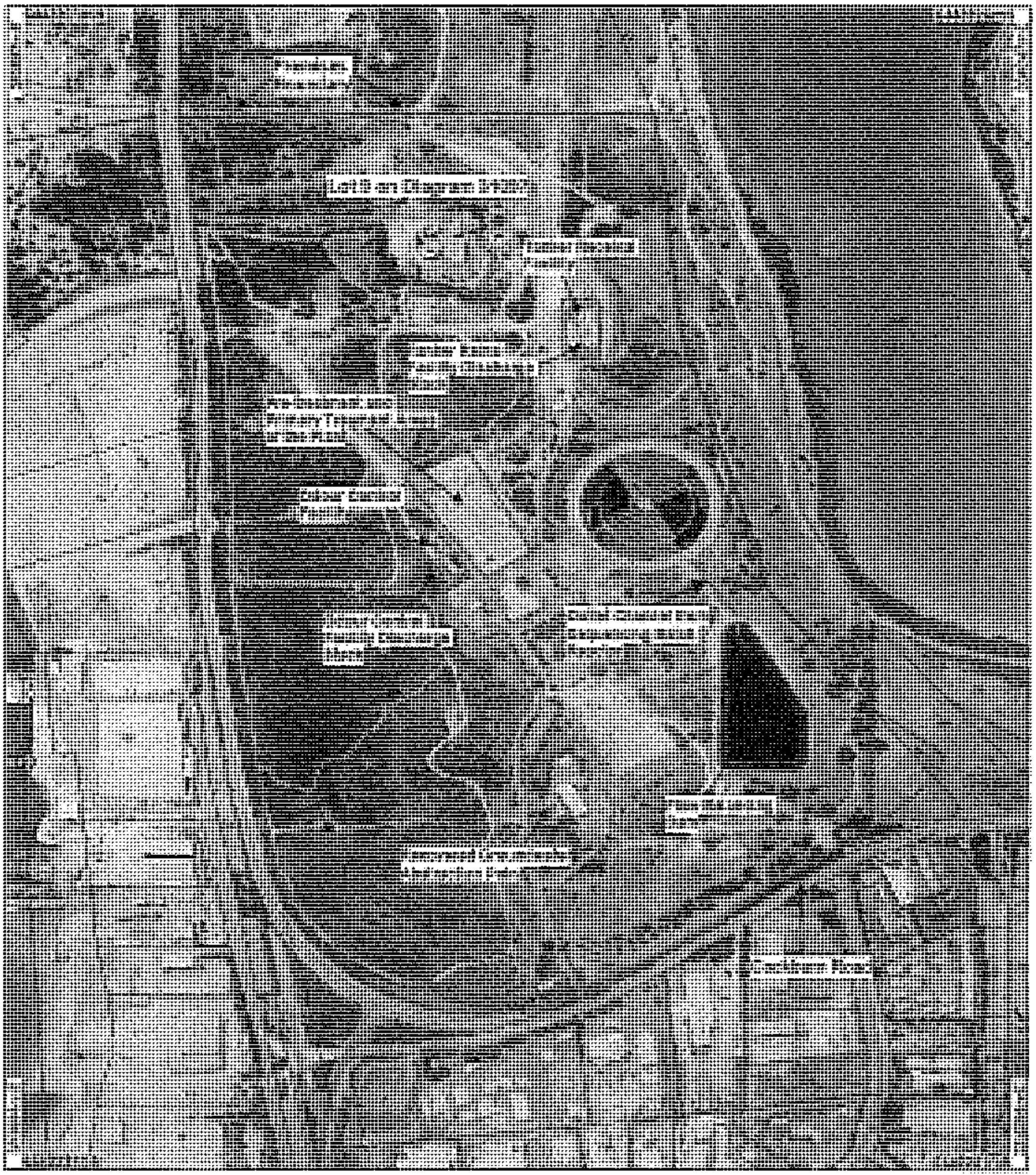
SOLIDS DISPOSAL

S1 The licensee shall dispose of sludge and biosolids in accordance with the document *Western Australian Guidelines for Direct Land Application of Biosolids and Biosolids Products*, Department of Environmental Protection, Water and Rivers Commission and Department of Health (February, 2002) (as amended).

ATTACHMENT 1
PLAN OF PREMISES

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658

Woodman Point Wastewater Treatment Plant
Lot 9 on Diagram 31097



LEGEND

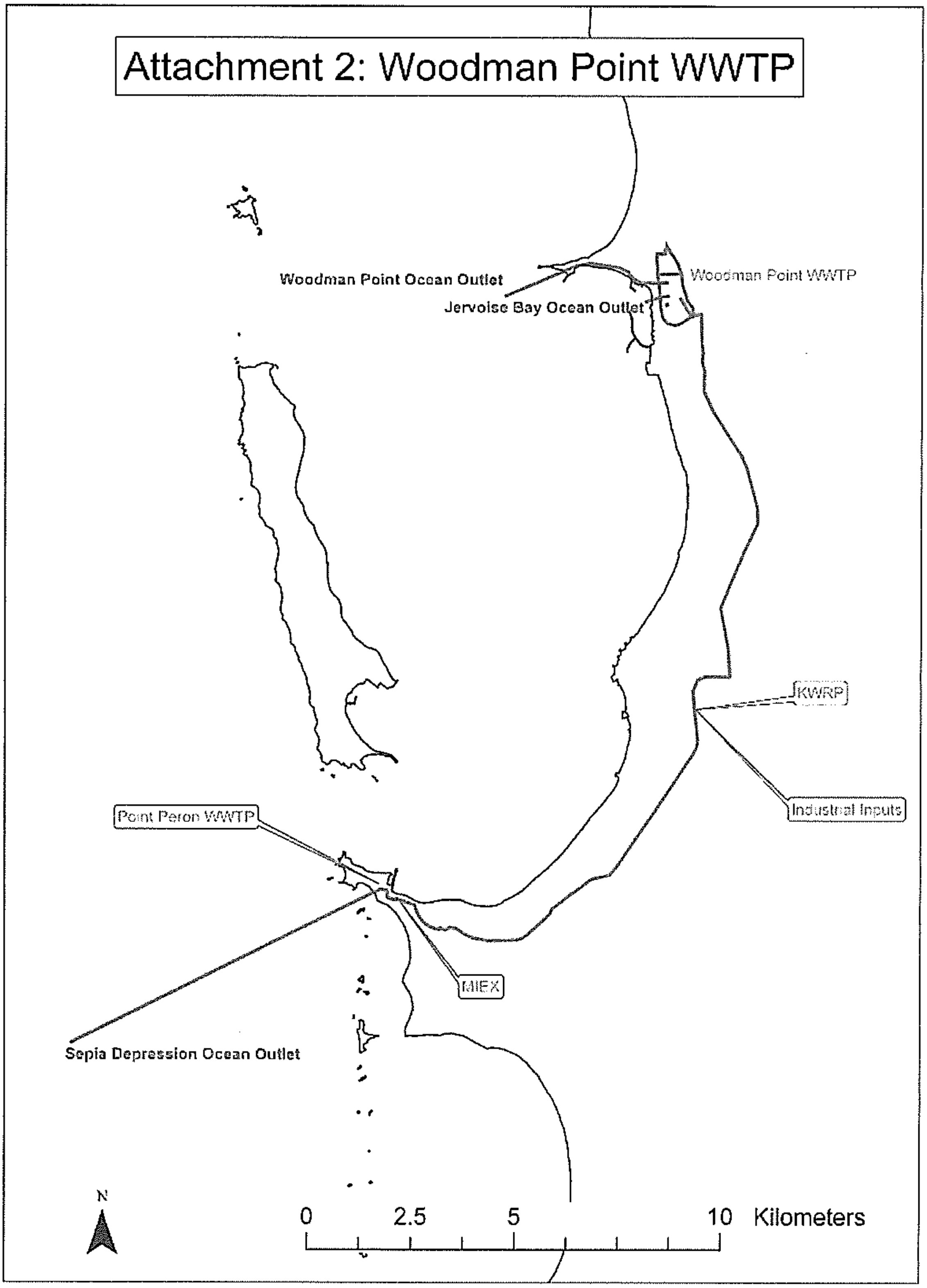
Scale 1:7737

Department of
Environment and Conservation

ATTACHMENT 2

MAP OF OCEAN DISCHARGE POINTS

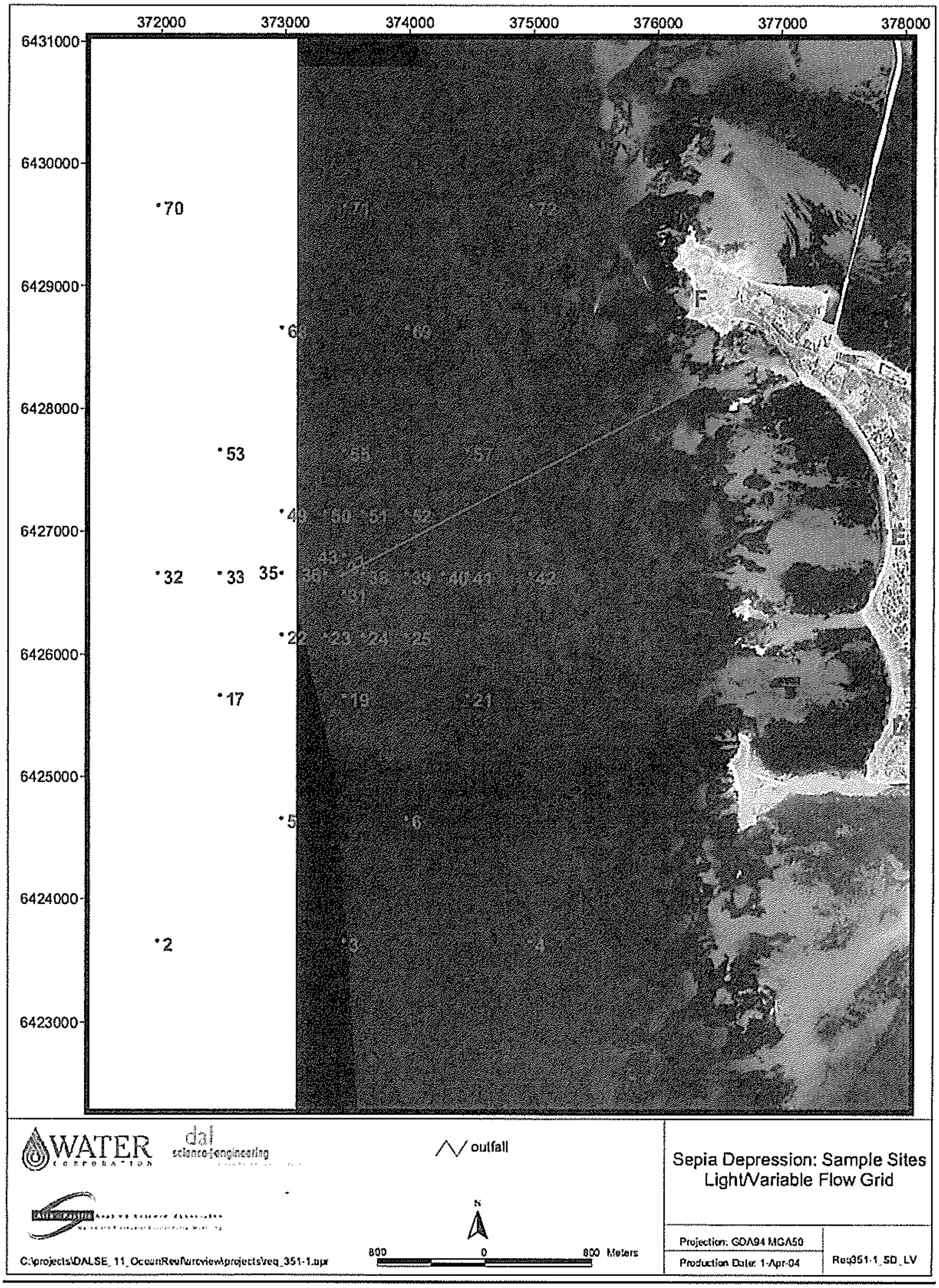
LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658



ATTACHMENT 3

OCEAN SAMPLING SITES: LIGHT/VARIABLE FLOW GRID

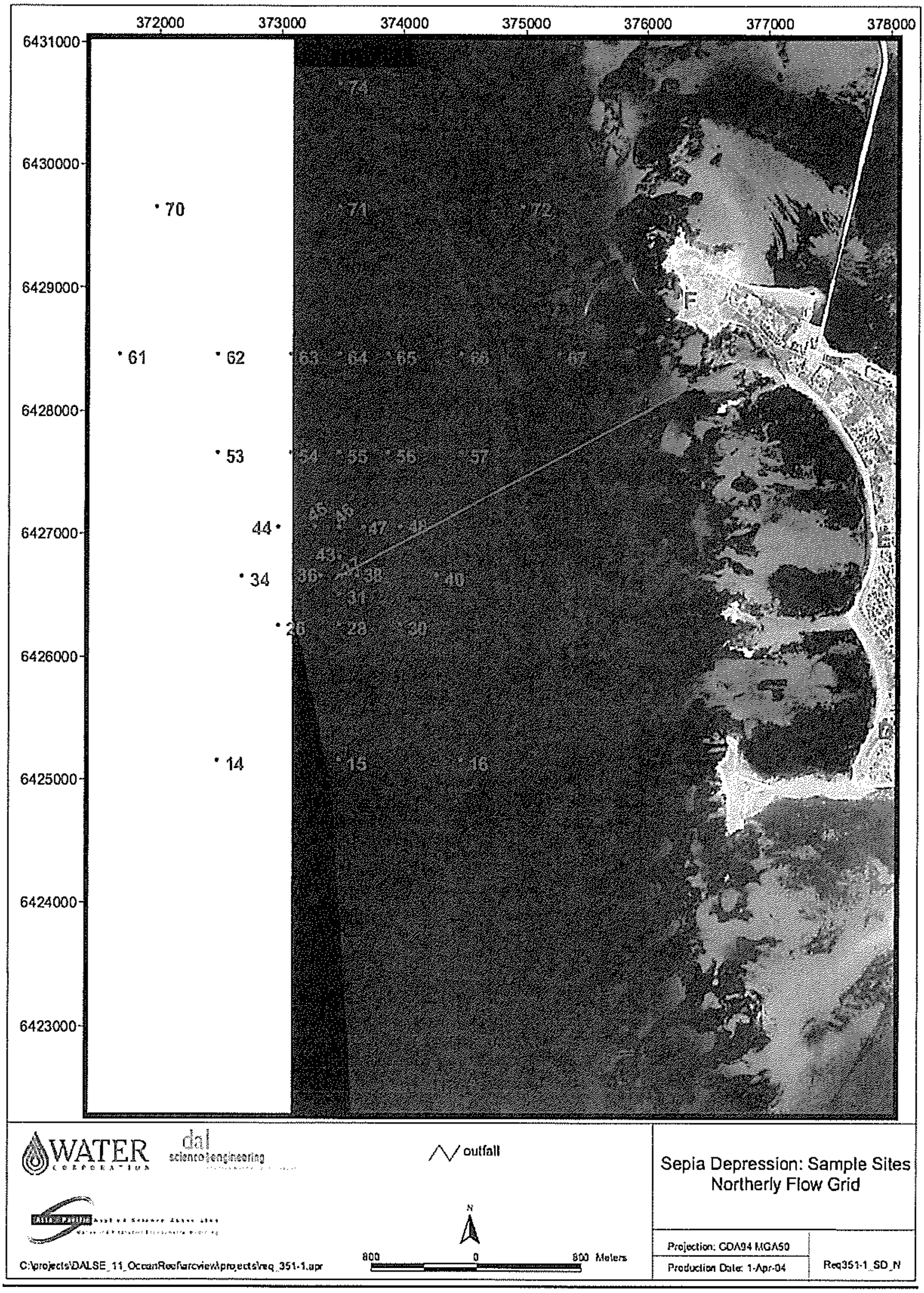
LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658



ATTACHMENT 4

OCEAN SAMPLING SITES: NORTHERLY FLOW GRID

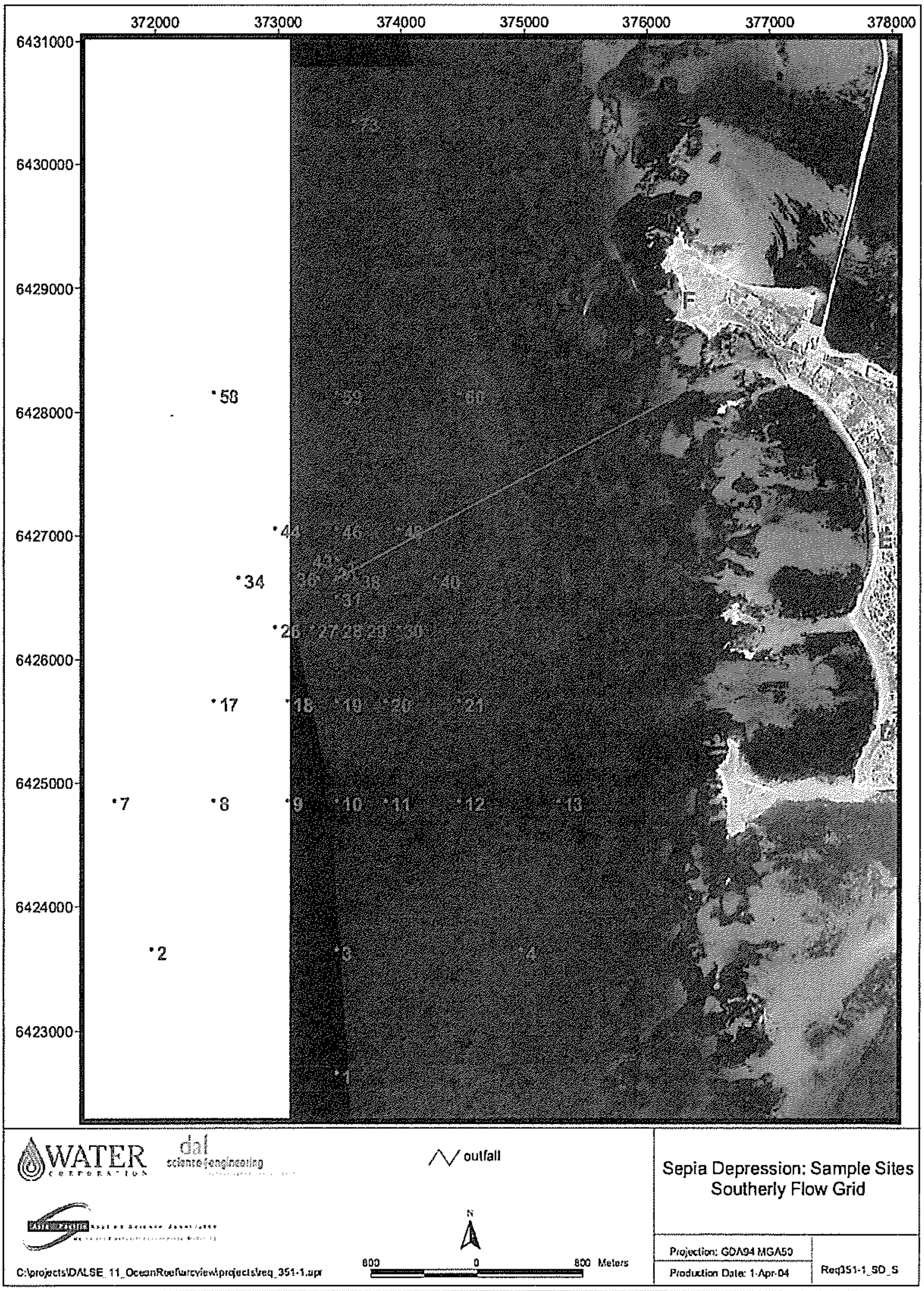
LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658



ATTACHMENT 5

OCEAN SAMPLING SITES: SOUTHERLY FLOW GRID

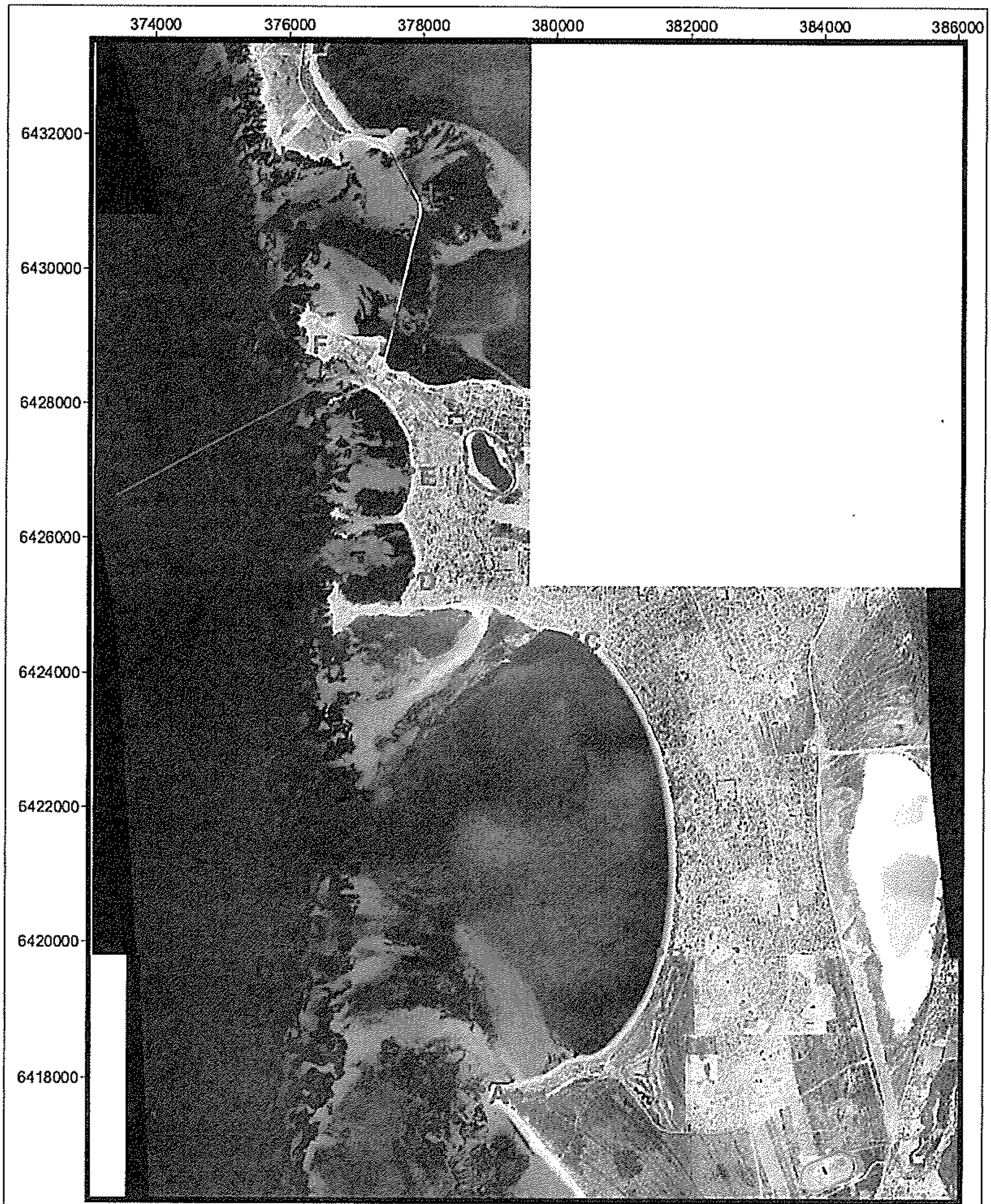
LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658



ATTACHMENT 6

OCEAN SHORE SAMPLING SITES

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658



outfall

N

1000 0 1000 Meters

C:\projects\DALSE_11_OceanReef\arcview\projects\req_351-1.apr

Sepia Depression:
Shore Sample Sites

Projection: GDA94 MGA50

Production Date: 1-Apr-04

Req351-1_SD_Shore

CONTROLLED WASTE CATEGORIES

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658

Table 7 – Controlled Waste Categories and Descriptions for acceptance at Woodman Point Wastewater Treatment Plant

Category Group No.	Category Group Name	Category No.	Description
1	Biological Wastes	1.01	Animal wastes – smallgoods; tallow; and animals slaughtered for quarantine purposes
		1.02	Septage wastes – wastes from apparatus for the treatment of sewage
		1.03	Grease wastes – wastes resulting from food preparation processes
		1.04	Vegetable oils and derivatives and other wastes (excluding wastes referred to in categories 1.01, 1.02 and 1.03)
		1.05	Sewage waste from the reticulated sewage system (i.e. Water Corporation)
13	Inorganic Chemicals	13.15	Non toxic salts
14	Low strength waste water	14.01	Industrial washwaters
		14.02	Stormwater
		14.03	Wash water
		14.04	Fire debris and washwater (may vary)

ATTACHMENT 8

ANNUAL AUDIT COMPLIANCE REPORT

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658

SECTION A

LICENCE DETAILS

Licence Number:	Licence File Number:
Company Name: Trading as:	ABN:
Reporting period: _________________ to _________________	

STATEMENT OF COMPLIANCE WITH LICENCE CONDITIONS

1. Were all conditions of licence complied with within the reporting period? (please tick the appropriate box)

Yes ☐ Please proceed to Section C

No ☐ Please proceed to Section B

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:_______________

ATTACHMENT 8

ANNUAL AUDIT COMPLIANCE REPORT

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658

SECTION B - DETAILS OF NON-COMPLIANCE WITH LICENCE CONDITION

Please use a separate page for each licence condition that was not complied with.

a) Licence condition not complied with?	
b) Date(s) when the non compliance occurred, if applicable?	
c) Was this non compliance reported to DEC?	
☐ Yes ☐ Reported to DEC verbally Date ___________ ☐ Reported to DEC in writing Date ___________	☐ No
d) Has DEC taken, or finalised any action in relation to the non compliance?	
e) Summary of particulars of non compliance, and what was the environmental impact?	
f) If relevant, the precise location where the non compliance occurred (attach map or diagram)	
g) Cause of non compliance	
h) Action taken or that will be taken to mitigate any adverse effects of the non compliance	
i) Action taken or that will be taken to prevent recurrence of the non compliance	

Each page must be initialed by the person(s) who signs Section C of this annual audit compliance report

INITIAL:___________

SECTION C - SIGNATURE AND CERTIFICATION

This Annual Audit Compliance Report may only be signed by a person(s) with legal authority to sign it. The ways in which the Annual Audit Compliance Report must be signed and certified, and the people who may sign the statement, are set out below.

ATTACHMENT 8

ANNUAL AUDIT COMPLIANCE REPORT

LICENCE NUMBER: L4201/1991/10 **FILE NUMBER:** DEC1658

Please tick the box next to the category that describes how this Annual Audit Compliance Report is being signed. If you are uncertain about who is entitled to sign or which category to tick, please contact the licensing officer for your premises.

If the licence holder is		The Annual Audit Compliance Report must be signed and certified:
an individual	□ □	by the individual licence holder, or by a person approved in writing by the Chief Executive Officer of the Department of Environment and Conservation to sign on the licensee's behalf.
A firm or other unincorporated company	□ □	by the principal executive officer of the licensee; or by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
A corporation	□ □ □ □ □ □	by affixing the common seal of the licensee in accordance with the Corporations Act 2001; or by two directors of the licensee; or by a director and a company secretary of the licensee, or if the licensee is a proprietary company that has a sole director who is also the sole company secretary – by that director, or by the principal executive officer of the licensee; or by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
A public authority (other than a local government)	□ □	by the principal executive officer of the licensee; or by a person with authority to sign on the licensee's behalf who is approved in writing by the Chief Executive Officer of the Department of Environment and Conservation.
a local government	□ □	by the chief executive officer of the licensee; or by affixing the seal of the local government.

It is an offence under section 112 of the Environmental Protection Act 1986 *for a person to give information on this form that to their knowledge is false or misleading in a material particular. There is a maximum penalty of $50,000 for an individual or body corporate.*

I/We declare that the information in this annual audit compliance report is correct and not false or misleading in a material particular.

SIGNATURE: ______________________NAME: (printed) ____________________________

POSITION: ________________________

DATE: _____/______/_______________

SIGNATURE: ______________________NAME: (printed) ____________________________

POSITION: ________________________

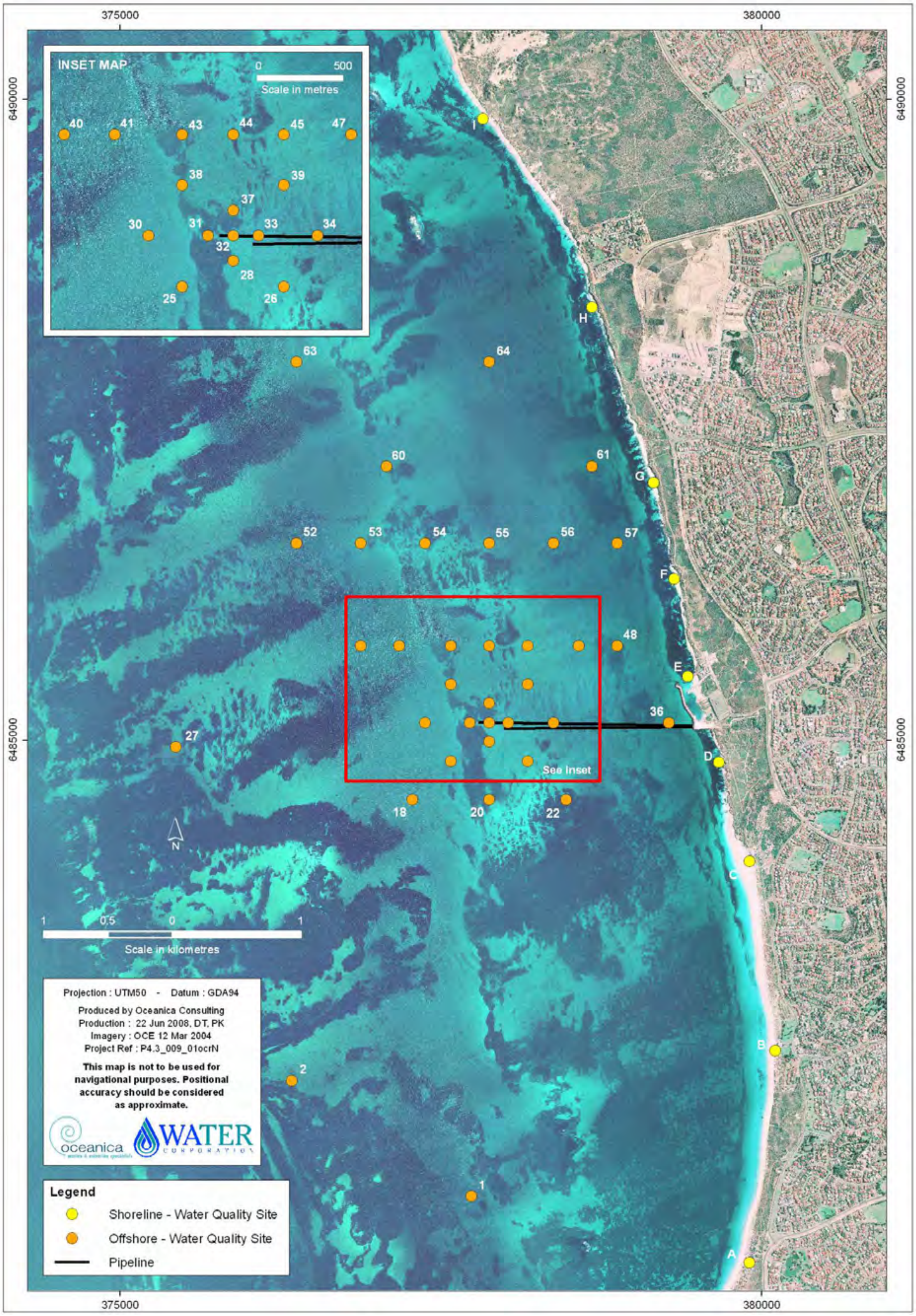
DATE: _____/______/_______________

SEAL (if signing under seal)

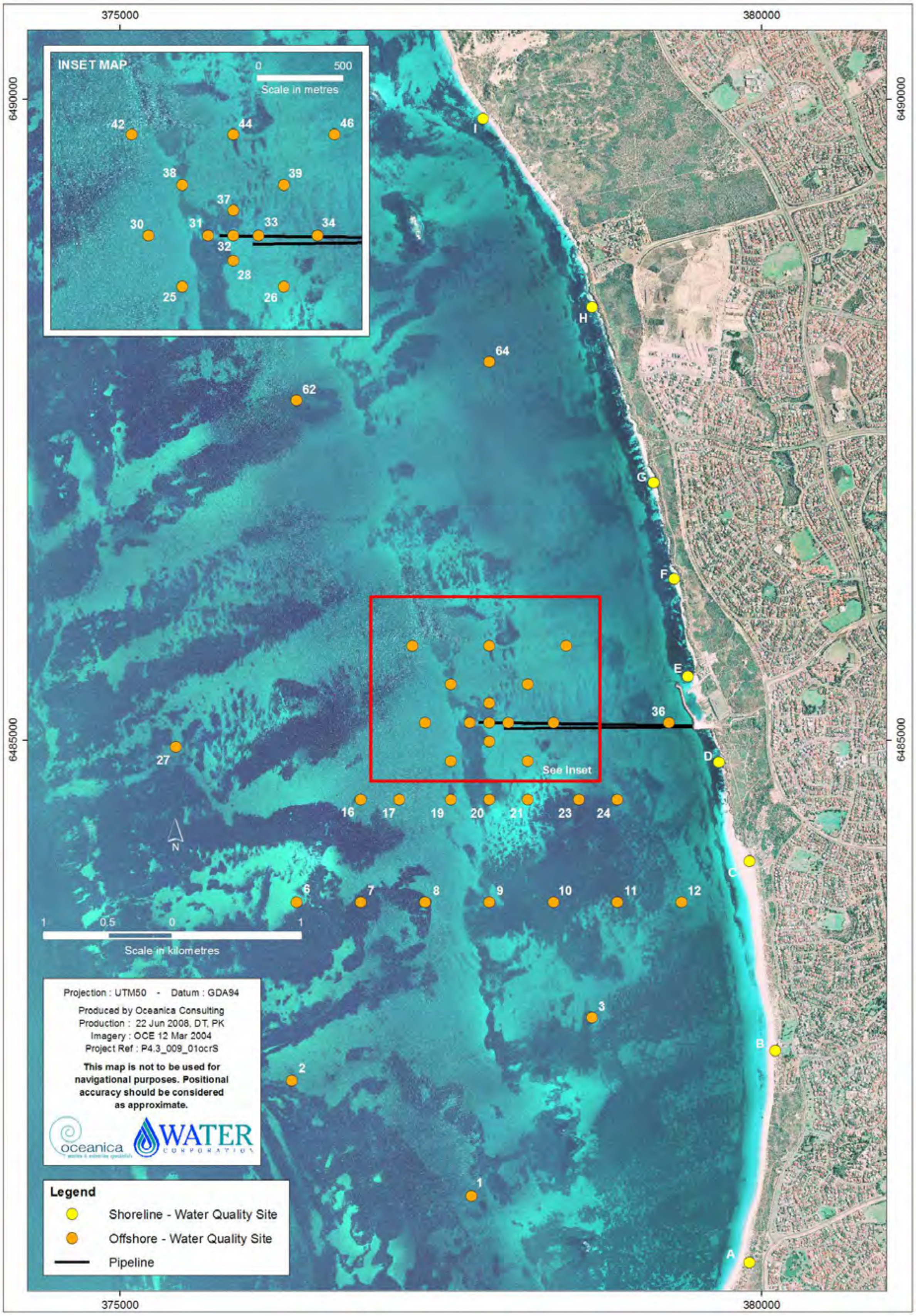
Appendix B

Sampling Grids for Summer Water Quality Survey

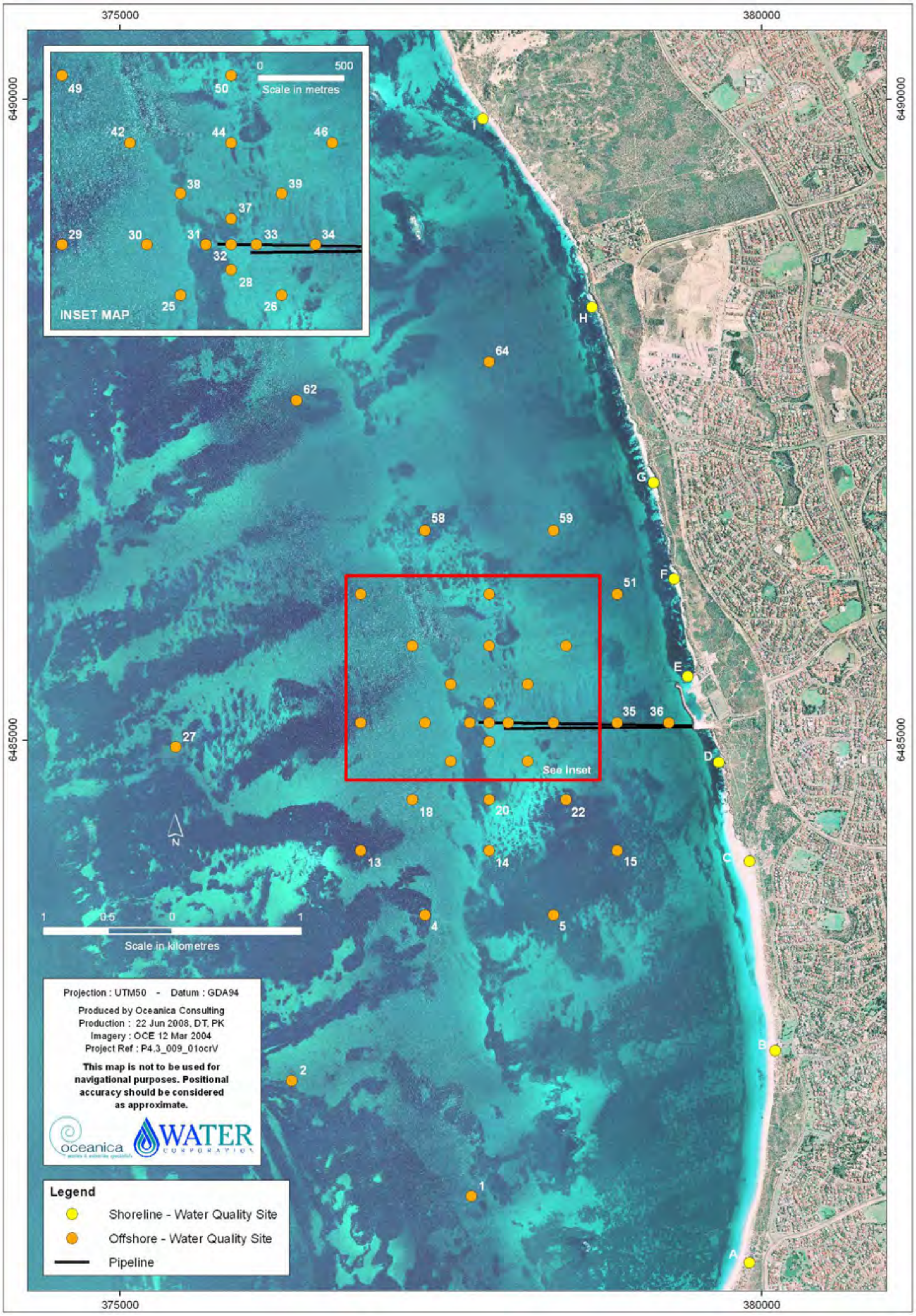
Ocean Reef Sample Sites - Northerly Flow Grid and Shoreline Sites



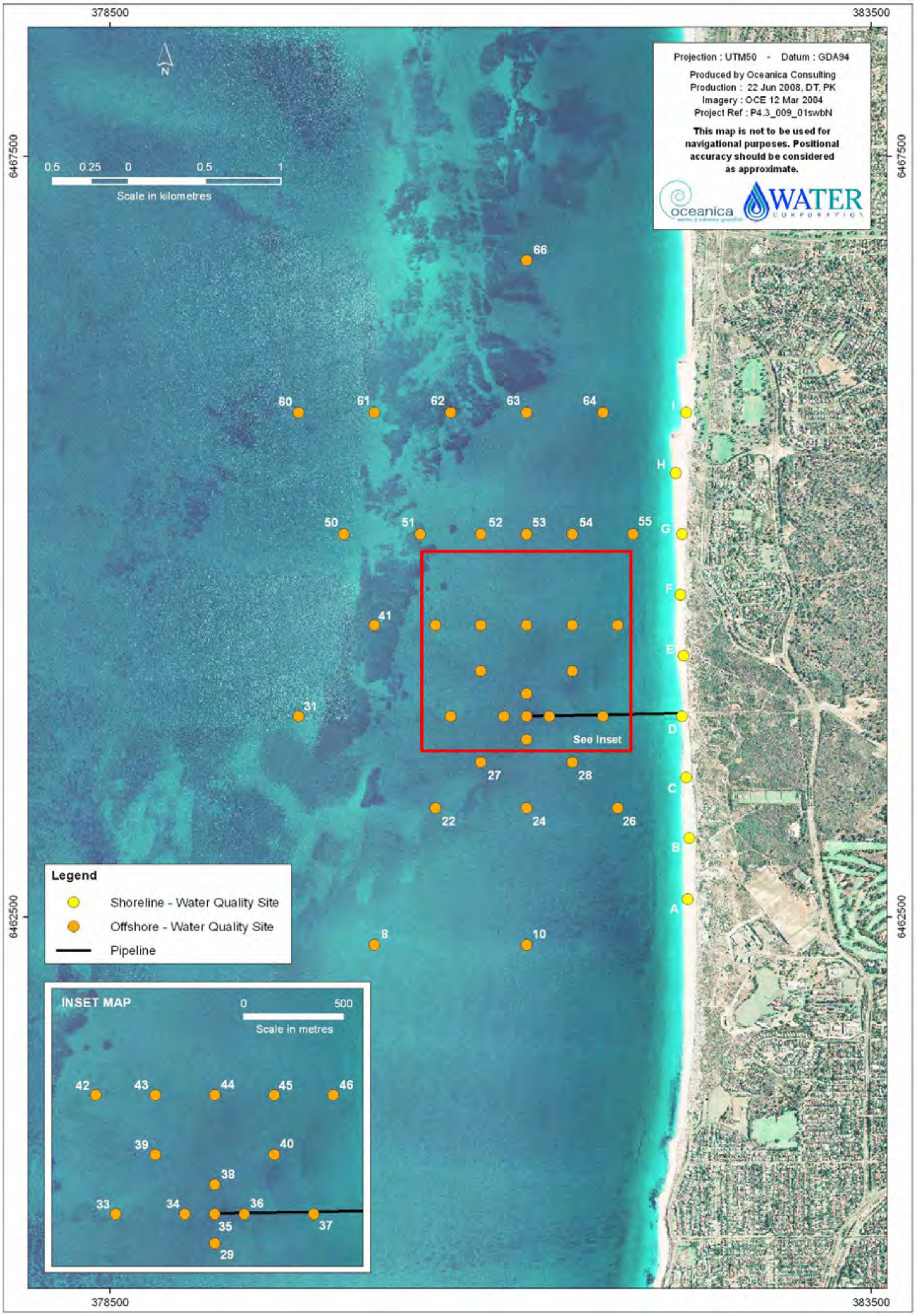
Ocean Reef Sample Sites: Southerly Flow Grid and Shoreline Sites



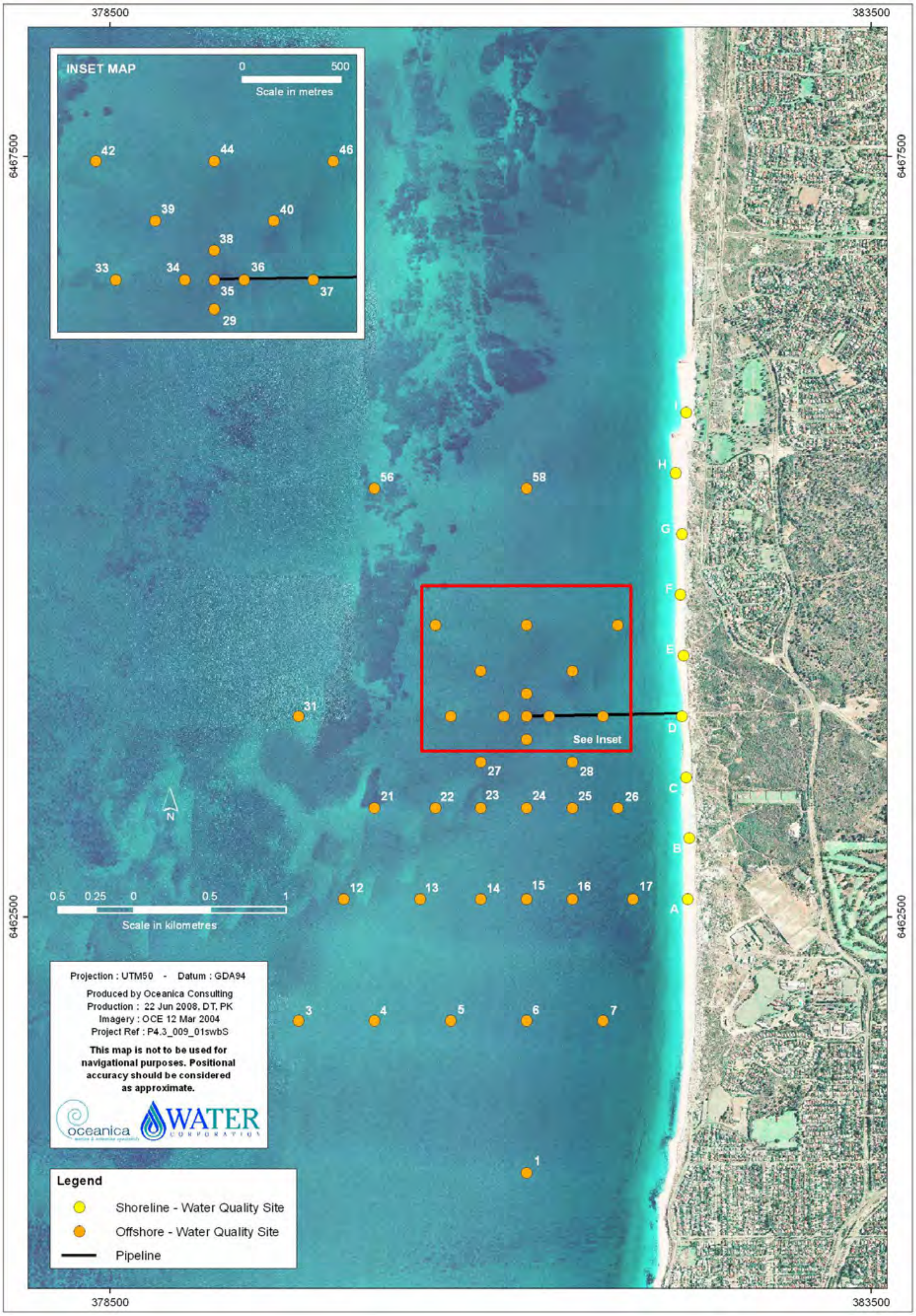
Ocean Reef Sample Sites: Light / Variable Flow Grid and Shoreline Sites



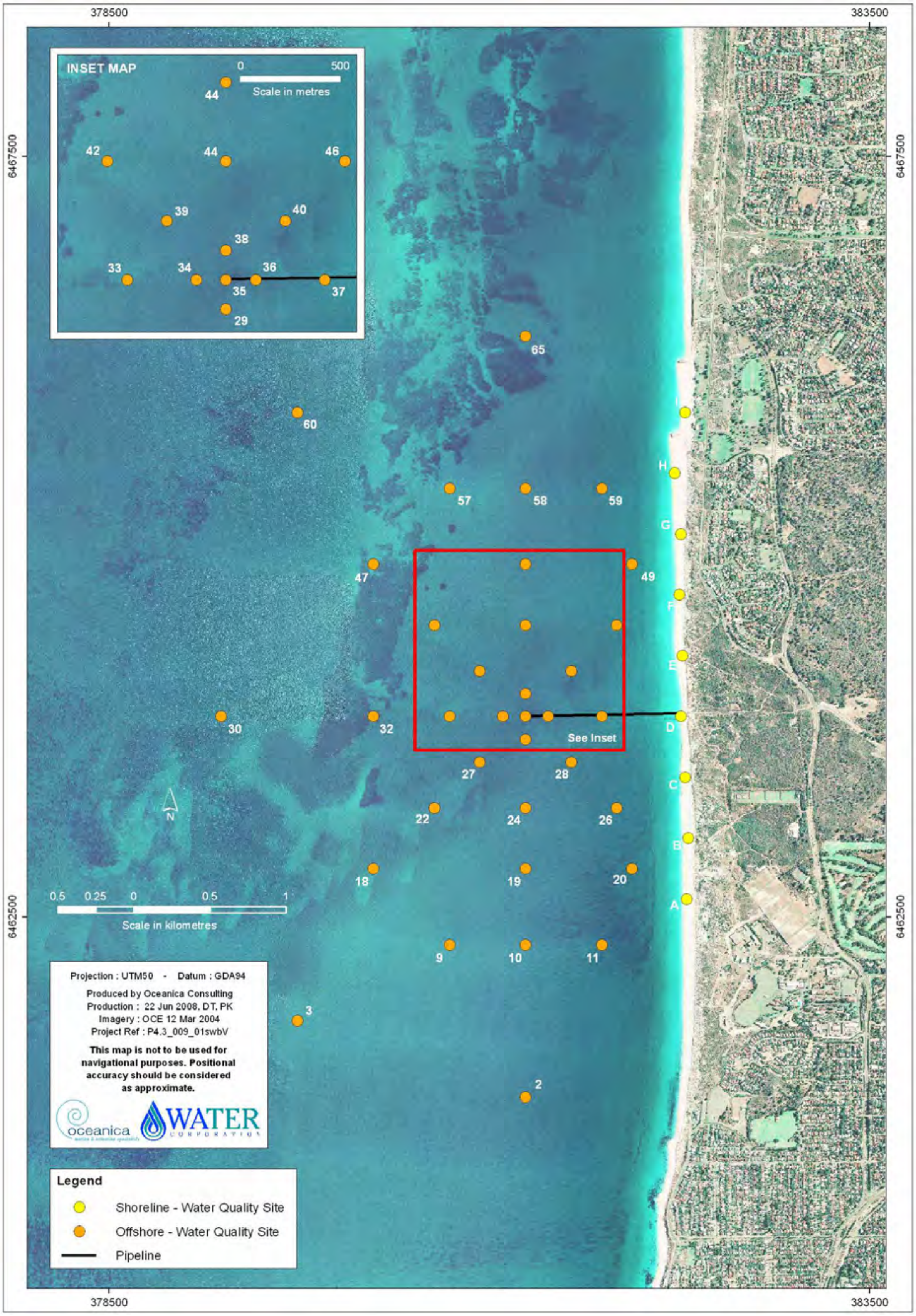
Swanbourne Sample Sites: Northerly Flow Grid and Shoreline Sites



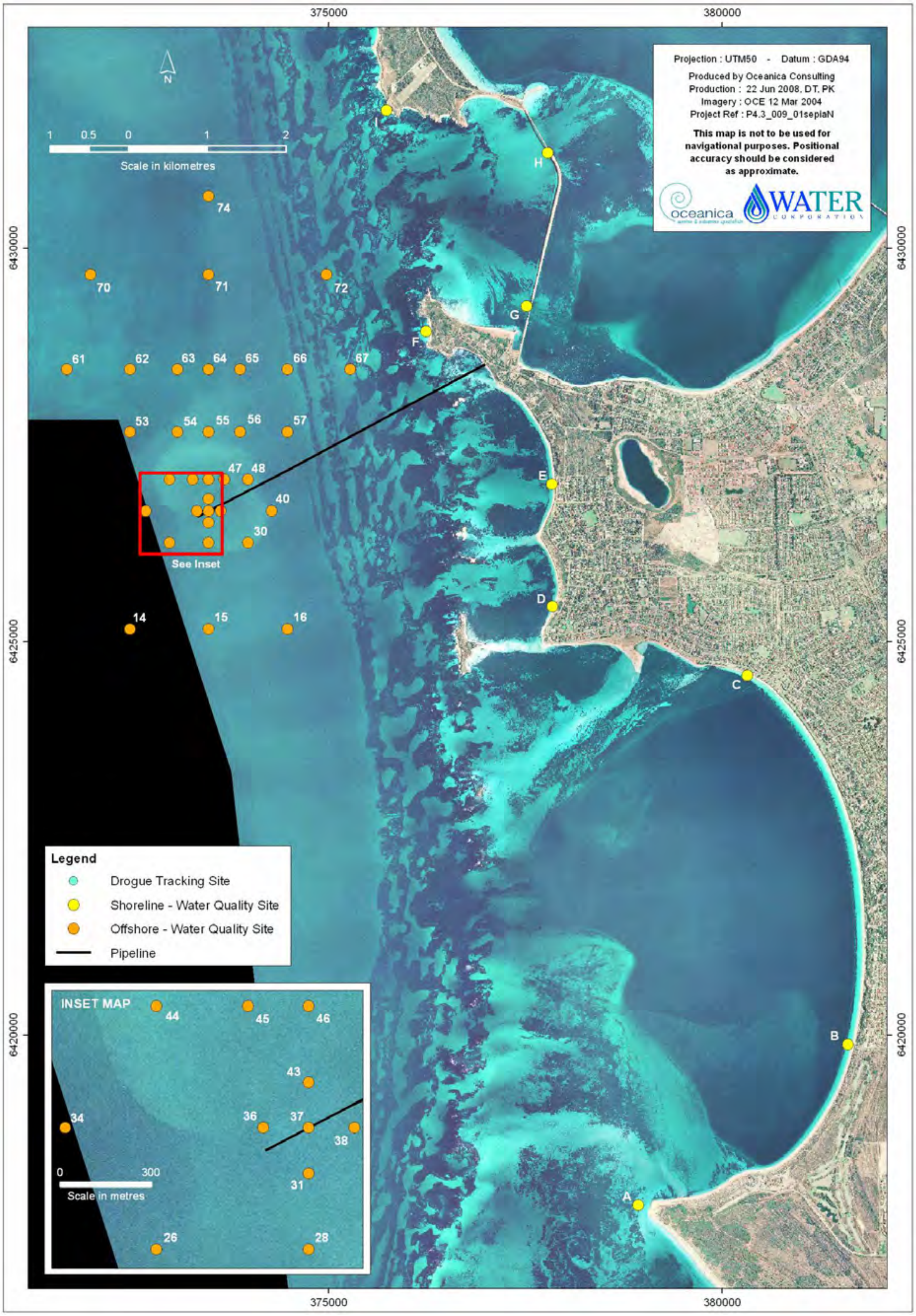
Swanbourne Sample Sites: Southerly Flow Grid and Shoreline Sites



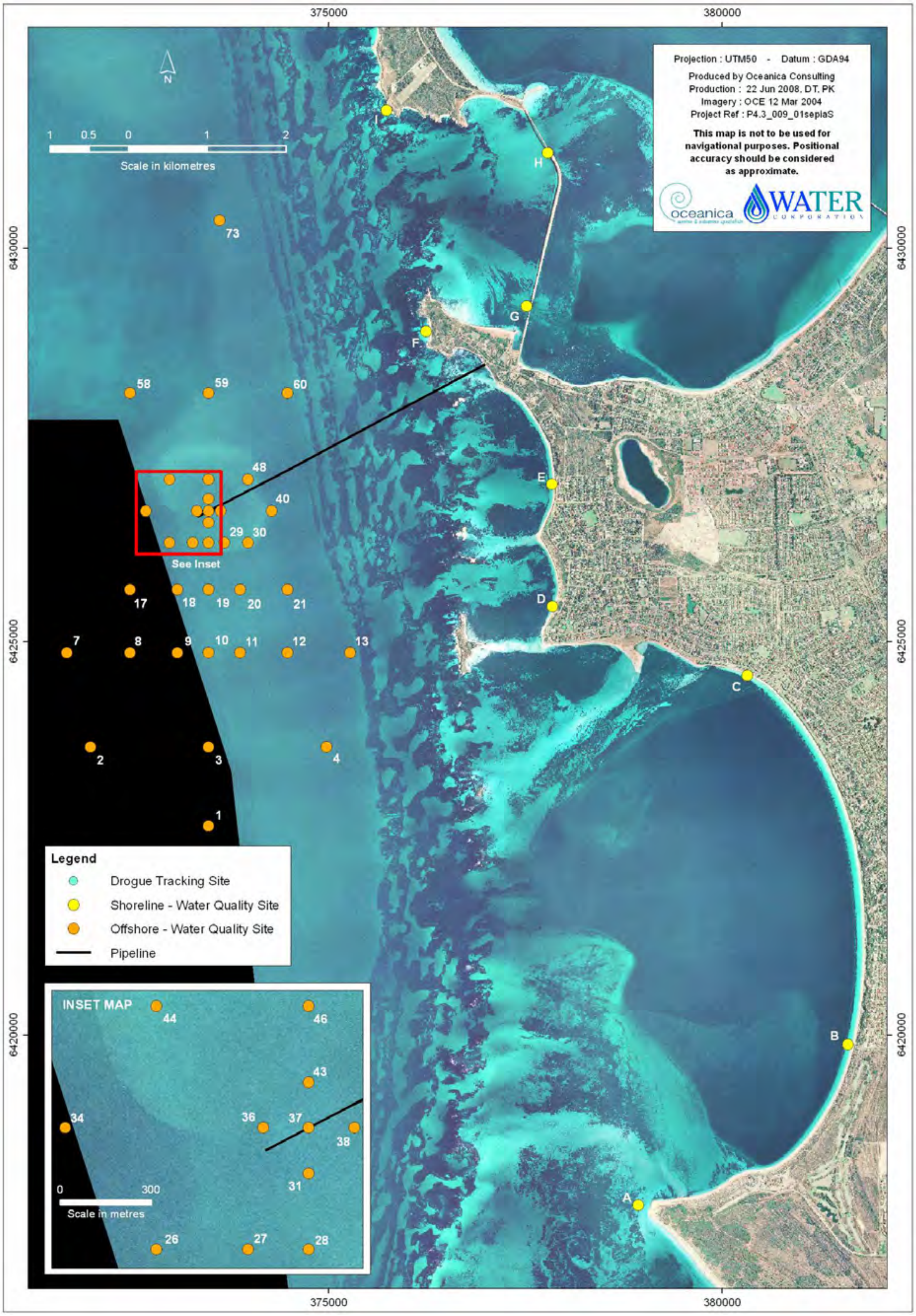
Swanbourne Sample Sites: Light / Variable Flow Grid and Shoreline Sites



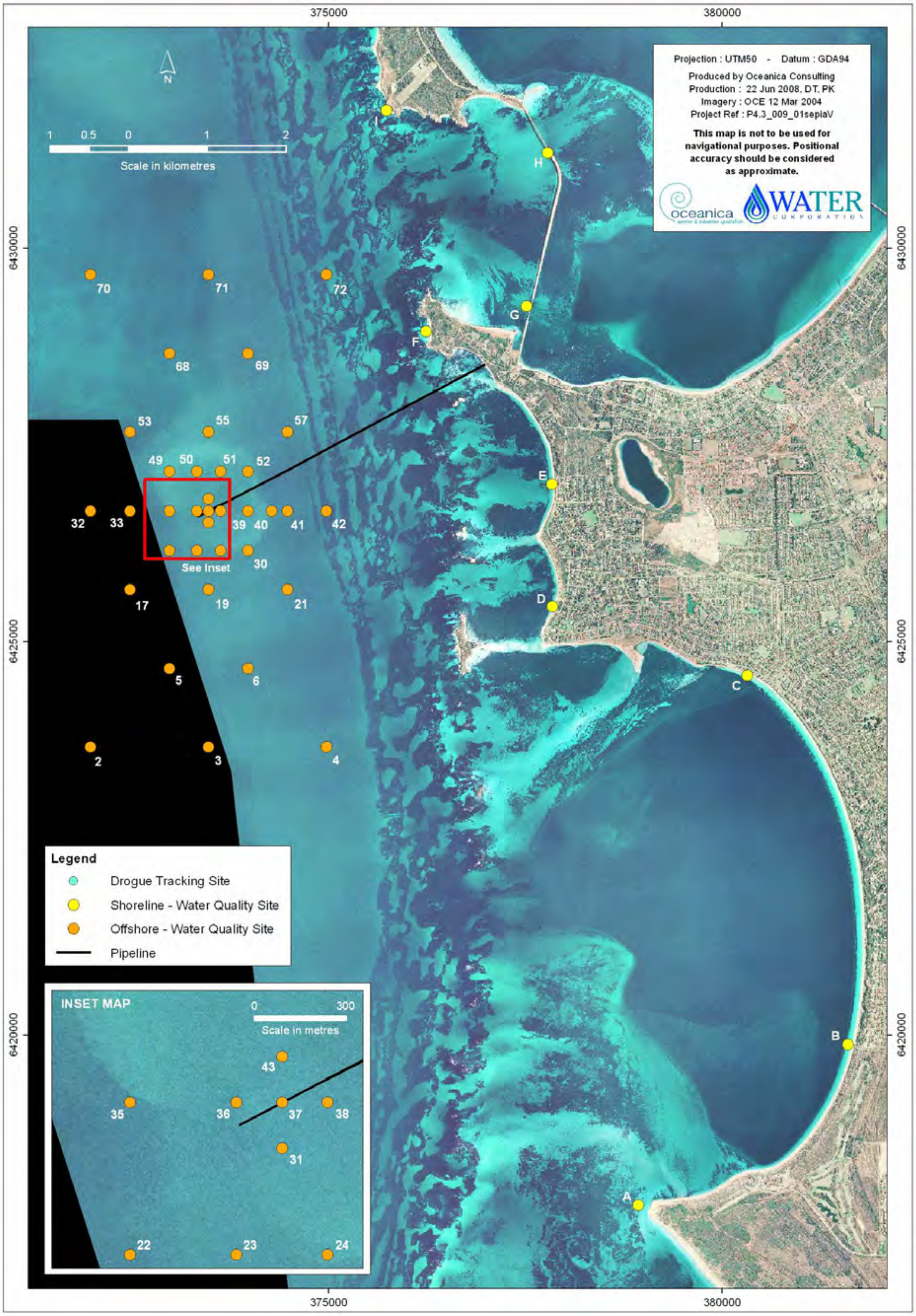
Sepia Depression Sample Sites: Northerly Flow Grid and Shoreline Sites



Sepia Depression Sample Sites: Southerly Flow Grid and Shoreline Sites



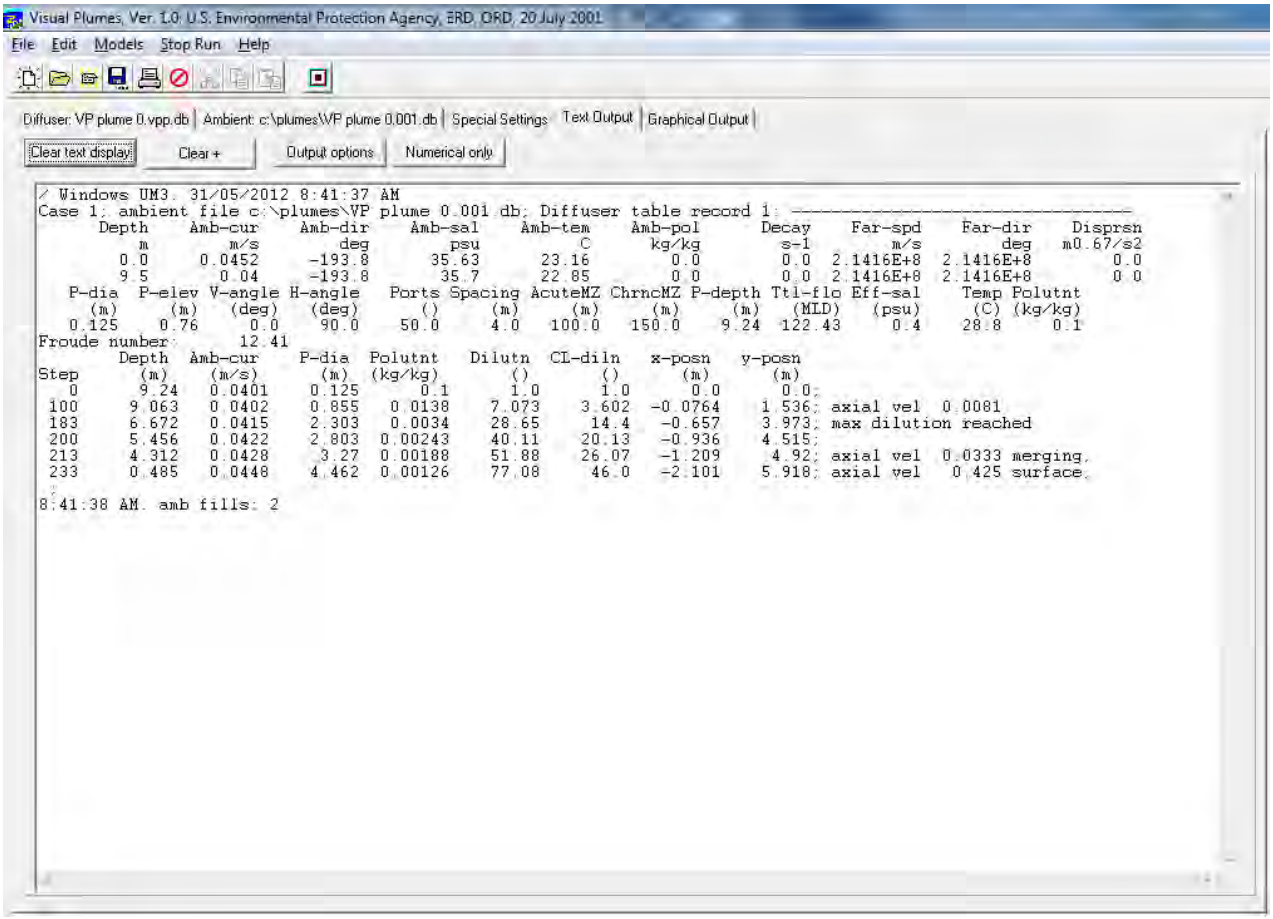
Sepia Depression Sample Sites: Light / Variable Flow Grid and Shoreline Sites

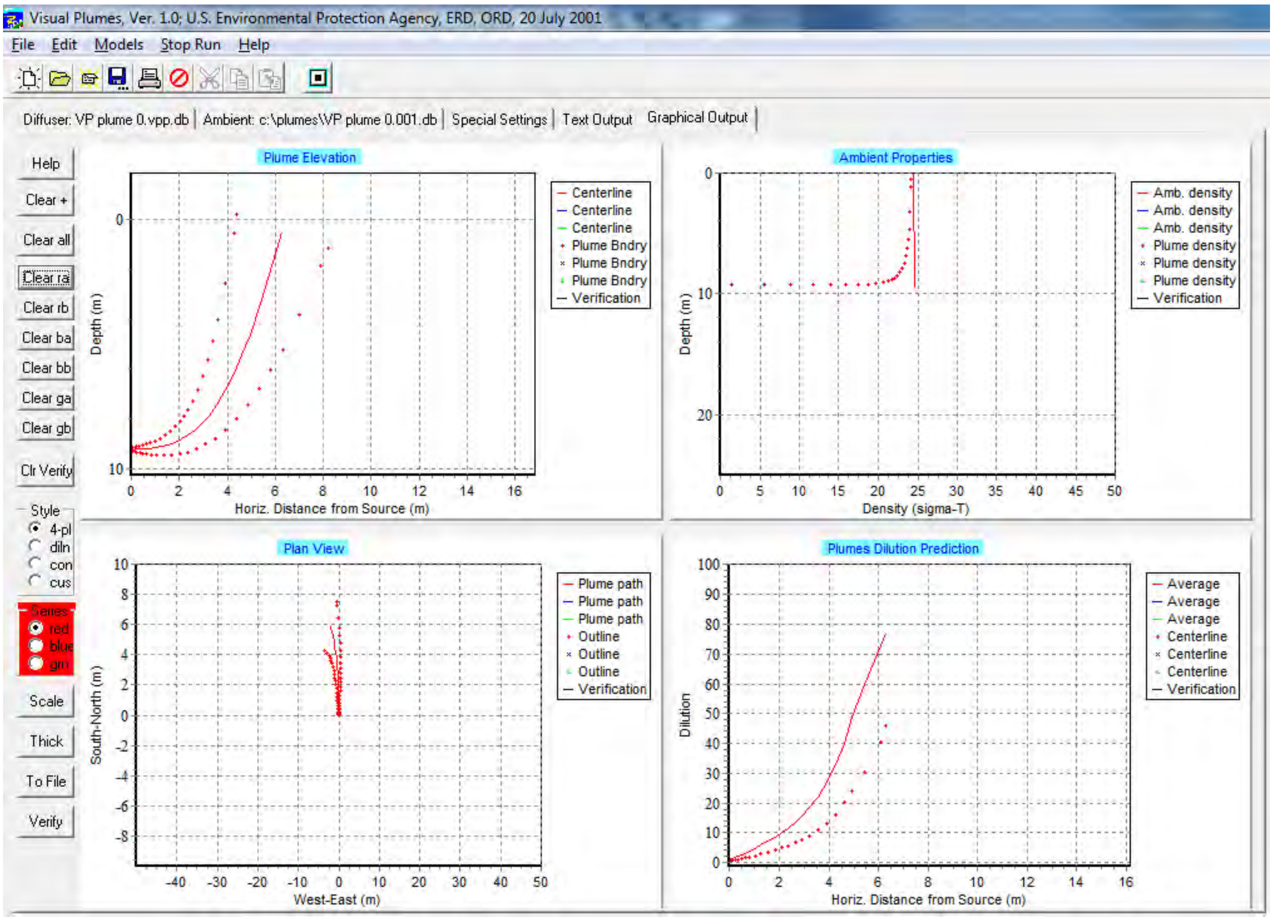


Appendix C

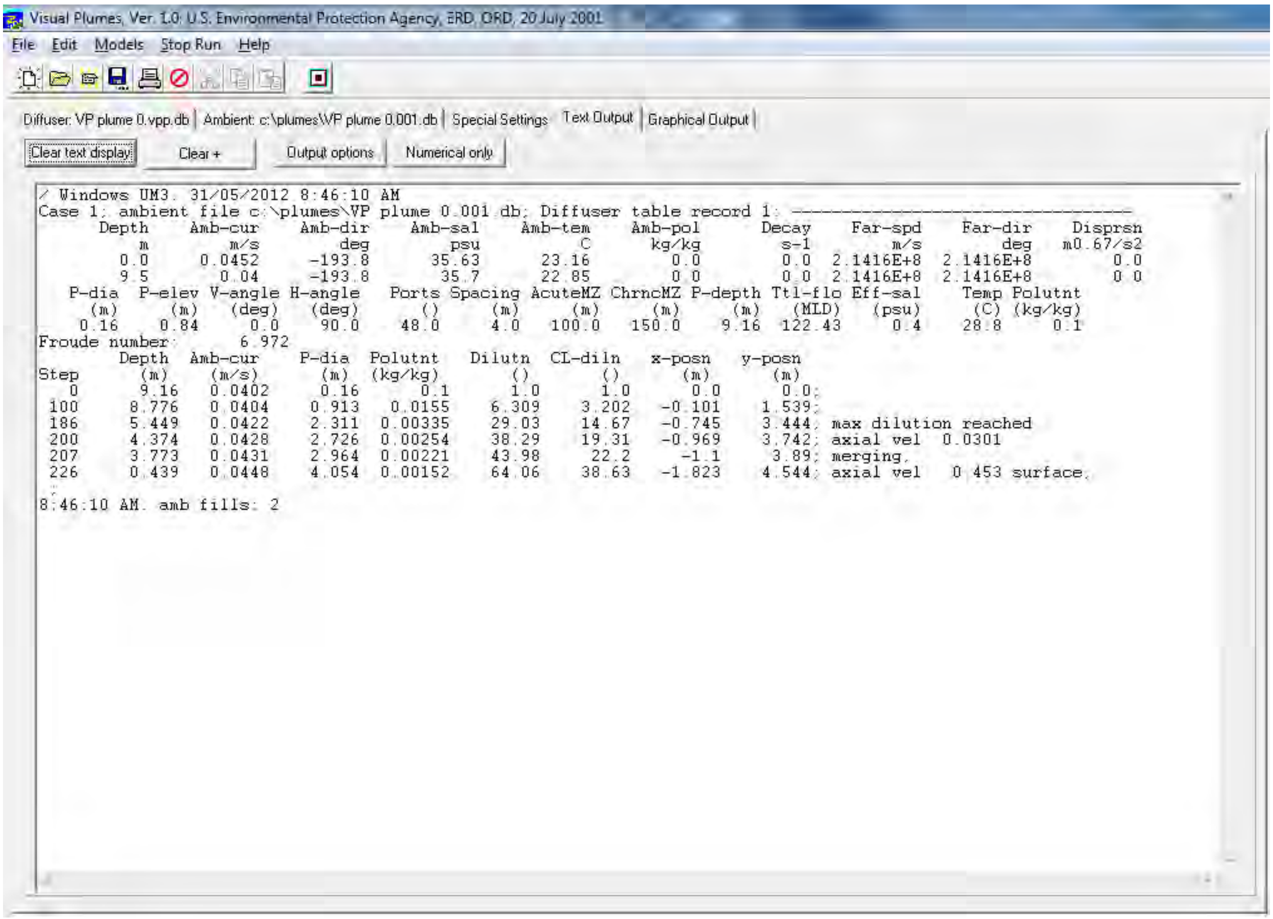
UM3 Initial Dilution Model Output

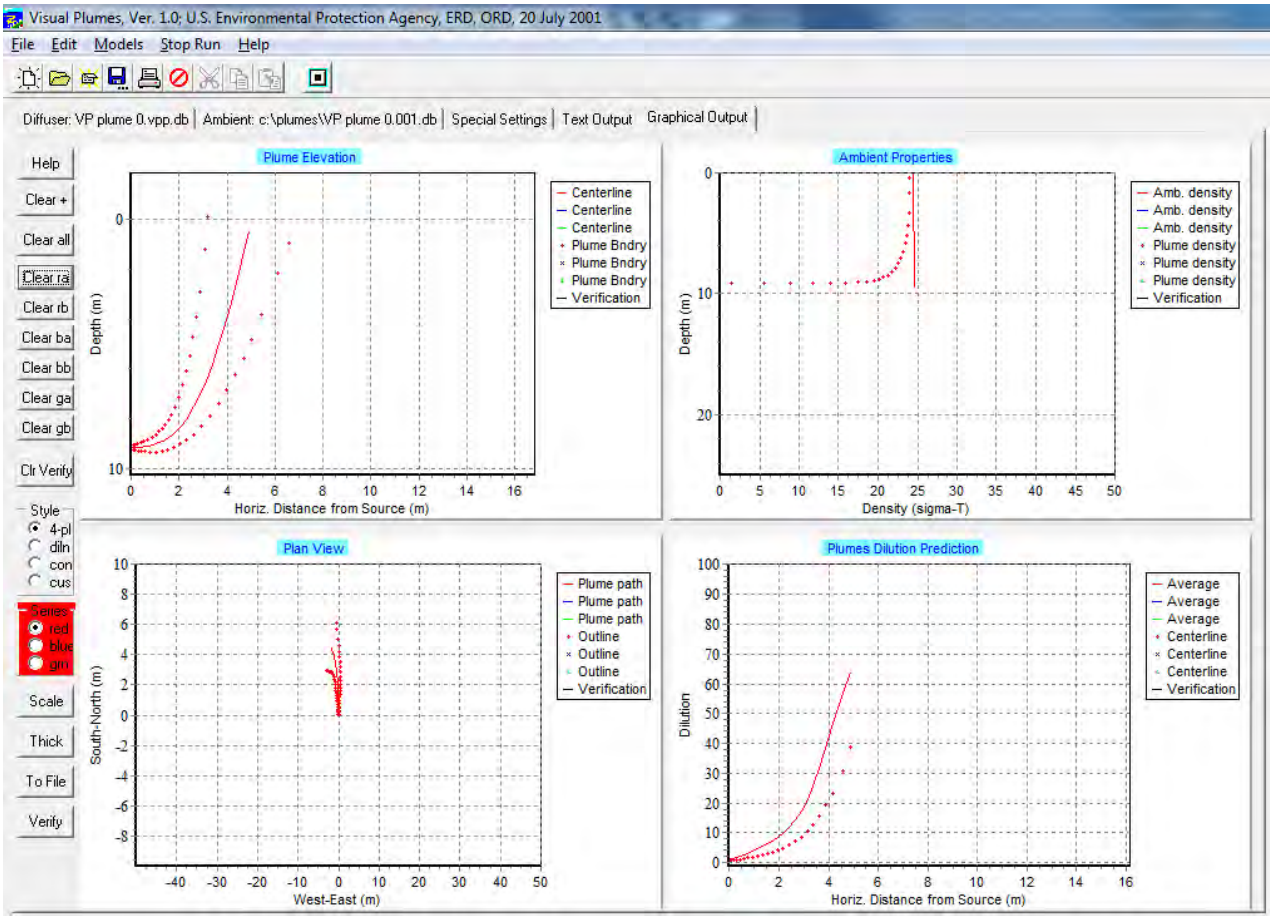
OCEAN REEF OUTLET A – INITIAL DILUTION MODELLING



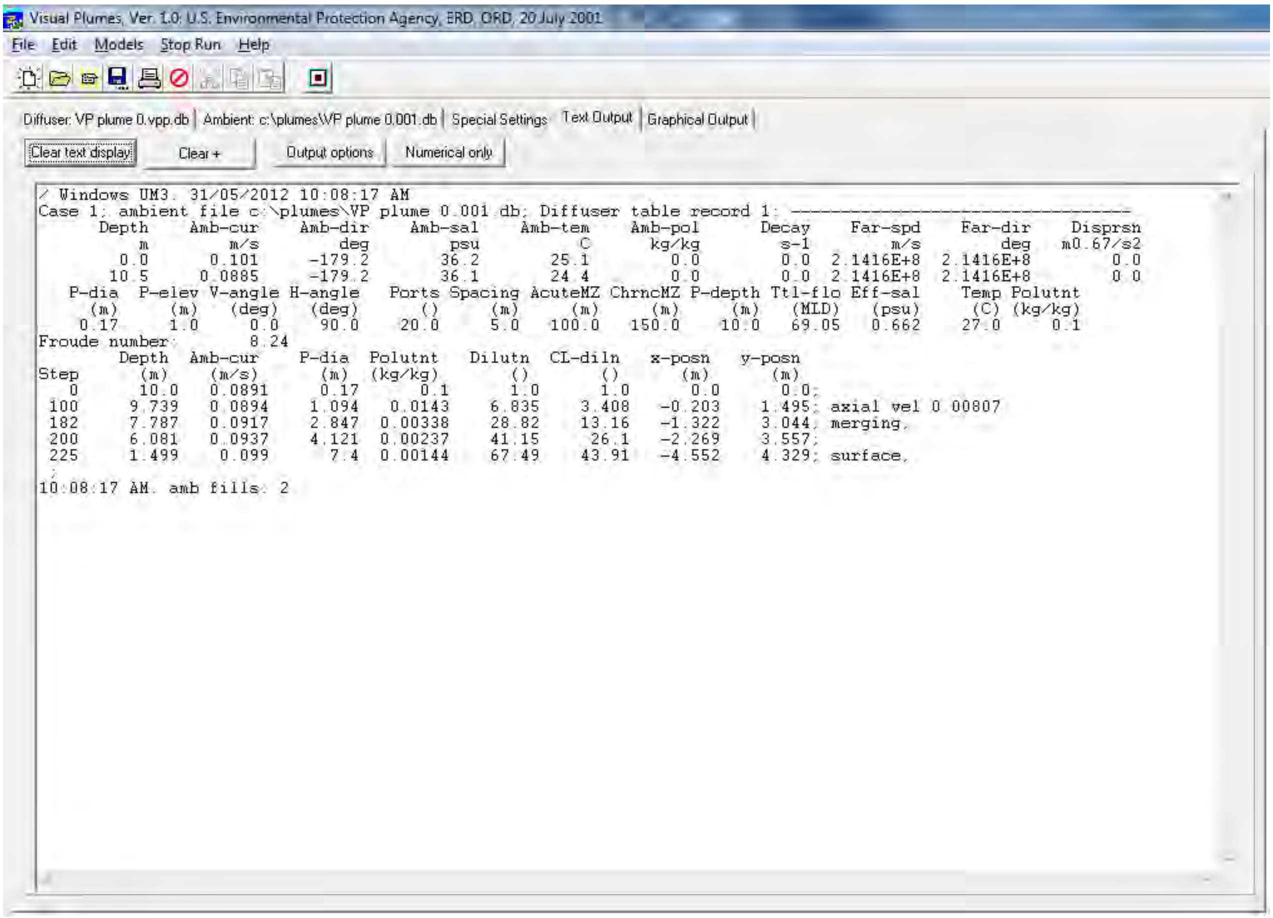


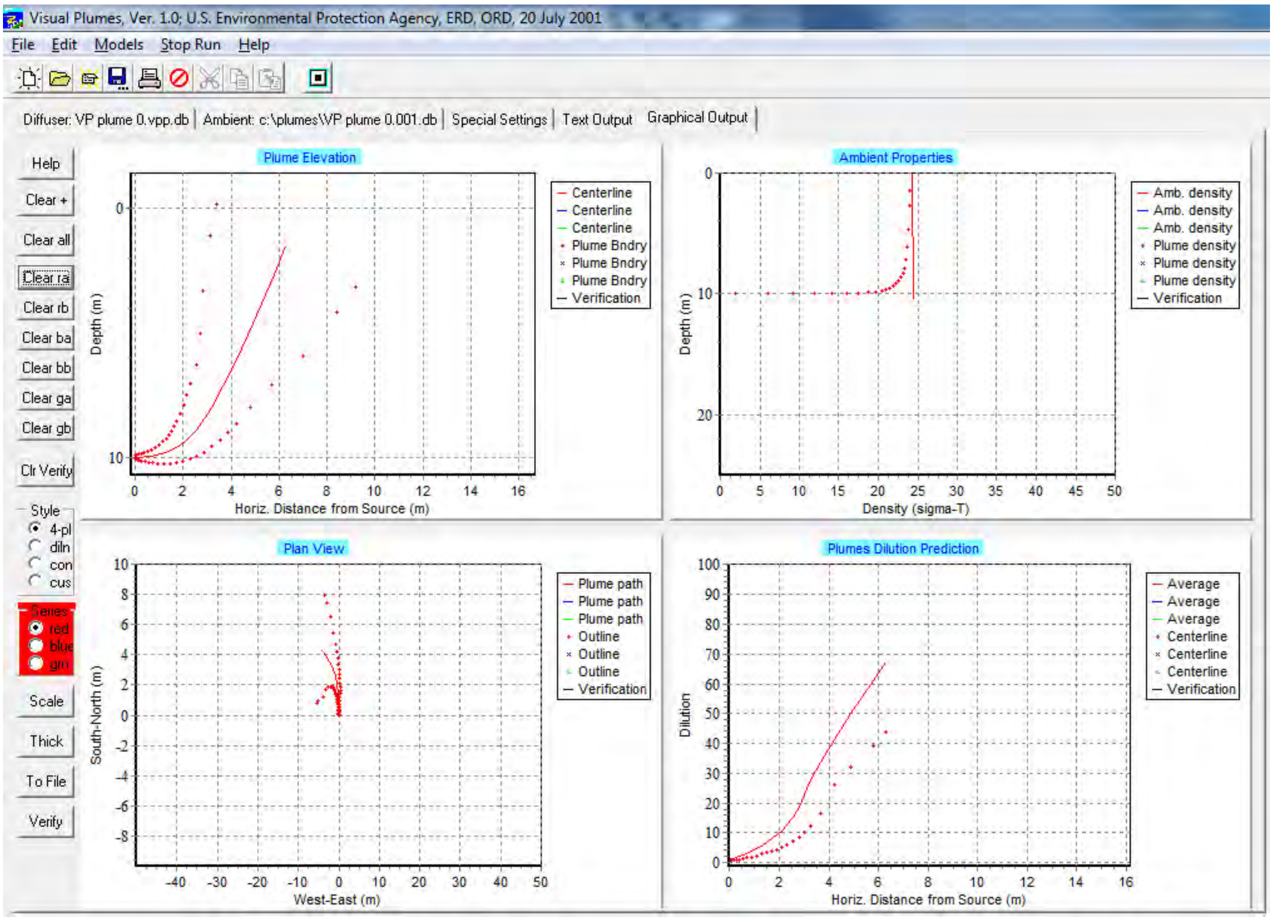
OCEAN REEF OUTLET B – INITIAL DILUTION MODELLING



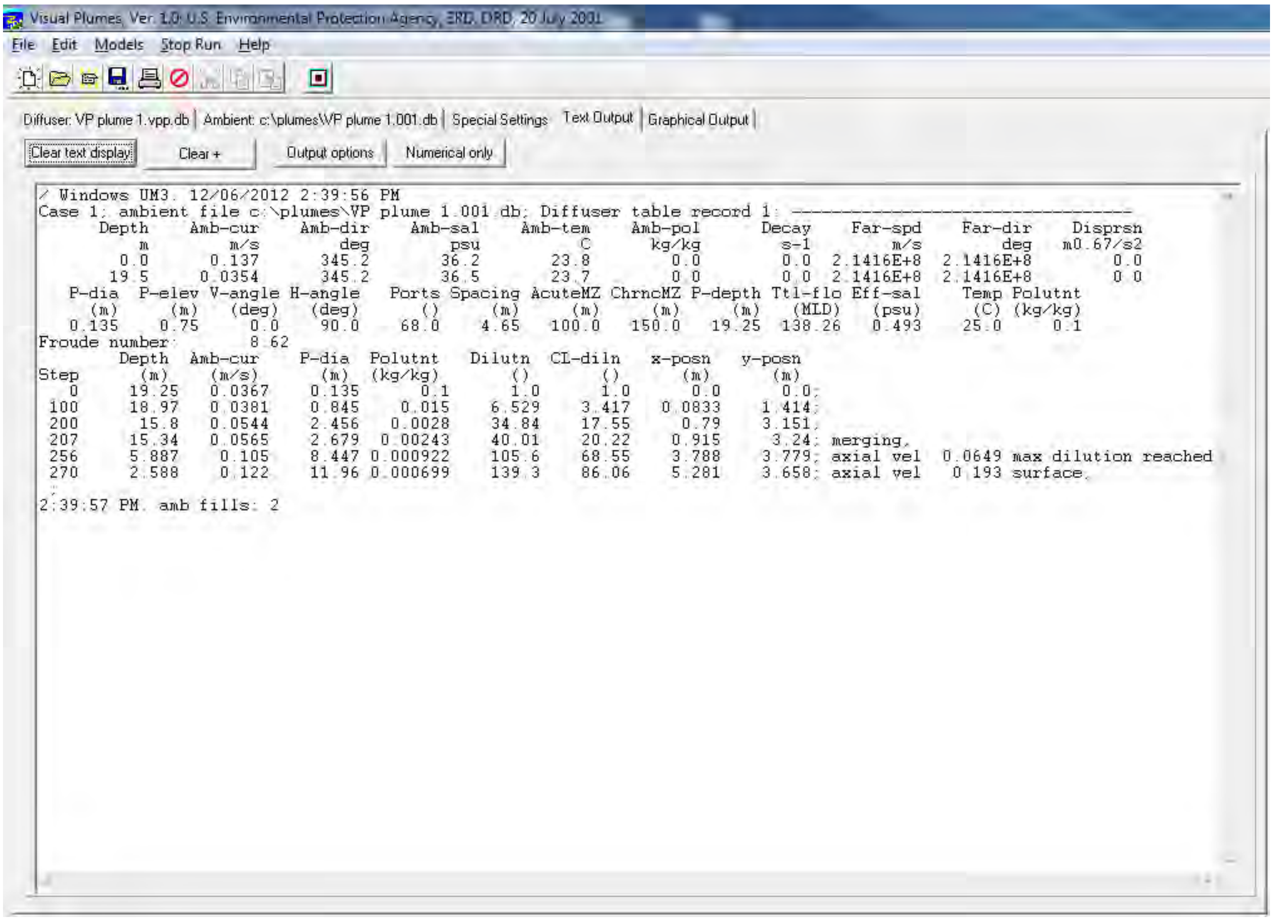


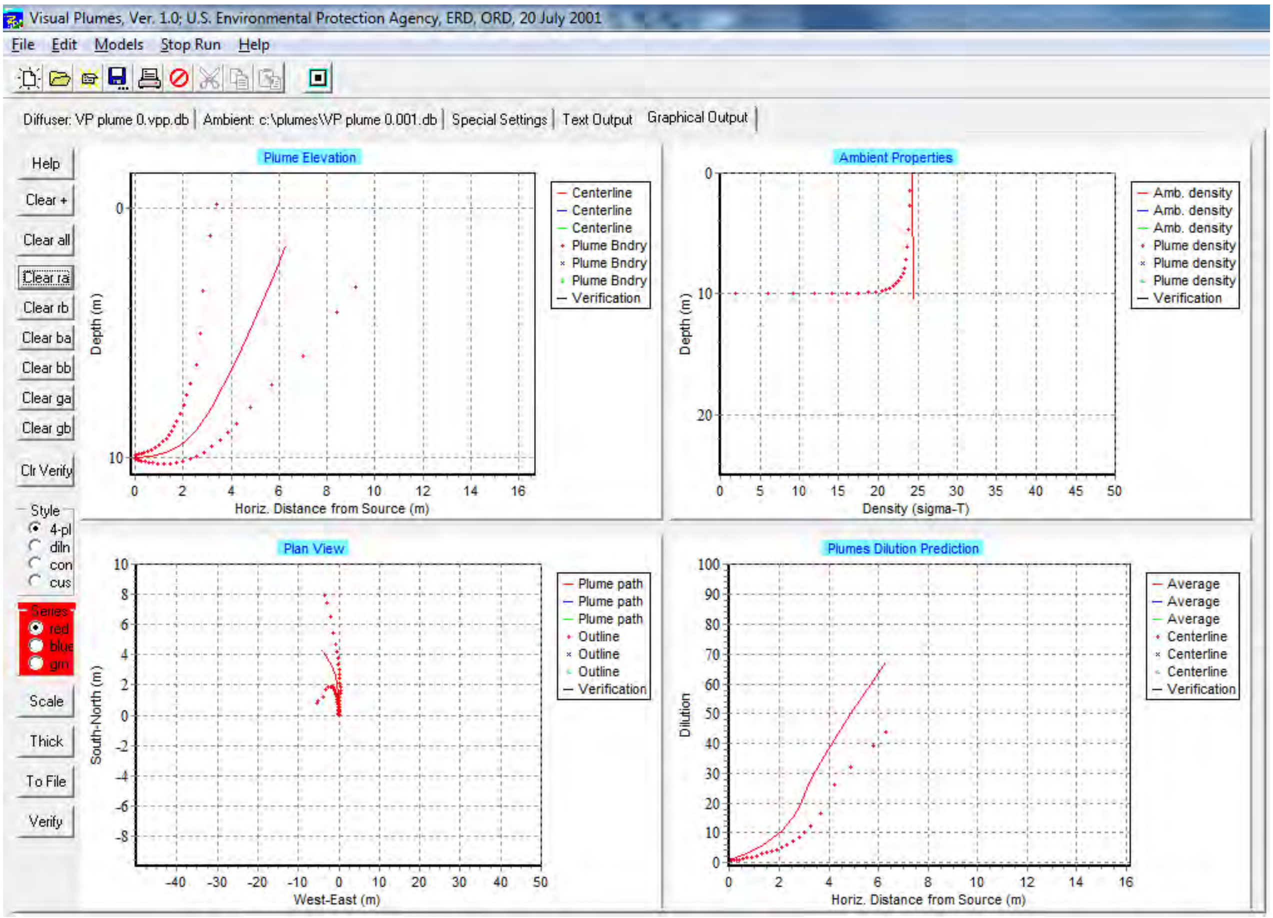
SWANBOURNE – INITIAL DILUTION MODELLING





SEPIA DEPRESSION – INITIAL DILUTION MODELLING





Appendix D

Water Quality Sampling Sites and Data

OCEAN REEF - SAMPLING SITES, 07 FEBRUARY 2012

Site	Time (hrs)	Latitude GDA94 S (actual)	Longitude GDA94 E (actual)	UTM50, GDA94 actual	
				Easting	Northing
1	10:06:43	31° 47.761' S	115° 42.513' E	377742	6481448
2	10:29:26	31° 47.264' S	115° 41.630' E	376338	6482349
18	10:47:47	31° 46.086' S	115° 42.244' E	377280	6484537
20	09:35:16	31° 46.090' S	115° 42.624' E	377880	6484538
22	10:56:37	31° 46.093' S	115° 43.005' E	378481	6484538
25	08:52:16	31° 45.926' S	115° 42.437' E	377581	6484837
26	09:40:29	31° 45.929' S	115° 42.817' E	378181	6484839
27	09:19:34	31° 45.850' S	115° 41.080' E	375438	6484951
28	08:58:26	31° 45.846' S	115° 42.624' E	377875	6484987
30	08:44:36	31° 45.762' S	115° 42.313' E	377382	6485137
31	08:07:51	31° 45.763' S	115° 42.535' E	377732	6485139
32	07:51:43	31° 45.766' S	115° 42.628' E	377880	6485136
33	08:17:08	31° 45.766' S	115° 42.723' E	378029	6485138
34	08:26:01	31° 45.768' S	115° 42.944' E	378378	6485139
36	08:35:13	31° 45.773' S	115° 43.513' E	379277	6485139
37	09:05:57	31° 45.682' S	115° 42.627' E	377876	6485290
38	09:51:32	31° 45.599' S	115° 42.440' E	377579	6485441
39	09:47:01	31° 45.608' S	115° 42.822' E	378182	6485431
40	11:06:38	31° 45.433' S	115° 41.999' E	376879	6485739
41	11:12:04	31° 45.434' S	115° 42.189' E	377179	6485741
43	11:17:47	31° 45.437' S	115° 42.442' E	377578	6485741
44	11:22:44	31° 45.442' S	115° 42.632' E	377879	6485734
45	11:33:05	31° 45.441' S	115° 42.820' E	378176	6485739
47	11:38:44	31° 45.444' S	115° 43.077' E	378581	6485740
48	11:42:55	31° 45.445' S	115° 43.265' E	378878	6485741
52	12:02:20	31° 45.000' S	115° 41.689' E	376380	6486534
53	12:08:14	31° 44.999' S	115° 42.005' E	376879	6486541
54	12:11:55	31° 45.003' S	115° 42.321' E	377378	6486540
55	12:18:28	31° 45.007' S	115° 42.638' E	377879	6486538
56	12:28:02	31° 45.010' S	115° 42.956' E	378380	6486538
57	12:34:02	31° 45.013' S	115° 43.271' E	378879	6486540
60	12:51:52	31° 44.677' S	115° 42.137' E	377080	6487138
61	12:38:47	31° 44.688' S	115° 43.151' E	378682	6487138
63	12:58:02	31° 44.232' S	115° 41.702' E	376384	6487953
64	01:05:44	31° 44.245' S	115° 42.648' E	377878	6487947
D1	07:51:43	31° 45.766' S	115° 42.628' E	377880	6485136
D2	08:15:37	31° 45.768' S	115° 42.537' E	377736	6485130
D3	08:42:17	31° 45.757' S	115° 42.429' E	377565	6485149
D4	09:13:41	31° 45.735' S	115° 42.355' E	377447	6485188
D5	09:31:33	31° 45.711' S	115° 42.330' E	377408	6485232
D6	09:54:11	31° 45.688' S	115° 42.317' E	377387	6485275
D7	10:44:20	31° 45.659' S	115° 42.250' E	377281	6485326
D8	11:56:50	31° 45.670' S	115° 42.174' E	377161	6485305
D9	12:45:56	31° 45.665' S	115° 42.170' E	377154	6485314
A	n/a	31° 48.560' S	115° 43.882' E	379908	6480928
B	n/a	31° 47.164' S	115° 43.210' E	380108	6482579
C	n/a	31° 46.362' S	115° 43.906' E	379910	6484058
D	n/a	31° 45.943' S	115° 43.759' E	379669	6484830
E	n/a	31° 45.579' S	115° 43.612' E	379429	6485500
F	n/a	31° 45.167' S	115° 43.548' E	379319	6486260
G	n/a	31° 44.760' S	115° 43.452' E	379158	6487010
H	n/a	31° 44.160' S	115° 43.159' E	378680	6488335
I	n/a	31° 43.215' S	115° 42.631' E	377828	6489877

OCEAN REEF - SURFACE AND SHORELINE WATER QUALITY, 07 FEBRUARY 2012

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll *a* (acetone) µg/L (<0.1)	Phaeophytin *a* µg/L (<0.2)	Chlorophyll *a* (fluorometry) µg/L (<0.1)	Thermal-tolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
1a	<3	7	8	16	100	0.3	<0.2	0.4	<10	<10
1b	<3	7	9	17	100	0.3	<0.2	0.3	<10	<10
1c	<3	8	9	16	90	0.3	<0.2	0.2	<10	<10
2	<3	6	16	14	80			0.2	<10	<10
18	<3	5	8	15	110			0.4	<10	<10
20	<3	4	<2	17	170			0.5	<10	<10
22	<3	4	<2	14	120			0.6	<10	<10
25	<3	6	6	15	90			0.5	<10	<10
26	<3	5	<2	15	100			0.5	<10	<10
27	<3	4	10	12	80	<0.1	<0.2	0.1	<10	<10
28	<3	4	<2	15	100			0.5	<10	<10
30	<3	6	7	15	90			0.4	<10	<10
31	<3	37	48	48	140			0.6	320	30
32	<3	42	56	53	150			0.5	470	74
33	<3	33	45	44	140			0.6	350	20
34	<3	5	<2	18	100			0.6	<10	<10
36	<3	4	<2	16	110	0.5	<0.2	0.4	<10	<10
37	<3	35	44	44	140			0.6	200	10
38	<3	33	43	43	220			0.5	10	10
39	<3	22	25	32	110			0.7	64	<10
40	<3	5	7	14	70			0.2	<10	<10
41	<3	4	6	13	100			0.4	<10	<10
43	<3	25	29	34	120			0.7	<10	<10
44	<3	26	30	35	120	0.6	<0.2	0.6	<10	<10
45	<3	23	24	33	100			0.7	20	<10
47	<3	13	7	24	90			0.8	<10	<10
48	<3	3	<2	13	110			0.4	<10	<10
52	<3	4	6	12	130			<0.1	<10	<10
53	<3	4	6	14	100			0.2	<10	<10
54	<3	5	2	12	90			0.5	<10	<10
55	<3	21	18	33	130			0.8	<10	<10
56	<3	5	<2	17	130			0.5	<10	<10
57	<3	5	5	17	110			0.4	<10	<10
60	<3	5	5	14	80			0.3	<10	31
61	<3	5	2	16	100			0.5	<10	<10
63	<3	5	6	16	90	0.3	<0.2	0.3	<10	<10
64	<3	8	<2	18	100	0.6	<0.2	0.6	<10	<10
A	5	5	4	23	160	1.4	0.5		20	<10
B	<3	8	35	30	220	1.5	0.6		<10	<10
C	7	4	10	23	170	1	0.3		<10	<10
D	6	7	10	24	150	0.9	0.9		<10	<10
E	<3	5	95	20	220	0.5	0.6		<10	<10
F	7	3	28	19	200	0.4	1.2		<10	<10
G	14	7	17	19	180	0.4	0.8		<10	<10
H	7	7	13	18	160	0.4	0.8		<10	<10
I	7	7	40	22	210	0.6	0.5		<10	<10

Notes:
1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter

OCEAN REEF - BOTTOM WATER QUALITY, 07 FEBRUARY 2012

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll *a* (acetone) µg/L (<0.1)	Phaeophytin *a* µg/L (<0.2)	Chlorophyll *a* (fluorometry) µg/L (<0.1)	Thermal-tolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
1a	<3	6	5	17	120			0.4	<10	<10
2	<3	5	13	15	100			0.2	<10	<10
18	<3	5	7	11	90			0.4	<10	<10
20	<3	5	<2	17	140			0.5	<10	<10
22	<3	6	3	16	90			0.4	<10	<10
25	<3	6	6	14	110			0.4	<10	<10
26	<3	4	<2	17	120			0.4	<10	<10
27	<3	5	12	14	100			<0.1	<10	<10
28	<3	5	<2	16	110			0.4	<10	<10
30	<3	6	7	15	90			0.4	<10	10
31	<3	9	7	18	120			0.4	80	<10
32	<3	9	8	20	120			0.4	40	10
33	<3	14	16	26	120			0.5	230	20
34	<3	6	<2	15	100			0.6	<10	20
36	<3	4	<2	17	110			0.5	<10	10
37	<3	11	10	22	110			0.5	27	10
38	<3	12	14	22	130			0.6	<10	<10
39	<3	14	14	25	110			0.6	64	<10
40	<3	5	7	12	70			0.2	<10	<10
41	<3	6	3	13	100			0.5	<10	<10
43	<3	6	5	16	90			0.6	<10	10
44	<3	14	14	24	110			0.7	10	<10
45	<3	20	19	30	120			0.6	<10	<10
47	<3	4	<2	15	90			0.9	<10	<10
48	<3	4	<2	13	140			0.4	<10	<10
52	<3	4	4	13	110			0.1	<10	<10
53	<3	4	5	14	110			0.3	<10	<10
54	<3	11	10	18	120			0.6	<10	<10
55	<3	6	<2	18	140			1.2	<10	<10
56	<3	4	<2	17	110			0.6	<10	<10
57	<3	4	<2	18	100			0.4	<10	<10
60	<3	5	3	15	90			0.6	<10	<10
61	<3	4	<2	17	120			0.5	<10	<10
63	<3	6	6	11	110			0.5	<10	<10
64	<3	4	<2	15	100			0.5	<10	<10

Notes:
1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter
2. Chlorophyll *a* (acetone) and Phaeophytin *a* were not measured in bottom waters

SWANBOURNE - SAMPLING SITES, 24 JANUARY 2012

Site	Time (hrs)	Latitude GDA94 S (actual)	Longitude GDA94 E (actual)	UTM50, GDA94 actual	
				Easting	Northing
8	15:29:20	31° 58.129' S	115° 43.955' E	380240	6462320
10	15:43:13	31° 58.137' S	115° 44.589' E	381240	6462316
22	08:12:14	31° 57.644' S	115° 44.216' E	380641	6463221
24	08:37:26	31° 57.648' S	115° 44.595' E	381239	6463220
26	08:47:29	31° 57.653' S	115° 44.977' E	381840	6463218
27	09:08:01	31° 57.484' S	115° 44.408' E	380940	6463519
28	08:58:53	31° 57.488' S	115° 44.788' E	381540	6463519
29	09:18:19	31° 57.404' S	115° 44.599' E	381239	6463670
31	11:14:56	31° 57.314' S	115° 43.648' E	379739	6463819
33	15:17:18	31° 57.324' S	115° 44.280' E	380735	6463813
34	09:29:37	31° 57.321' S	115° 44.505' E	381090	6463823
35	09:46:13	31° 57.323' S	115° 44.601' E	381241	6463820
36	10:02:40	31° 57.324' S	115° 44.696' E	381390	6463820
37	10:14:52	31° 57.327' S	115° 44.917' E	381739	6463819
38	10:37:54	31° 57.244' S	115° 44.598' E	381235	6463966
39	10:50:42	31° 57.160' S	115° 44.412' E	380939	6464119
40	10:27:11	31° 57.163' S	115° 44.792' E	381538	6464119
41	11:33:14	31° 56.993' S	115° 43.971' E	380242	6464419
42	11:48:54	31° 56.994' S	115° 44.224' E	380641	6464421
43	12:00:43	31° 56.999' S	115° 44.414' E	380940	6464416
44	12:14:42	31° 57.001' S	115° 44.602' E	381236	6464415
45	12:29:43	31° 57.001' S	115° 44.794' E	381539	6464419
46	12:39:52	31° 57.002' S	115° 44.985' E	381839	6464420
50	13:46:15	31° 56.667' S	115° 43.847' E	380039	6465019
51	13:35:54	31° 56.671' S	115° 44.163' E	380537	6465017
52	13:25:18	31° 56.672' S	115° 44.419' E	380940	6465019
53	13:13:37	31° 56.674' S	115° 44.609' E	381239	6465019
54	13:01:54	31° 56.675' S	115° 44.798' E	381538	6465021
55	12:51:44	31° 56.679' S	115° 45.054' E	381941	6465018
60	13:56:51	31° 56.232' S	115° 43.661' E	379737	6465819
61	14:13:32	31° 56.236' S	115° 43.979' E	380238	6465817
62	14:26:31	31° 56.237' S	115° 44.297' E	380738	6465821
63	14:36:29	31° 56.241' S	115° 44.615' E	381240	6465819
64	14:50:15	31° 56.245' S	115° 44.932' E	381739	6465819
66	15:01:07	31° 55.701' S	115° 44.622' E	381239	6466818
D1	08:08:37	31° 57.320' S	115° 44.651' E	381320	6463827
D2	08:08:37	31° 57.321' S	115° 43.954' E	380222	6463812
A	n/a	31° 57.980' S	115° 45.264' E	382299	6462619
B	n/a	31° 57.763' S	115° 45.273' E	382309	6463020
C	n/a	31° 57.547' S	115° 45.263' E	382289	6463419
D	n/a	31° 57.330' S	115° 45.274' E	382259	6463819
E	n/a	31° 57.114' S	115° 45.256' E	382268	6464218
F	n/a	31° 57.897' S	115° 45.247' E	382250	6464619
G	n/a	31° 57.681' S	115° 45.256' E	382259	6465018
H	n/a	31° 57.464' S	115° 45.233' E	382218	6465419
I	n/a	31° 56.248' S	115° 45.281' E	382289	6465819

Notes:

1. Only two drogue coordinates were recorded at Swanbourne, the release (D1) and pick-up (D2) points

SWANBOURNE - SURFACE AND SHORELINE WATER QUALITY, 24 JANUARY 2012

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll *a* (acetone) µg/L (<0.1)	Phaeophytin *a* µg/L (<0.2)	Chlorophyll *a* (fluorometry) µg/L (<0.1)	Thermal-tolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
8	<3	<2	<2	13	180			0.5	<10	<10
10a	<3	2	<2	12	100	0.3	<0.2	0.3	<10	<10
10b	<3	2	<2	12	130	0.4	<0.2	0.3	<10	<10
10c	<3	2	<2	12	100	0.4	<0.2	0.4	<10	<10
22	<3	2	<2	15	120			0.3	<10	<10
24	<3	2	<2	17	120			<0.1	<10	<10
26	<3	2	<2	15	120			0.5	<10	<10
27	<3	14	20	26	160			0.6	20	<10
28	<3	3	<2	16	120			0.3	<10	<10
29	<3	23	30	36	150			0.4	100	20
31	<3	2	<2	13	100	0.4	<0.2	0.3	<10	<10
33	<3	17	15	26	120			0.8	<10	<10
34	<3	11	16	23	130			0.4	40	<10
35	<3	43	47	59	190			0.5	650	52
36	<3	9	12	23	130			0.7	440	52
37	<3	4	3	16	110			0.5	<10	<10
38	<3	50	58	65	180			0.6	340	20
39	<3	22	28	33	140			0.5	<10	<10
40	<3	6	6	17	130			0.6	10	<10
41	<3	5	5	17	100			0.4	<10	<10
42	<3	7	9	18	100			0.6	<10	<10
43	<3	7	9	18	110			0.4	<10	<10
44	<3	3	<2	15	100			0.3	<10	<10
45	<3	3	<2	15	100			0.4	<10	<10
46	<3	4	<2	17	130			0.4	<10	<10
50	<3	4	<2	12	110			0.7	<10	<10
51	<3	6	4	15	140			0.7	<10	<10
52	<3	5	4	16	150			0.6	<10	<10
53	<3	4	<2	14	120			0.5	<10	<10
54	<3	4	<2	14	120	0.5	<0.2	0.6	<10	<10
55	<3	6	4	19	110	0.5	<0.2	0.5	<10	<10
60	<3	<2	<2	11	120			0.2	<10	<10
61	<3	3	<2	10	100			0.3	<10	<10
62	<3	4	<2	15	120			0.3	<10	<10
63	<3	4	<2	14	120			0.3	<10	<10
64	<3	4	<2	15	100			<0.1	<10	<10
66	<3	4	<2	14	120	0.5	<0.2	0.4	<10	<10
A	3	10	9	25	110	0.5	0.4		10	<10
B	12	7	4	21	160	0.5	0.3		<10	<10
C	13	6	3	23	210	0.8	0.5		<10	<10
D	8	7	5	24	140	0.6	0.4		<10	<10
E	<3	9	8	25	130	0.6	0.4		<10	<10
F	3	10	9	24	120	0.6	0.4		<10	<10
G	5	9	10	25	210	0.7	0.4		<10	<10
H	<3	10	3	25	130	0.6	0.4		<10	<10
I	4	7	2	24	140	0.5	0.4		<10	<10

Notes:
1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter

SWANBOURNE - BOTTOM WATER QUALITY, 24 JANUARY 2012

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll a (acetone) µg/L (<0.1)	Phaeophytin a µg/L (<0.2)	Chlorophyll a (fluorometry) µg/L (<0.1)	Thermal-tolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
8	<3	<2	<2	14	150			0.3	<10	<10
10a	<3	<2	<2	12	160			0.4	<10	<10
22	<3	<2	<2	15	120			0.3	<10	<10
24	<3	2	<2	19	150			<0.1	<10	<10
26	<3	2	<2	17	120			0.3	<10	<10
27	<3	6	9	19	160			0.3	<10	10
28	<3	3	<2	16	140			0.4	<10	<10
29	<3	4	3	22	140			0.5	10	<10
31	<3	<2	<2	16	170			0.4	<10	<10
33	<3	2	<2	12	120			0.4	<10	<10
34	<3	8	12	22	170			0.4	<10	10
35	<3	4	3	19	160			0.5	10	20
36	<3	34	38	50	200			0.7	60	<10
37	4	5	4	19	160			0.6	<10	<10
38	<3	8	10	21	140			0.6	10	<10
39	<3	5	5	20	140			0.4	<10	<10
40	<3	7	7	19	120			0.7	<10	10
41	<3	3	2	15	120			0.5	<10	<10
42	<3	5	5	16	110			0.5	<10	<10
43	<3	7	7	20	110			0.5	<10	<10
44	<3	6	4	20	120			0.5	<10	<10
45	<3	4	<2	18	130			0.4	<10	<10
46	<3	4	<2	18	140			0.8	<10	<10
50	<3	2	<2	15	120			0.4	<10	<10
51	<3	3	<2	12	130			0.5	<10	<10
52	<3	4	<2	13	120			0.7	<10	<10
53	30	4	2	18	290			0.7	<10	<10
54	<3	3	<2	15	150			0.8	<10	<10
55	<3	4	<2	19	140			0.9	<10	<10
60	<3	<2	<2	12	130			0.3	<10	<10
61	<3	<2	<2	13	180			0.3	<10	<10
62	<3	2	<2	11	130			0.2	<10	<10
63	<3	2	<2	13	160			0.3	<10	<10
64	<3	4	<2	16	120			0.2	<10	<10
66	<3	2	<2	12	110			0.5	<10	<10

Notes:
1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter
2. Chlorophyll *a* (acetone) and Phaeophytin *a* were not measured in bottom waters

SEPIA DEPRESSION - SAMPLING SITES, 21 FEBRUARY 2012

Site	Time (hrs)	Latitude GDA94 S (actual)	Longitude GDA94 E (actual)	UTM50, GDA94 actual	
				Easting	Northing
14	10:32:51	32° 18.188' S	115° 38.731' E	372479	6425157
15	10:10:01	32° 18.195' S	115° 39.369' E	373480	6425157
16	10:04:37	32° 18.201' S	115° 40.005' E	374478	6425159
26	09:45:47	32° 17.596' S	115° 39.059' E	372980	6426259
28	09:51:03	32° 17.599' S	115° 39.377' E	373480	6426259
30	09:56:20	32° 17.602' S	115° 39.694' E	373977	6426260
31	08:08:25	32° 17.465' S	115° 39.377' E	373477	6426507
34	10:42:11	32° 17.378' S	115° 38.870' E	372678	6426658
36	07:59:35	32° 17.381' S	115° 39.284' E	373329	6426660
37	07:48:42	32° 17.381' S	115° 39.379' E	373478	6426662
38	08:16:38	32° 17.383' S	115° 39.477' E	373632	6426660
40	08:35:29	32° 17.388' S	115° 39.889' E	374278	6426659
43	08:24:15	32° 17.302' S	115° 39.381' E	373479	6426808
44	08:42:10	32° 17.161' S	115° 39.065' E	372979	6427062
45	08:50:09	32° 17.165' S	115° 39.256' E	373280	6427059
46	08:54:46	32° 17.164' S	115° 39.380' E	373475	6427062
47	09:03:12	32° 17.166' S	115° 39.511' E	373680	6427061
48	09:07:31	32° 17.168' S	115° 39.701' E	373978	6427061
53	09:14:12	32° 16.835' S	115° 38.753' E	372482	6427658
54	09:19:17	32° 16.839' S	115° 39.133' E	373078	6427659
55	09:24:00	32° 16.841' S	115° 39.387' E	373478	6427659
56	09:31:08	32° 16.844' S	115° 39.643' E	373879	6427659
57	09:36:05	32° 16.848' S	115° 40.024' E	374478	6427660
61	10:51:52	32° 16.395' S	115° 38.246' E	371676	6428461
62	10:59:01	32° 16.401' S	115° 38.757' E	372478	6428460
63	11:05:43	32° 16.407' S	115° 39.141' E	373082	6428457
64	11:10:25	32° 16.409' S	115° 39.394' E	373478	6428458
65	11:19:46	32° 16.411' S	115° 39.648' E	373877	6428459
66	11:24:23	32° 16.415' S	115° 40.031' E	374479	6428459
67	11:29:53	32° 16.419' S	115° 40.541' E	375280	6428462
70	11:56:37	32° 15.749' S	115° 38.448' E	371979	6429659
71	11:48:09	32° 15.761' S	115° 39.406' E	373483	6429656
72	11:37:11	32° 15.769' S	115° 40.359' E	374979	6429659
74	12:04:03	32° 15.217' S	115° 39.411' E	373478	6430660
D1	07:48:42	32° 17.381' S	115° 39.379' E	373478	6426662
D2	08:15:34	32° 17.331' S	115° 39.381' E	373480	6426754
D3	08:32:59	32° 17.276' S	115° 39.365' E	373454	6426856
D4	08:49:13	32° 17.209' S	115° 39.328' E	373393	6426978
D5	09:11:22	32° 17.123' S	115° 39.284' E	373322	6427136
D6	09:42:41	32° 17.001' S	115° 39.244' E	373256	6427361
D7	10:48:31	32° 16.692' S	115° 39.244' E	373250	6427932
D8	11:18:09	32° 16.546' S	115° 39.248' E	373252	6428203
D9	12:16:48	32° 16.211' S	115° 39.258' E	373260	6428822
A	n/a	32° 22.192' S	115° 42.791' E	378939	6417838
B	n/a	32° 21.105' S	115° 44.502' E	381599	6419879
C	n/a	32° 18.559' S	115° 43.722' E	380320	6424568
D	n/a	32° 18.670' S	115° 42.154' E	377848	6425448
E	n/a	32° 17.228' S	115° 42.160' E	377839	6426998
F	n/a	32° 16.167' S	115° 41.156' E	376239	6428939
G	n/a	32° 16.300' S	115° 41.974' E	377519	6429258
H	n/a	32° 14.949' S	115° 42.161' E	377789	6431209
I	n/a	32° 14.643' S	115° 40.859' E	375738	6431749

SEPIA DEPRESSION - SURFACE AND SHORELINE WATER QUALITY, 21 FEBRUARY 2012

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll a (acetone) µg/L (<0.1)	Phaeophytin a µg/L (<0.2)	Chlorophyll a (fluorometry) µg/L (<0.1)	Thermal-tolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
14	<3	<2	2	9	90			0.2	<10	<10
15a	<3	<2	<2	10	90	0.3	<0.2	0.2	<10	<10
15b	<3	<2	<2	10	80	0.2	<0.2	0.2	<10	<10
15c	<3	<2	<2	9	80			0.2	<10	<10
16	<3	<2	<2	11	80			0.3	<10	<10
26	<3	<2	<2	11	90			0.2	<10	<10
28	<3	<2	<2	10	140			<0.1	<10	<10
30	<3	<2	<2	12	160			0.5	<10	<10
31	<3	<2	<2	8	70			0.2	<10	<10
34	<3	<2	<2	11	140			0.1	<10	<10
36	27	9	10	18	120			0.1	8200	520
37	<3	2	<2	8	70			0.2	10	10
38	<3	<2	<2	9	90			0.2	<10	<10
40	<3	<2	<2	10	100			0.2	10	<10
43	31	10	11	20	150			0.3	7000	630
44	21	7	9	16	130			0.2	750	270
45	26	9	11	20	180			0.2	1700	200
46	30	10	10	21	130			0.2	5600	400
47	31	10	10	21	170			0.3	2600	400
48	28	9	11	21	130			0.4	450	340
53	<3	<2	<2	9	140			0.3	<10	<10
54	24	8	13	17	120			0.2	91	110
55	20	8	11	20	140			0.2	91	170
56	27	9	12	20	160			0.3	120	140
57	<3	<2	<2	10	80			0.3	<10	<10
61	<3	2	6	10	110	0.1	<0.2	0.1	<10	<10
62	20	7	13	18	170			0.3	<10	10
63	18	7	9	17	110			0.5	<10	<10
64	16	6	7	16	140			0.2	<10	31
65	23	8	7	19	160			0.2	<10	10
66	<3	<2	<2	12	110			0.2	<10	<10
67	<3	3	8	12	110	0.4	<0.2	0.6	<10	<10
70	<3	<2	3	10	140			0.2	<10	<10
71	19	7	11	18	180			0.3	<10	<10
72	<3	3	10	11	150	0.4	<0.2	0.4	<10	<10
74	5	4	8	15	100	0.3	<0.2	0.4	<10	<10
A	17	6	2	19	150	1.0	0.3		<10	<10
B	<3	5	5	15	120	0.8	0.2		<10	<10
C	4	2	<2	11	130	0.5	<0.2		<10	<10
D	6	2	4	13	140	0.4	<0.2		<10	<10
E	10	3	3	16	140	0.8	<0.2		<10	<10
F	7	3	4	12	190	0.3	0.4		<10	<10
G	5	2	10	21	230	0.9	0.4		10	20
H	11	4	10	21	240	1.4	0.4		<10	<10
I	3	3	3	13	140	0.4	<0.2		<10	<10

Notes:
1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter

SEPIA DEPRESSION - BOTTOM WATER QUALITY, 21 FEBRUARY 2012

Site	Ammonia µg.N/L (<3)	Ortho-phosphate µg.P/L (<2)	Nitrate + Nitrite µg.N/L (<2)	Total Phosphorus µg.P/L (<5)	Total Nitrogen µg.N/L (<50)	Chlorophyll *a* (acetone) µg/L (<0.1)	Phaeophytin *a* µg/L (<0.2)	Chlorophyll *a* (fluorometry) µg/L (<0.1)	Thermal-tolerant Coliforms CFU/100mL (<10)	Enterococci MPN/100mL (<10)
14	<3	<2	3	9	120			0.1	<10	<10
15a	<3	<2	<2	11	90	0.2	<0.2	0.3	<10	<10
16	<3	<2	<2	10	140			0.2	<10	<10
26	<3	<2	<2	11	140			0.3	<10	<10
28	<3	<2	<2	11	90			0.2	10	<10
30	<3	<2	<2	11	100			0.3	<10	<10
31	<3	<2	<2	8	80			0.2	<10	<10
34	<3	<2	2	12	140			0.3	<10	<10
36	<3	<2	<2	9	70			0.2	70	10
37	<3	<2	<2	10	100			0.2	130	10
38	<3	<2	<2	10	90			0.2	<10	<10
40	<3	<2	<2	11	110			0.2	10	10
43	5	3	2	12	90			0.2	800	84
44	3	<2	2	14	120			0.4	80	10
45	<3	<2	<2	11	90			0.3	20	<10
46	<3	<2	<2	12	110			0.3	60	<10
47	<3	<2	<2	12	110			0.3	<10	<10
48	4	<2	<2	12	130			0.3	<10	10
53	<3	<2	<2	11	140			0.2	<10	<10
54	<3	<2	<2	10	110			0.5	<10	10
55	<3	<2	<2	10	110			0.4	10	10
56	<3	2	<2	12	90			0.4	<10	<10
57	<3	<2	<2	10	110			0.4	<10	<10
61	<3	<2	2	10	120			0.5	<10	<10
62	<3	<2	<2	9	100			0.4	<10	<10
63	<3	<2	<2	10	100			0.5	20	<10
64	<3	<2	<2	12	100			0.5	30	<10
65	<3	<2	<2	11	90			0.2	<10	<10
66	<3	<2	<2	9	100			0.3	<10	<10
67	3	<2	5	11	110			0.4	<10	<10
70	<3	<2	<2	10	100			0.3	<10	<10
71	<3	<2	<2	10	100			0.4	<10	<10
72	<3	2	6	12	130			0.5	<10	<10
74	<3	<2	<2	11	90			0.4	<10	<10

Notes:
1. Numbers in parenthesis after the units indicate the detection limit for each water quality parameter
2. Chlorophyll *a* (acetone) and Phaeophytin a were only measured in bottom waters at site 15a in Sepia Depression

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Report QA/QC Form

Section A: Author to complete	
Project No. and Name:	788_02_005/1 PLOOM 6.2 Summer Water Quality
Client:	Water Corporation of Western Australia
Report Title:	Perth Long-term Ocean Outlet Monitoring (PLOOM) Program - 2012 Summer Water Quality Survey
Report Revision:	Rev 0
Author:	David Rivers
Technical Reviewer:	Martin Lourey
Editorial Reviewer:	Julia Phillips
Admin Reviewer:	Rachael Hillman

Section B: Author checklist

	YES	NO	N/A
General			
Is an editorial review required? (Consultant has confirmed with PD)	☑	☐	
Cover page details match Title Page	☑	☐	☐
Agreed report title	☑	☐	☐
Correct client name/spelling	☑	☐	☐
Oceanica report number issued by Rachael	☑	☐	☐
Report history & distribution up to date	☑	☐	☐
Front page photo credits are correct	☑	☐	☐
Contents page matches content	☑	☐	☐
Rev0 – Endnote updated with final report	☐	☐	☐
Main report/document			
Consistent with Oceanica Style Manual	☑	☐	☐
List of abbreviations/terms included if appropriate	☐	☐	☑
Executive Summary consistent with main report	☑	☐	☐
Methods/approaches used are justified	☑	☐	☐
Site location GPS co-ordinates (incl. projection & datum) are tabulated	☑	☐	☐
Critical results/analyses double-checked	☑	☐	☐
All figures and tables checked for errors	☑	☐	☐
All citations included in References	☑	☐	☐
Appendices complete and with standalone reference list where appropriate	☑	☐	☐

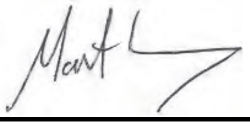
Comments

Sign-off	**Author: David Rivers** **Date: 26/06/2012**	David Rivers

Section C: Technical reviewer checklist

	YES	NO	N/A
Executive Summary			
Content consistent with main report	☑	☐	☐
No new material introduced	☑	☐	☐
Recommendations agree with main report	☑	☐	☐
Main report/document			
Report/project objectives clearly described	☑	☐	☐
Report addresses objectives of project	☑	☐	☐
Report complies with any specific client requirements	☑	☐	☐
Background literature appropriate and sufficient	☑	☐	☐
Methods			
Methods/approaches used are justified	☑	☐	☐
Statistical analyses/data manipulation techniques are appropriate and correct	☑	☐	☐
Results			
Results compared with any prelim data/data reports/field reports	☐	☐	☑
Results consistent with figures/tables	☑	☐	☐
Figures/tables add to report content	☑	☐	☐
Interpretations valid and appropriate	☑	☐	☐
Discussion/Conclusion			
Consistent with results	☑	☐	☐
Consistent with Executive Summary	☑	☐	☐
All key/relevant references are cited	☑	☐	☐
Concluding statements are justified and appropriate	☑	☐	☐
Appendices			
Appendices are appropriate to report	☑	☐	☐

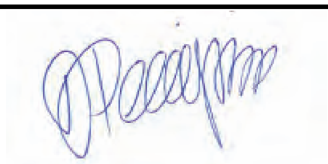
Comments

Sign-off	**Technical reviewer: Martin Lourey** **Date: 14/06/2012**	

Section D: Editorial reviewer checklist

	YES	NO	N/A
Main report/document			
Report history table up to date	☑	☐	☐
Exec Summary clear and logical structure	☑	☐	☐
Figure/table captions informative and succinct	☑	☐	☐
All figures & tables placed after first text reference	☑	☐	☐
Figure/table notes & source references appropriate and correct	☑	☐	☐
All figures & tables are standalone	☑	☐	☐
All citations included in reference list	☑	☐	☐
Reference list format correct	☑	☐	☐
Appendices checked and standalone	☑	☐	☐
Overall			
Document structure is clear and logical	☑	☐	☐
Document style and content appropriate for audience	☑	☐	☐
Document is consistent with Style Guide	☑	☐	☐
Correct use of abbreviations, etc	☑	☐	☐
Spelling & punctuation correct—edited if not	☑	☐	☐
Grammar & sentence structure correct—edited if not	☑	☐	☐

Comments

Sign-off	**Editorial reviewer: Julia Phillips** **Date: 22/06/2012**	

Section E: Admin reviewer checklist

	YES	NO	N/A
QA/QC - reviews			
Author checklist completed and signed off	☑	☐	☐
Technical review completed and signed off	☑	☐	☐
Editorial review completed and signed off	☑	☐	☐
Cover page			
Correct Oceanica format (Font/style, images correct size and position)	☑	☐	☐
Title page			
Author & director signatures inserted in Rev0	☑	☐	☐
Contents page			
Page numbers correct	☑	☐	☐
Figures, tables & appendices listed and TOC fields updated	☑	☐	☐
Client name & report title in footer	☑	☐	☐
Page numbers unique (i, ii, iii...)	☑	☐	☐
Executive Summary			
Page numbers unique (i, ii, iii...)	☑	☐	☐
Client name & report title in footer	☑	☐	☐
Main report			
Correct Oceanica format/style	☑	☐	☐
Page numbers checked	☑	☐	☐
Client name & report title in footer	☑	☐	☐
Figures & tables			
Oceanica figures inserted are correctly sized (A3/A4/A5) and rotated	☑	☐	☐
All captions correctly formatted	☑	☐	☐
All notes/source references correctly formatted and correct placement	☑	☐	☐
Fields			
Fields updated before PDFing	☑	☐	☐
Report checked for broken cross references	☑	☐	☐
Appendices			
All appendices added to report pdf before printing	☑	☐	☐
Multiple digital versions (print/email/etc.)			
Content of all versions identical	☑	☐	☐
QA/QC - documentation			
This form completed and attached to Rev0 pdf for hardcopy printing	☑	☐	☐

Comments

Sign-off	**Admin reviewer: Rachael Hillman** **Date: 12/07/2012**	Rachael Hillman.

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Appendix 3: Beenyup Advanced Water Recycling Plant - Impact Assessment of Water Recycling Reject Stream Discharge
November 2011

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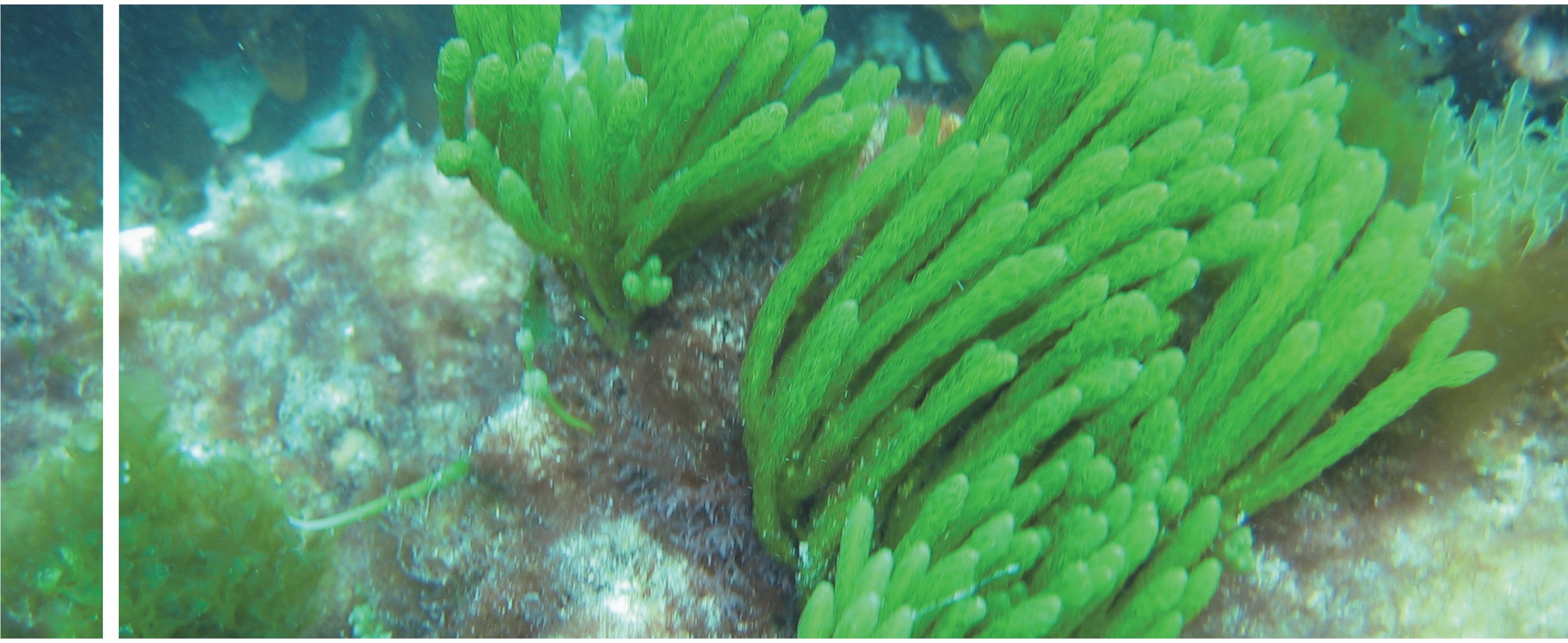
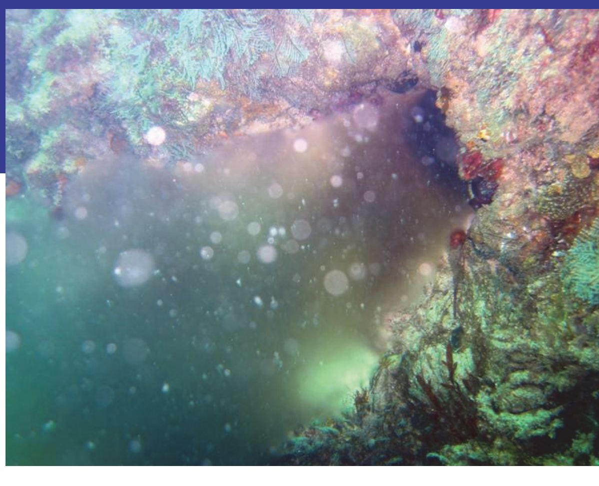


Beenyup Advanced Water Recycling Plant

Impact Assessment of Water Recycling Reject Stream Discharge

November 2011



Beenyup Advanced Water Recycling Plant

Impact Assessment of Water Recycling Reject Stream Discharge

Prepared for

Water Corporation of Western Australia

Prepared by

Oceanica Consulting Pty Ltd

November 2011

Report No. 906_001/1

Client: Water Corporation of Western Australia

Revisions history

Revision	Author	DISTRIBUTION			REVIEW		
		Recipients	No. Copies & Format	Date	Reviewer	Intent	Date
A	T. Amrita M. Bailey	V. Moscovis K. Hillman	1 x electronic	16/08/11	Not reviewed		
B	M. Bailey	T. Amrita	1 x electronic	07/09/11	T. Amrita	Technical	08/09/11
C	M. Bailey	K. McManus	1 x electronic	08/09/11	N. Turner V. Moscovis	Client Review	20/9/11
D	M. Bailey	K. McManus	1 x electronic	5/10/11	K. McManus	Client Review	25/10/11
E	M. Bailey	T. Amrita	1 x electronic	01/11/11	T. Amrita	Technical & Editorial	02/11/11
Rev 0	M. Bailey	K. McManus	2 x hardcopy 1 x PDF	02/11/11			

Quality Assurance

The current version of this report has been subject to the following level of Quality Assurance:

Level	Definition	Status
A: Full	Underlying data, calculations and data entry have been checked. Report format has been checked and contents have been reviewed and signed off by Director.	☑
B: Partial	Some data and underlying calculations have been checked. Report format has been checked. Review has been undertaken by a third-party.	☐
C: Minimal	No formal review completed.	☐

Status

This report is "Draft" until the author and director have signed it off for final release. A "Draft" report should not be used for any purpose other than to be reviewed with the intention of generating a "Final" version.

Approved for final release:

Author Director

Disclaimer

Cover

Main image: Ocean Reef (Lumps Reef) (Oceanica Consulting)

Minor images: Beenyup wastewater treatment plant (Water Corporation); Ocean Reef Ocean Outlet A: diffuser port (Water Corporation

Contents

List of Figures

List of Tables

List of Appendices

Executive Summary

The Water Corporation of Western Australia (Water Corporation) is undertaking a Groundwater Replenishment Trial (GWRT) at the Beenyup wastewater treatment plant (WWTP), recharging the confined Leederville aquifer with recycled wastewater treated to drinking water standard. Planning is underway for a staged expansion of GWR. The advanced water recycling plant (AWRP) for GWR comprises ultrafiltration (UF) reverse osmosis (RO) and ultraviolet (UV) disinfection, and at this stage it is anticipated that this will be the treatment train for any expansion. The UF and RO treatments together produce a reject stream which comprises about 30% of total influent flows and 95 to 100% of most contaminants.

The resultant ocean discharge will be a combination of the AWRP reject stream and any portion of the Beenyup secondary treated wastewater which has not been introduced to the AWRP. This report examines the potential effects on the marine environment of increasing the amount of treated wastewater passed through the AWRP up to 100% of the current 120 ML/d of treated wastewater produced by the Beenyup WWTP. The Water Corporation is planning to proceed with a 7 GLpa scheme as the initial stage of a long-term water resource strategy (Stage 1); this report examines three stages against the base case of the no AWRP.

a) Stage 1 (7 GLpa recycled): Of the 120 ML/d coming out of the Beenyup WWTP; 30 ML/d is directed to the AWRP of which 20 ML/d is recycled and 10 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 100 ML/d.

b) Stage 2 (14 GLpa recycled): Of the 120 ML/d coming out of the Beenyup WWTP, 60 ML/d is directed to the AWRP, of which 41 ML/d is recycled and 19 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 79 ML/d.

c) Stage 3 (28 GLpa recycled): All of the 120 ML/d coming out of the Beenyup WWTP is directed to the AWRP, of which 81 ML/d is recycled and 39 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 39 ML/d.

Effect on initial dilution

Under all current conditions, for both Outlet A and B, the initial dilution is predicted to increase with increasing ratio of reject flow to pre-recycling flow. Comparing Stage 3 with the pre-recycling case, the increase in dilution may be more than 200% due to lower flows. The effect of introducing a slightly higher salinity stream was found to be inconsequential as the plume is still significantly more buoyant than seawater and it was the overall reduction in flows that dominated the effect of the AWRP on initial dilution.

Environmental considerations

Potential environmental implications of the proposed AWRP include the increased concentration of nutrients and toxicants being discharged to the marine environment (by a factor of up to 3.16-fold if 100% of these contaminants are removed to the reject stream). However, as the concentration factor increases, the flow decreases and the dilution increases, therefore the higher contaminant concentrations of the post-recycling discharge are largely offset.

Toxicants

The toxicant of primary concern is copper as it is closest to the environmental quality guideline under any conditions (this is a due to the extensive use of copper piping in domestic plumbing). Under conditions of the currents typical of the region, the EPA (2005) High Protection guideline (99% species protection) is met for the 95th percentile concentrations of contaminants of concern (ammonium, copper and zinc) under both pre-recycling discharge and post-recycling discharge stages.

Pathogens

Chloramination is required in order to maintain the effectiveness of the AWRP RO membranes, according to data supplied by the Water Corporation the ARWP process significantly reduces enterococci counts. As such, the AWRP has a net benefit with regard to pathogen concentrations after discharge to the ocean compared to the existing discharge.

Nutrients

With respect to nutrient-related effects, there are presently no guidelines for assessing these at Ocean Reef. However, the AWRP will not alter the total nutrient loads discharged to Ocean Reef and therefore will not require any amendment to the existing Ministerial Conditions or Licence Conditions. Further, nutrient concentrations after initial dilution will not change under typical conditions and it is considered highly unlikely that there will be any change in nutrient-related effects due to wastewater discharge under the AWRP.

Maintenance and Clean in Place chemicals

It will be necessary to establish a schedule of cleaning for the ultra filtration membrane and reverse osmosis filters with batches of 'Maintenance Wash' (MW) and 'Clean in Place' (CIP) chemicals. The CIP chemicals do not contain material quantities of the contaminants of concern and are introduced at extremely low volumes proportional to the total flow, the combination of their high degree of dilution in the reject stream followed by the dilution after discharge means that they pose negligible risk.

1. Introduction

1.1 Background

The Water Corporation of Western Australia (Water Corporation) is undertaking a Groundwater Replenishment Trial (GWRT) at the Beenyup wastewater treatment plant (WWTP) (Figure 1.1), recharging the confined Leederville aquifer with recycled wastewater treated to drinking water standard (Figure 1.2). Planning is underway for a staged expansion of GWR. The advanced water recycling plant (AWRP) for GWR comprises ultrafiltration (UF) reverse osmosis (RO) and ultraviolet (UV) disinfection, and at this stage it is anticipated that this will be the treatment train for any expansion. The UF and RO treatments together produce a reject stream which comprises about 30% of total influent flows and 95 to 100% of most contaminants.

The Water Corporation is seeking approval for Stage 1 of the AWRP, which is to recycle 7 gigalitres per annum (GL). However, recognising the longer-term potential to increase flows this document examines an AWRP capable of recycling 28 GL. The anticipated stages are:

1. Stage 1 (7 GL): Of the 120 ML/d coming out of the Beenyup WWTP; 30 ML/d is directed to the AWRP of which 20 ML/d is recycled and 10 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 100 ML/d.
2. Stage 2 (14 GL): Of the 120 ML/d coming out of the Beenyup WWTP, 60 ML/d is directed to the AWRP, of which 41 ML/d is recycled and 19 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 79 ML/d.
3. Stage 3 (28 GL): All of the 120 ML/d coming out of the Beenyup WWTP is directed to the AWRP, of which 81 ML/d is recycled and 39 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 39 ML/d

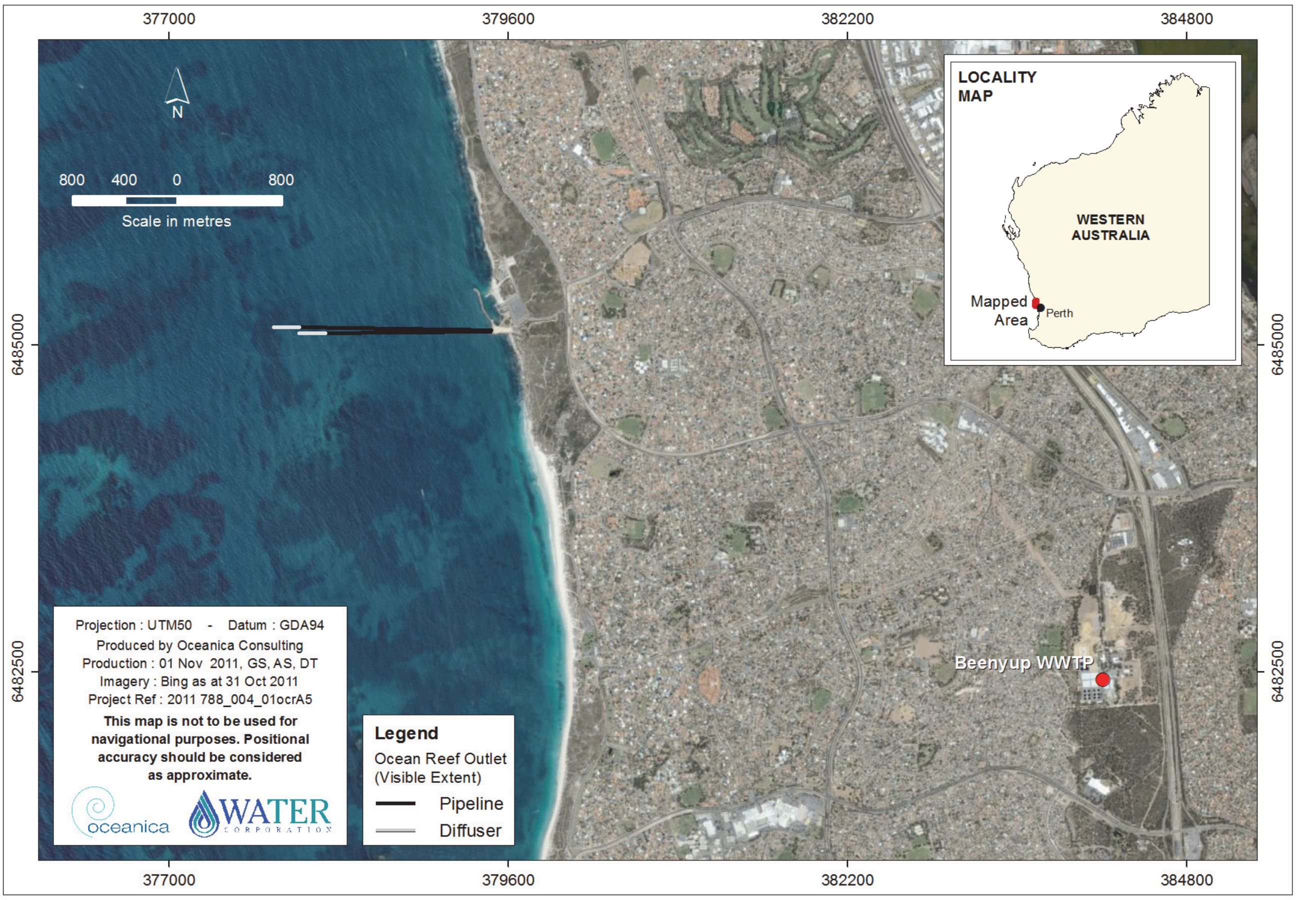


Figure 1.1 Location of the Beenyup wastewater treatment plant and the Ocean Reef ocean outlets

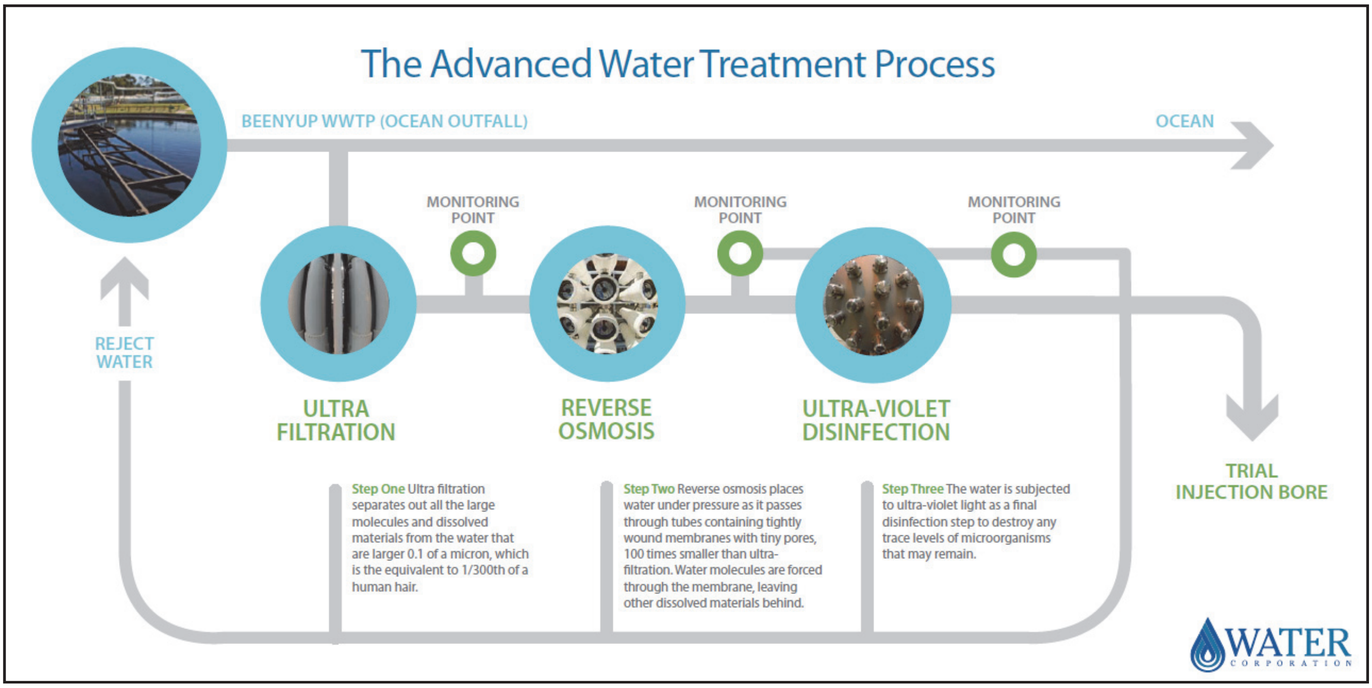


Figure 1.2 Schematic diagram of the Advanced Water Treatment Process

1.2 This document

The resultant ocean discharge will be a combination of the AWRP reject stream and any portion of the secondary treated wastewater which has not been introduced to the AWRP. This document examines the potential effects on the marine environment of increasing the amount of treated wastewater passed through the AWRP up to 100% of the current 120 ML/d of treated wastewater produced by the Beenyup WWTP. The Water Corporation is planning to proceed with a 7 GLpa scheme (Stage 1) as the initial stage of a long-term water resource strategy.

1.3 Effect of AWRP on ocean discharge

This project will marginally increase the density (the RO reject will have higher salinity than the TWW) and reduce volume of the flow to the ocean while increasing concentrations of contaminants already discharged. In addition, there will be trace amounts of additional chemicals introduced by the need to maintain cleanliness of the plant membranes and pipework. By increasing density and reducing flows, the AWRP project will change the characteristics of the dilution that the wastewater undergoes after it is discharged from the two subsea diffusers at Ocean Reef.

A key aspect of the performance of ocean outlets is the effectiveness of the initial mixing of the discharge plume (i.e. how well the treated wastewater mixes due to momentum and buoyancy effects). The amount of dilution achieved in the initial mixing area largely determines how rapidly the concentrations of contaminants attain 'background' levels.

Typically, treated wastewater is less dense than the surrounding seawater, and will initially act as a buoyant plume, rising and mixing through the water column. The initial dilution occurs from the point of discharge on the seafloor, to a point of maximum rise or fall of the plume. For unstratified, calm conditions, this maximum rise is likely to occur when the edge of the plume first reaches the ocean surface.

Initial dilution modelling has been used to assess the potential modifications to dilution by including the denser AWRP reject stream in modifying the dilution.

1.4 Initial dilution models

Models are often used to help understand and to predict the behaviour of discharged wastewater within the near-field. While computer modelling programs cannot provide definitive predictions of what will happen in the environment, a model provides a good approximation of what is likely to happen under a given set of environmental conditions.

Near-field is defined as within the immediate vicinity of the outlet, where the treated wastewater characteristics of the initial outlet (such as momentum and buoyancy) have an influence on mixing while far-field is defined outside this region where environmental forces such as the ocean current plays a more important role. For this study, near-field modelling was undertaken to provide an assessment for relative change against licensed discharge.

The near-field modelling was completed using the UM3 (Updated Merge three-dimensional) sub-model within the Visual Plumes framework (Davis, 1999). Visual Plumes is a USEPA released modelling package that allows the user to simulate single and multiple port submerged discharge in a range of configurations (Frick et al., 2003). Arbitrary ambient conditions can be specified, including temperature, salinity, concentration of solubles, current speed and direction. Far-field dilution is also approximated using empirical plume dispersion relationships; however the primary use of the modelling package is to estimate near-field dilution. Visual Plumes has been applied widely to similar environmental outlet assessments in Western Australia, and is familiar framework to the WA Environmental Protection Authority.

UM3 is a Lagrangian model that features the projected-area-entrainment (PAE) hypothesis (Winiarski and Frick, 1976; Frick, 1984). The established hypothesis (Rawn, Bowerman and Brooks, 1960) quantifies forced entrainment; the rate at which mass is incorporated into the plume in the presence of current. In UM3 it is assumed that the plume is in steady state.

In a recent comparison of commonly used mathematical models against the results of a physical model, UM3 returned better dilution estimates compared to those predicted using CORMIX (Roberts and Tian 2004). UM3 and CORMIX have different methods of handling a diffuser design that includes ports on alternating sides—in UM3 it is assumed that all ports discharge horizontally from the downstream side of the diffuser (with the 'port spacing' halved so as to maintain the correct diffuser length); whereas, CORMIX will approximate this case using a row of vertically discharging jets. It was suggested by Roberts and Tian (2004) that the overestimations made by CORMIX may be due to this approximation of port configuration.

The Ocean Reef ocean outlets have an alternating horizontal port orientation, thus suiting the use of either the RSB or UM3 models over the CORMIX model. The full APASA report is included as Appendix A.

2. Ocean Reef

2.1 Ambient conditions

2.1.1 Physical

As part of the Perth Long-term Ocean Outlet Monitoring (PLOOM) Program, physical profiles have been recorded in the vicinity of the Ocean Reef ocean outlet for several years. Average surface and bottom salinity and temperature readings for summer and autumn have been determined using data from 2003 to 2005 (Table 2.1) (Oceanica 2005a, 2005b), for use in the initial dilution modelling stages. The data were collated as part of an earlier modelling study for the GWRT in 2006, however the results are consistent with those from later studies (e.g. Oceanica 2010) and so this earlier collation of background data was considered appropriate for the ambient conditions for the present study.

Table 2.1 Ambient temperature and salinity conditions during summer and autumn in the vicinity of the Ocean Reef ocean outlets

Season	Temperature (°C)		Salinity (ppt)	
	Surface (1,2)	Bottom (1,3)	Surface (1,2)	Bottom (1,3)
Summer	22.10	21.75	36.35	36.33
Autumn	21.27	20.67	36.43	36.42

Notes:

1. Site ORR1, an 'Intensive Summer' monitoring reference site located approximately 3,000 m south of the Ocean Reef ocean outlets, and site N1, a 'Seasonal' monitoring site located approximately 4,000 m south of the Ocean Reef ocean outlets were used to determine average ambient conditions.
2. Surface water column readings were taken at 0.5 m below water level.
3. Bottom water column readings were taken at 9.5 m below water level.

2.1.2 Currents

Surface current measurements[1] have been recorded during the annual summer water quality surveys as part of the PLOOM Program since 1996. Over 11 summers of monitoring to 2006, the typical surface current measured was north or north-westerly flowing (although southerly flowing currents have been observed on occasion), with an average speed of approximately 0.12 ms^{-1}.

Runs of the initial dilution model have been conducted using this summer average as a typical surface current speed, but also under 'worst case' (calm) conditions (0 ms^{-1}) and more energetic conditions (0.30 ms^{-1}).

These surface currents were used to synthesise vertical velocity profiles based on the findings of Pattiaratchi et al. (1995), who installed current meters at 3 m and 7 m above the seabed at the Ocean Reef ocean outlets and recorded current speeds for a year. The difference between the mean currents at these depths was used as an indication of a likely linear decrease in current speeds from the surface to the seabed. It was calculated that the current speed drops by approximately 1.2%/m at Ocean Reef.

Surface currents at Ocean Reef recorded over one year (1993) ranged between 0 and 5 cms^{-1} (0 and 0.05 ms^{-1}) for 9% of the time, between 5 and 15 cms^{-1} (0.05 and 0.15 ms^{-1}) for approximately 75% of the time, and greater than 15 cms^{-1} (>0.15 ms^{-1}) for 15% of the time. Calm (i.e. zero current) conditions were rare (Pattiaratchi et al. 1995 in Brown & Root 2000). Thus although calm (i.e. zero current) conditions were modelled for the purposes of this report (to investigate 'absolute worst-case' conditions), such events are very rare.

[1] *Surface current speed and direction measurements are determined from tracking the position of a surface drogue released above the operational outlet diffuser during the PLOOM summer water quality surveys.*

2.2 Outlet conditions

2.2.1 Diffuser characteristics

There are two discharge outlets, with 30 ports on Outlet A and 48 ports on Outlet B. Flow volumes are split evenly between two outlets and the two diffusers are sufficiently far apart such that the initial mixing zones do not overlap. The plume from each outlet, thus, has been modelled separately. The set-up parameters used to represent the Ocean Reef ocean outlets are shown in Table 2.2.

Table 2.2 Ocean Reef ocean outlets diffuser characteristics

Diffuser Characteristics	Outlet A	Outlet B
Port diameter	0.125 m	0.16 m
Port elevation	0.758 m	0.843 m
Number of open ports	30	48
Port spacing (1)	3.7 m	4.05 m
Port orientation	Alternating horizontal	Alternating horizontal
Water depth	10 m	10 m

Note:
1. In the case of alternate ports, they are all assumed to be on one side of the diffuser and 'port spacing' is the distance between each port irrelevant of the actual position on either side of the diffuser.

2.3 Flows

The projected flow rates for implementation of the AWRP are, on average, 120 ML/d. Three operation stages were modelled (Table 2.3), they are:

1. Stage 1 (7 GLpa): Of the 120 ML/d coming out of the Beenyup WWTP; 30 ML/d is directed to the AWRP of which 20 ML/d is recycled and 10 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 100 ML/d.
2. Stage 2 (14 GLpa): Of the 120 ML/d coming out of the Beenyup WWTP, 60 ML/d is directed to the AWRP, of which 41 ML/d is recycled and 19 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 79 ML/d.
3. Stage 3 (28 GLpa): All of the 120 ML/d coming out of the Beenyup WWTP is directed to the AWRP, of which 81 ML/d is recycled and 39 ML/d is reject flow which is discharged back to the ocean outlet, making for a total discharge to the ocean of 39 ML/d.

Table 2.3 Modelled flows for ocean discharge

Operation Stage	PRE-RECYCLING	AWRP (ML/d)			POST-RECYCLING
	Beenyup TWW discharge (ML/d)	Inflow	Outflow	Reject flow	Combined flow to ocean (ML/d)
Stage 1 (7 GL)	120	30	20	10	100
Stage 2 (14 GL)	120	60	41	19	79
Stage 3 (28 GL)	120	120	81	39	39

2.4 Discharge quality

2.4.1 Temperature

Temperature measurements are collected by the Water Corporation for each of their active WWTPs. The average monthly temperature of the treated wastewater at the Beenyup WWTP is shown in Figure 2.1. Using these data, typical summer and autumn discharge temperatures were estimated as 27°C and 25.5°C, respectively. It was assumed that the water recycling reject stream would have a similar seasonal temperature variation to the treated wastewater discharge, so the same summer and autumn temperatures were used in the modelling.

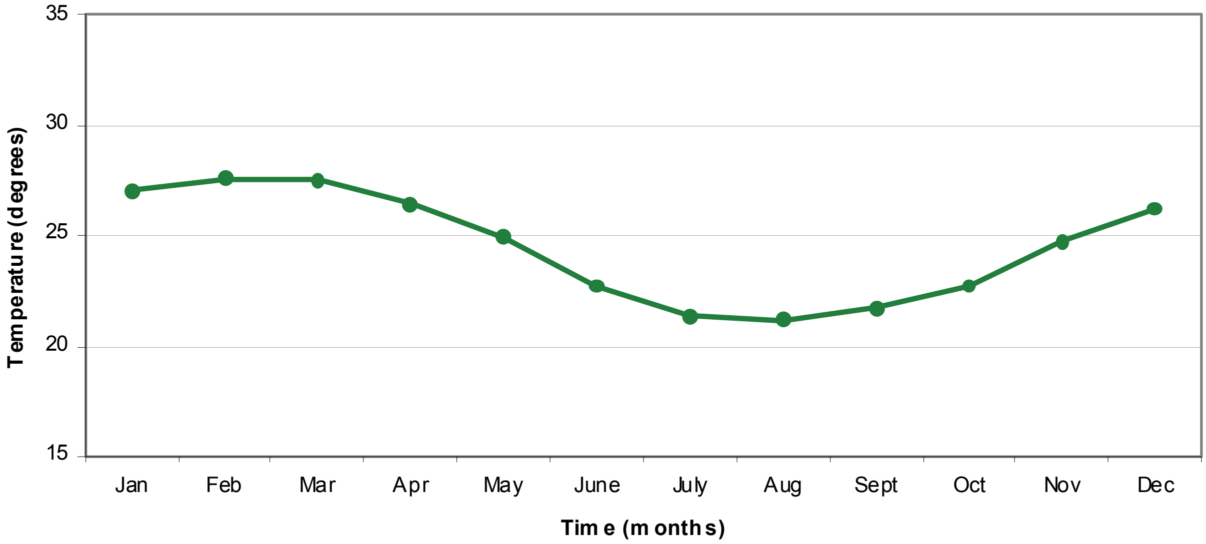


Figure 2.1 Average monthly temperature variation of the treated wastewater discharge of the Beenyup WWTP (data collected 2000 to 2003)

2.4.2 Total dissolved solids

Total dissolved solids (TDS) results allow the density of the discharge to be calculated, data for the Beenyup WWTP is collected on an approximately monthly basis. The values between 2000 and 2005 were in a fairly narrow range of 650-810 mgL^{-1} and there is no reason to expect more recent results to be different as the wastewater catchment and treatment process has remained the same throughout. There was no seasonal trend present in the TDS data and therefore the worst case of 810 mgL^{-1} has been used in the modelling for the secondary treated wastewater discharge. The Water Corporation predicts that the TDS of the water recycling reject stream will be 2,574 mgL^{-1}. For modelling of the blended discharge stream, the concentration of TDS in the water recycling reject stream and the secondary treated wastewater stream have been proportionally combined to give a blended TDS values of 982, 1242, and 2574 mgL^{-1} for Stages 1, 2, and 3 respectively.

2.4.3 Metals

The metals of concern with regard to this discharge are copper and zinc. Oceanica and the Water Corporation have been measuring filtered (0.45 um) concentrations of these metals in the Beenyup treated wastewater and part of the PLOOM and GWRT sampling programs. The values collated over the past three years are provided in Table 2.4 and the maximum value (in bold) was used for the impact assessment. The maximum was used as the number of values required to calculate a 95th percentile is less than optimum (usually 20 values or more) and any 95th percentile with this small amount of data would be very close to the maximum recorded value.

Table 2.4 Concentrations of Cu and Zn (filtered through 0.45 um filter), maximum value is bold

Data collected by	Date	Cu (ug/L)	Zn
Oceanica	29/01/2008	**9**	52
Oceanica	03/02/2009	7	48
Oceanica	23/02/2010	7.3	54
Oceanica	15/02/2011	7.6	46
Water Corp	16/12/2009	4.9	48
Water Corp	08/03/2010	5.8	47
Water Corp	13/04/2010	6.9	71
Water Corp	16/02/2011	7	70
Water Corp	19/05/2011	8.4	63

2.4.4 Nutrients

The Water Corporation collects extensive nutrient data from the Beenyup WWTP discharge as part of the standard operations. An example of the data is provided in Figure 2.2, where it can be seen that the ammonia levels in the discharge have reduced significantly over the past two years. The previous 12 months of data were analysed to generate 95th percentile data for use in the assessment and the results are provided in Table 2.5.

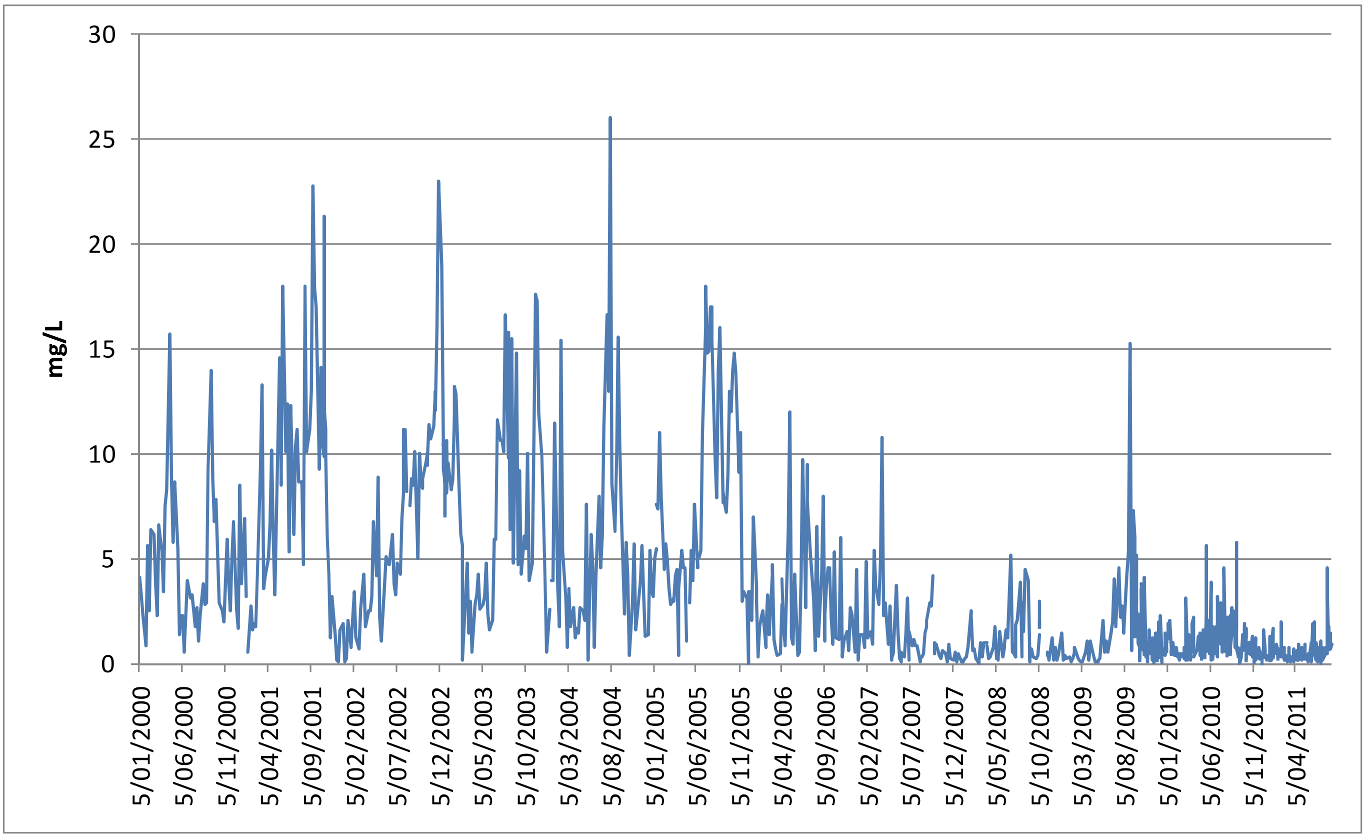


Figure 2.2 Example of Beenyup nutrient data: Ammonia as nitrogen, 2000-2011

Table 2.5 Characteristics of the nutrient related quality of the Beenyup discharge for the period 02/08/2010 to 11/08/2011

	Ammonia as nitrogen	Nitrate as nitrogen	Nitrite as nitrogen	Total phosphorus
Number of samples in period	248	237	54	65
Mean (ug/L)	727	15,108	166	8,806
Median (ug/L)	500	15,000	140	8,840
95^{th}%ile (ug/L)[1]	**1,900**	**20,120**	**354**	**10,180**

Note:
1. Calculated using excel

2.4.5 Pathogens

Sampling by the Water Corporation of the feed water quality from the GWRT AWRP for enterococci has returned the results in Table 2.6. The use of chloramination to maintain membranes results in a significant reduction in the number of enterococci prior to UF treatment. The results apply to both WWTP discharge (feedwater into AWRP) and the resulting log removal shown in the AWRP feed water stream post chloramination and post chloramination and UF treatment (see Process Diagram in Figure 3.1 for sampling point locations).

If it is conservatively assumed that the worst case log removal is applied (using 1.81 log, post chloramination pre UF) to the highest concentration (12,000 MPN/100ml) then an initial enterococci concentration of 12,000 MPN/100ml would be reduced to 186 MPN/100ml. The UF has a certified pathogen removal of 3 log, it can be assumed that under normal operation any remaining pathogens are rejected into the reject stream during the UF process (AWRP rejects approximately 5% of total reject stream volume during the UF process).

Overall, this means that the AWRP will result in reduced pathogen concentrations in the TWW plume into the ocean and a reduction in load to the ocean, with greater reduction as recycling increases.

As such the project acts to reduce the concentrations of pathogens from the levels currently discharged which may be interpreted as an environmental benefit.

Table 2.6 Enterococci values prior to entering the GWRT AWRP and post-discharge in reject stream

Sampling date	Beenyup WWTP MPN/100 mL	Log removal post chloramination	Log removal post chloramination and UF
08/03/2010	12000		
13/04/2010	4900		
16/02/2011	2500		
19/05/2011	2400		
16/08/2011	1900	2.20	3.28
17/08/2011	1600	1.90	3.20
18/08/2011	1700	2.12	3.23
22/08/2011	2900	2.16	3.46
23/08/2011	1300	**1.81**	3.11
25/08/2011	2200	2.34	3.34

2.5 Model results

Table 2.7 and Table 2.8 provide the initial dilution results for the pre- and post-recycling wastewater streams for Ocean Reef Outlet A and B, under different ambient current speeds and two different seasonal conditions. It was found that the initial dilution was slightly higher at Outlet B than at Outlet A. In terms of seasonal differences in initial dilution, there was negligible difference between the summer and autumn conditions for Outlet A for both the pre-recycling and post-recycling dilutions. The same was found for Outlet B, with the exception of Stage 3 with current speed of 0.3 ms^{-1}, in which the dilution under the autumn condition is 15-20% lower than that under the summer condition.

Under all current conditions, for both Outlet A and B, the initial dilution is predicted to increase with increasing ratio of reject flow to pre-recycling flow. Comparing Stage 3 with the pre-recycling case, the increase in dilution may be more than 200%. The effect of increasing salinity (which may reduce dilution) is negligible compared to the effects of reducing flows (which acts to increase dilution).

Higher dilutions are shown under the presence of higher background current and the distance where the plume is predicted to reach the surface increases with increasing background current, as well as with the ratio of reject flow to pre-recycling flow.

Table 2.7 Initial dilution modelling results for pre- and post-recycling wastewater streams at Ocean Reef Outlet A under different ambient current speeds

	Current: 0.00 ms^{-1}	**Current: 0.12 ms^{-1}**	**Current: 0.30 ms^{-1}**
SUMMER			
(a) Pre-recycling, 60 ML/day			
Average initial dilution	1:69	1:178	1:434
Centreline initial dilution	1:36	1:95	1:199
Horizontal distance for edge of plume to reach surface	~3.5 m	~9.5 m	~30 m
(b) Post-recycling, 50 ML/day (Stage 1)			
Average initial dilution	1:73	1:208	1:518
Centreline initial dilution	1:38	1:111	1:237
Horizontal distance for edge of plume to reach surface	~3 m	~9.5 m	~32 m
(c) Post-recycling, 39.5 ML/day (Stage 2)			
Average initial dilution	1:79	1:254	1:644
Centreline initial dilution	1:41	1:132	1:293
Horizontal distance for edge of plume to reach surface	~2.5 m	~9.5 m	~36 m
(d) Post-recycling, 19.5 ML/day (Stage 3)			
Average initial dilution	1:106	1:489	1:1290
Centreline initial dilution	1:55	1:236	1:582
Horizontal distance for edge of plume to reach surface	~1 m	~12 m	~52 m
AUTUMN			
(a) Pre-recycling, 60 ML/day			
Average initial dilution	1:69	1:178	1:433
Centreline initial dilution	1:36	1:95	1:199
Horizontal distance for edge of plume to reach surface	~3.5 m	~9.5 m	~30 m
(b) Post-recycling, 50 ML/day (Stage 1)			
Average initial dilution	1:73	1:204	1:518
Centreline initial dilution	1:38	1:107	1:236
Horizontal distance for edge of plume to reach surface	~3 m	~9.5 m	~32 m
(c) Post-recycling, 39.5 ML/day (Stage 2)			
Average initial dilution	1:78	1:254	1:644
Centreline initial dilution	1:40	1:130	1:293
Horizontal distance for edge of plume to reach surface	~2.5 m	~9.5 m	~36 m
(d) Post-recycling, 19.5 ML/day (Stage 3)			
Average initial dilution	1:105	1:489	1:1290
Centreline initial dilution	1:55	1:233	1:581
Horizontal distance for edge of plume to reach surface	~1 m	~12 m	~55 m

Table 2.8 Initial dilution modelling results for pre- and post-recycling wastewater streams for Ocean Reef Outlet B under different ambient current speeds

	Current: 0.00 ms^{-1}	Current: 0.12 ms^{-1}	Current: 0.30 ms^{-1}
SUMMER			
(a) Pre-recycling, 60 ML/day			
Average initial dilution	1:74	1:268	1:725
Centreline initial dilution	1:38	1:121	1:329
Horizontal distance for edge of plume to reach surface	~2.5 m	~8.5 m	~35 m
(b) Post-recycling, 50 ML/day (Stage 1)			
Average initial dilution	1:80	1:316	1:867
Centreline initial dilution	1:42	1:140	1:393
Horizontal distance for edge of plume to reach surface	~2 m	~9 m	~40 m
(c) Post-recycling, 39.5 ML/day (Stage 2)			
Average initial dilution	1:90	1:405	1:1094
Centreline initial dilution	1:47	1:181	1:494
Horizontal distance for edge of plume to reach surface	~1.5 m	~10 m	~45 m
(d) Post-recycling, 19.5 ML/day (Stage 3)			
Average initial dilution	1:134	1:825	1:2213
Centreline initial dilution	1:70	1:375	1:996
Horizontal distance for edge of plume to reach surface	~0.5 m	~15 m	~70 m
AUTUMN			
(a) Pre-recycling, 60 ML/day			
Average initial dilution	1:74	1:268	1:725
Centreline initial dilution	1:38	1:120	1:329
Horizontal distance for edge of plume to reach surface	~2.5 m	~8.5 m	~35 m
(b) Post-recycling, 50 ML/day (Stage 1)			
Average initial dilution	1:80	1:315	1:867
Centreline initial dilution	1:42	1:139	1:392
Horizontal distance for edge of plume to reach surface	~2 m	~9 m	~40 m
(c) Post-recycling, 39.5 ML/day (Stage 2)			
Average initial dilution	1:90	1:402	1:1091
Centreline initial dilution	1:47	1:178	1:492
Horizontal distance for edge of plume to reach surface	~1.5 m	~10 m	~45 m
(d) Post-recycling, 19.5 ML/day (Stage 3)			
Average initial dilution	1:134	1:819	1:1921
Centreline initial dilution	1:70	1:369	1:804
Horizontal distance for edge of plume to reach surface	~0.5 m	~15 m	~ 70 m

3. Assessment of Environmental and Health Considerations

3.1 Environmental considerations

The potential environmental implications of the proposed AWRP discharge are:

1. Slightly higher concentration of contaminants (e.g. nutrients and metals) being discharged to the marine environment. This is because, with the exception of pathogens (which are reduced via the AWRP process), the total daily loading of nutrients and contaminants will stay the same, but the concentration at which they are discharged will increase slightly due to the reduced volume of flow.
2. Slight increase in salinity of the discharge, potentially affecting initial dilution.

3.2 Concentration factor

The factor by which the contaminants are concentrated in the reject stream is based on average water quality results from AWRP GWT commissioning and operational sampling (March 2010 – 2011). The concentration factors were derived from calculating the mass balance in the trial (Figure 3.1):

Reject Load = Feed Load - Recharge Load

The Reject Load volume is based on the recovery rates of the UF and RO units (these rates are taken from design specifications of the installed units). Also included in the reject water is process water which makes up for approx 4% of the total treated water produced. The RO unit has an assigned recovery rate of 75% while the UF unit has an assigned recovery rate of 95%. The worst case scenario was used to calculate the concentration factor, whereby there was 100% efficiency in removal of contaminants such that the Feed Load = Reject Load. This gives a concentration factor of 3.16, i.e. the concentration of contaminants in the wastewater reject is 3.16 times greater than the concentration in the feed treated wastewater.

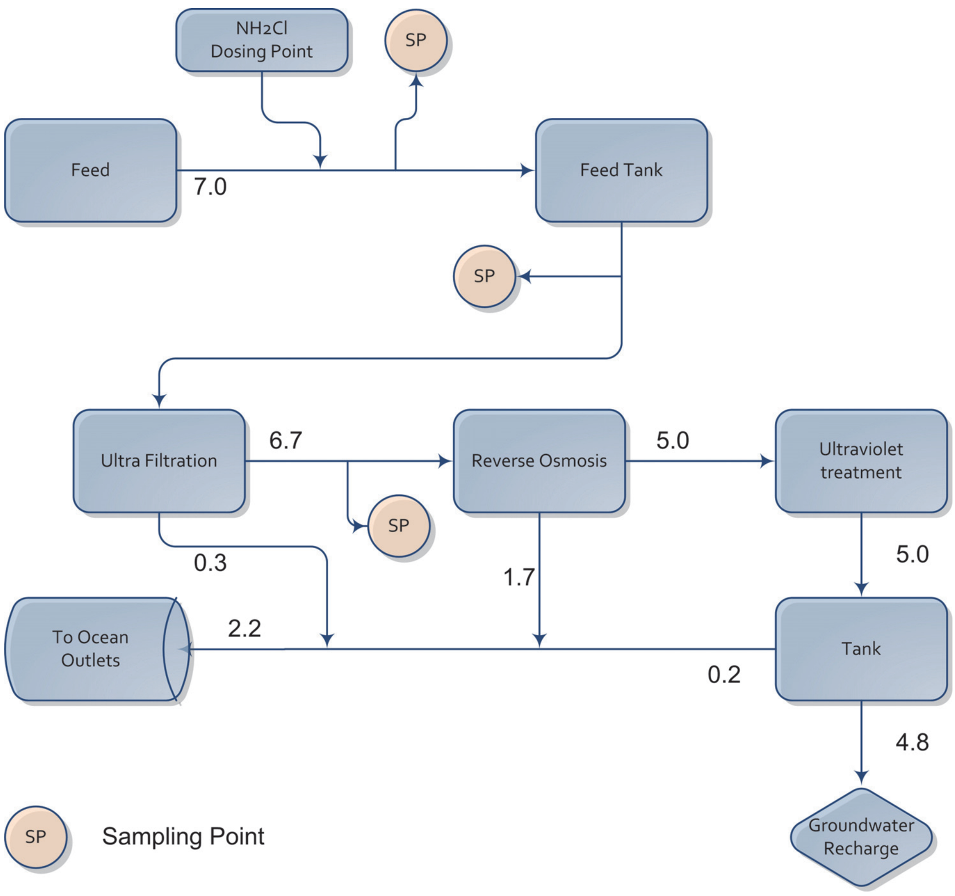


Figure 3.1 Schematic representation of flows for the 7 ML/d GWT scheme (values are ML/d)

3.3 Estimating surface concentrations

Predictions of worst case concentrations of selected contaminants within the initial mixing zone have been made using results from the initial dilution modelling. Key contaminants of concern investigated were inorganic nutrients (due to the potential for nutrient-related effects), and ammonium, copper and zinc – which are present in undiluted wastewater at concentrations which exceed National (ANZECC/ARMCANZ 2000) guidelines for a high level of ecosystem protection.

The surface concentrations of a contaminant within the initial mixing zone can be estimated by the following equation, which assumes that in the time from release to the surface there is only dilution of the contaminant and not any change due to chemical or biological processes (i.e. the contaminant behaves conservatively in this period):

$$[\,\text{Surface}\,] = \frac{[\,\text{Wastewater} + (\text{Dilution} - 1) * \text{Background}]}{(\text{Dilution})}$$

Where:

- Wastewater-is the concentration of the nutrient/contaminant in the treated wastewater discharge (i.e. either secondary treated wastewater or the combined stream);
- Background-is the background concentration of the nutrient/contaminant found in seawater; and
- Dilution-is the modelled initial dilution factor under autumn conditions (the slightly lower dilution values for some stages occurred in autumn).

3.4 Surface concentrations under calm, average and energetic conditions

The presence of a current enhances the initial dilution of contaminants in the discharged wastewater. In particular, the influence of an ambient current on wastewater discharge increases with decreasing volumes of discharge. Thus, the reduced volumes of the post-recycling discharge undergo higher initial dilution than the pre-recycling discharge.

3.4.1 Relevant Environmental Quality Objectives and guidelines

The EPA has developed local water quality Environmental Quality Objectives (EQO) and associated Environmental Quality Criteria (EQC) comprising of Environmental Quality Guidelines (EQG) and Environmental Quality Standards (EQS) (EPA 2005). The relevant EQO for Ocean Reef in relation to this project are:

1. EQO 1 (Maintenance of ecosystem integrity);
2. EQO 2 (Maintenance of aquatic life for human consumption); and
3. EQOs 3 and 4 (Maintenance of primary contact recreation values and Maintenance of secondary contact recreation values).

With regard to EQO 1, as with other ocean outlets in WA, a Low Ecological Protection Area (LEPA) is required around the immediate vicinity of the diffusers. Within this region the bio-accumulating metals must meet the 80% species protection triggers. At the edge of this area, the High Ecological Protection Area (HEPA) triggers will apply (EPA 2005; Table 3.1).

There are yet to be formally defined boundaries at Ocean Reef for where the EQOs and associated levels of protection for EQO 1 will apply and it is not the purpose of this report to establish them. This assessment solely compares the concentrations in the wastewater plume against the relevant guidelines after the process of initial dilution has taken place, which typically occurs within the order of 10s of metres from the diffuser in these waters depths (~10 m).

3.4.2 Comparison with guidelines

Table 3.1 shows the predicted average nutrient and contaminant concentrations after initial dilution for all stages and the three current regimes. The autumn stage is presented because although initial dilution at Outlet A differed little between summer and autumn, it was fractionally less in autumn than in summer at Outlet B. The estimated average surface concentrations of all contaminants meet the High Protection EQG (EPA 2005) after initial mixing for both outlets with the exception for copper in stage 3 under dead calm conditions, where the predicted concentration is slightly higher than the guideline value (the 0.3 ug/L guideline value was exceeded by 0.05 ug/L). This very limited exceedance is not reflective of typical operating conditions as it is attained through the combination of maximum measured concentration coupled with dead calm conditions and if such an event occurred it would be for an extremely limited duration and is not within the management intent of the EPA (2005) guidelines.

As the proposal results in a reduction in concentration of bacterial pathogens, the project is an improvement of current practise; pathogens are managed by the Water Corporation in accordance with the terms of the existing licence for the Beenyup WWTP (L7882/1991/13).

Table 3.1 Post initial dilution concentrations

	ID[6]	CF[7]	NH4+ (ug/L)	NOx (ug/L)	TP[8] (ug/L)	Cu (ug/L)	Zn (ug/L)
Concentration in TWW[1]			1900	20474	10180	9	70.7
Background value[2, 4]			4	8	9	0.08	0.15
High Protection Guideline[5]			500	ND[3]	ND[3]	0.3	7
Dead calm (Ambient current speed 0.0 m/s)							
Outlet A							
Pre-recycling	69	1	31.5	304.6	156.4	0.21	1.18
Stage 1	73	1.2	35.2	344.4	176.2	0.23	1.32
Stage 2	78	1.5	40.5	401.6	204.7	0.25	1.51
Stage 3	105	3.16	61.1	624.1	315.3	0.35	2.29
Outlet B							
Pre-recycling	62	1	34.6	338.1	173.0	0.22	1.29
Stage 1	74	1.2	34.8	339.9	174.0	0.22	1.30
Stage 2	80	1.5	39.6	391.8	199.8	0.25	1.48
Stage 3	134	3.16	48.8	490.8	249.0	0.29	1.82
Ambient current speed = 0.12 m/s							
Outlet A							
Pre-recycling	178	1	14.7	123.0	66.1	0.13	0.55
Stage 1	204	1.2	15.2	128.4	68.8	0.13	0.57
Stage 2	254	1.5	15.2	128.9	69.1	0.13	0.57
Stage 3	489	3.16	16.3	140.3	74.8	0.14	0.61
Outlet B							
Pre-recycling	201	1	13.4	109.8	59.6	0.12	0.50
Stage 1	268	1.2	12.5	99.6	54.5	0.12	0.47
Stage 2	315	1.5	13.0	105.5	57.4	0.12	0.49
Stage 3	819	3.16	11.3	87.0	48.3	0.11	0.42
Ambient current speed = 0.3 m/s							
Outlet A							
Pre-recycling	433	1	8.4	55.3	32.5	0.10	0.31
Stage 1	518	1.2	8.4	55.4	32.6	0.10	0.31
Stage 2	644	1.5	8.4	55.7	32.7	0.10	0.32
Stage 3	1290	3.16	8.7	58.1	33.9	0.10	0.32
Outlet B							
Pre-recycling	550	1	7.4	45.2	27.5	0.10	0.28
Stage 1	725	1.2	7.1	41.9	25.8	0.09	0.27
Stage 2	867	1.5	7.3	43.4	26.6	0.10	0.27
Stage 3	1921	3.16	7.1	41.7	25.7	0.09	0.27

Notes:

1. Maximum value recorded for metals, 95^{th} percentiles for nutrients
2. The background nutrient values are the median concentrations of measurements taken from January 2000 to December 2006 for PLOOM seasonal monitoring at site N1
3. ND: nutrient guideline is not defined
4. Background metals concentration data from McAlpine et. al. 2005
5. Ammonium and metal guidelines are the 99% species protection levels specified in Table 3.4.1 of the ANZECC/ARMCANZ (2000) guidelines, the enterococci guideline is the EQG value from EPA (2005)
6. ID: Initial Dilution
7. CF: Concentration Factor
8. TP: Total Phosphorus

3.5 ‘Clean in Place’ chemicals

It will be necessary to establish a schedule of cleaning for the ultra filtration membrane and reverse osmosis filters with batches of 'Maintenance Wash' (MW) and ‘Clean in Place’ (CIP) chemicals. The membrane ultra filtration chemicals, schedules and volumes are given in Table 3.2 and the reverse osmosis CIP chemicals in Table 3.3. Once processed, the CIP batch volume will be combined with the water recycling and secondary treated wastewater and discharged via the ocean outlets. Any changes to the characteristics (e.g. density, pH) of the wastewater will be negligible due to the low volume and concentrations of the CIP chemicals. The CIP chemicals do not contain material quantities of the contaminants of concern and the combination of their high degree of dilution in the reject stream followed by the dilution after discharge means that they pose negligible risk.

Table 3.2 Ultra filtration membrane maintenance and clean in place (CIP) volumes

Maintenance Wash (MW)			
Once per day, per train: 3 days Chlorine MW then 1 day Acid MW consecutively			
Chemical	**Stage 1 (7 GL=19 ML/d)**	**Stage 2 (14 GL=38 ML/d)**	**Stage 3 (28 GL = 77 ML/d)**
	Volume (L/d)	**Volume (L/d)**	**Volume (L/d)**
Chlorine MW			
Sodium Hypochlorite (12.5%)	84	168	336
Acid MW			
Sulphuric Acid (98%)	42	84	168
Citric Acid (50%)	56	112	224
Clean in Place (CIP)			
Once per 30 days, per train 5 Chlorine CIPs to 1 Acid CIP CONSECUTIVELY			
Chemical	**Stage 1 (7 GL)**	**Stage 2 (14 GL)**	**Stage 3 (28 GL)**
	Volume (L)	**Volume (L)**	**Volume (L)**
Chlorine CIP			
Sodium Hypochlorite (12.5%)	84	168	336
Acid CIP			
Sulphuric Acid (98%)	70	140	280
Citric Acid (50%)	196	392	784

Table 3.3 Reverse osmosis clean in place (CIP) chemicals

	Stage 1 (7 GL)	**Stage 2 (14 GL)**	**Stage 3 (28 GL)**
Chemical	**Volume (L)**	**Volume (L)**	**Volume (L)**
Caustic CIP Estimated Frequency: every 2-3 months			
Caustic (50%) maximum	260	520	1045
Acid CIP Estimated Frequency: every 5-6 months			
Citric (50%) maximum	2221	4443	8885
Hydrex CIP Estimated Frequency: To be advised			
Hydrex 4705 (Veolia) maximum	1867	3733	7467

4. Conclusions

4.1 Project overview

The AWRP will treat up to 100% of the total wastewater flow for reinjection into the groundwater aquifer, and from this volume a reject stream of up to 38 MLd^{-1} (when the entire flow of 120 MLd^{-1} of treated wastewater is recycled) containing 95-100% of the contaminants contained in the original volume will be discharged to the ocean. Initial dilution modelling was completed for a range of stages for both Ocean Reef ocean outlets A and B to investigate the effect of altering the characteristics of the discharged treated wastewater. The initial dilutions were then used to predict surface contaminant concentrations within the initial mixing zone under conditions of typical ambient currents and worst case (calm) conditions.

4.2 Effect on initial dilution

Under all current conditions, for both Outlet A and B, the initial dilution is predicted to increase with increasing ratio of reject flow to pre-recycling flow. Comparing Stage 3 with the pre-recycling case, the increase in dilution may be more than 200%. The effect of increasing salinity (which acts to increase density, in turn reduce buoyancy and reduce dilution) was found to be negligible compared to the effects of reducing flows (which acts to increase dilution).

4.3 Environmental considerations

Potential environmental implications of the proposed AWRP include the increased concentration of pathogens, nutrients and toxicants being discharged to the marine environment (by a factor of up to 3.16-fold). However, as the concentration factor increases, the flow decreases and the dilution increases, therefore the higher contaminant concentrations of the post-recycling discharge are largely offset.

4.3.1 Toxicants

The toxicant of primary concern is copper as it is closest to the environmental quality guideline under any conditions (this is a due to the extensive use of copper piping in domestic plumbing). Under conditions of the currents typical of the region, National (ANZECC/ARCMANZ 2000) water quality guidelines for the highest level of protection (99% species protection) were met when the 95th percentile concentrations of contaminants (ammonium, copper and zinc) under both pre-recycling discharge and post-recycling discharge stages were assessed. However, the guideline for copper was marginally exceeded when the 100% reuse stage was modelled for dead calm conditions (the 0.3 ug/L guideline value was exceeded by 0.05 ug/L). This was not considered to be a significant issue as the combination of dead calm conditions and the 95th percentile concentration is a very low probability. It is recommended that, if and when approval for Stage 3 is sought, that a more detailed review of the key metals concentrations is undertaken based on a project specific sampling program and the potential risk and any necessary management measures committed to (e.g. Whole Effluent Toxicity testing).

4.3.2 Primary contact recreation

As the proposal results in a reduction in concentration of bacterial pathogens, the project is an improvement of current practise; pathogens are managed by the Water Corporation in accordance with the terms of the existing licence for the Beenyup WWTP (L7882/1991/13). As such there is no need for this report to address impacts on primary contact recreation.

4.3.3 Nutrients

There are presently no guidelines for assessing nutrient related effects at Ocean Reef. However, the AWRP will not alter the total nutrient loads discharged to Ocean Reef and therefore will not require any amendment to the existing Ministerial Conditions or Licence Conditions. Further, nutrient concentrations after initial dilution will not change under typical conditions and it is considered highly unlikely that there will be any change in to nutrient-related effects due to wastewater discharge under the AWRP.

4.3.4 Maintenance and Clean in Place chemicals

It will be necessary to establish a schedule of cleaning for the ultra filtration membrane and reverse osmosis filters with batches of 'Maintenance Wash' (MW) and 'Clean in Place' (CIP) chemicals. The CIP chemicals do not contain material quantities of the contaminants of concern and the combination of their high degree of dilution in the reject stream followed by the dilution after discharge means that they pose negligible risk.

5. References

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Appendix A

APASA Initial dilution modelling report

MEMORANDUM

TO:	Mark Bailey	**DATE:**	Aug 8, 2011
FROM:	Murray Burling/Sandy Ng	**REFERENCE:**	J0123
RE:	Ocean Reef Outfall Diffuser Modelling		

BACKGROUND

In response to your request to proceed (Aug 1, 2011), we have undertaken an analysis of the likely nearfield behaviour for discharges from the Water Corporation's Beenyup Wastewater Treatment Plant (WWTP). The current analysis is for the full scale development of an Advanced Water Reclamation Plant (AWRP) as part of the facility. The modelling for the pilot stage of the project was previously completed by Oceanica.

The discharge outlet is located at 309,049.54E and 6,568,681.16N (Latitude: 31° 45' 46.29" S Longitude: 115° 43' 25.93" E). The discharge is a combination of the secondary treated wastewater originating from the Beenyup WWTP, and a by-product of effluent which undergoes treatment in the AWRP to produce high quality water that will be injected into the confined Leederville aquifer. The combined discharge will result in the same load of contaminants but in slightly smaller volume with slightly higher contaminant concentrations and density.

Three operation scenarios (varying with discharge volumes), two seasonal cases (summer and autumn), and three current speeds have been considered. The discharge is spilt 50/50 between the pipes of two diffuser arrays with multiple ports active at the seabed. Each diffuser array is slightly different. The details of the operational scenarios, discharge characteristics, physical, current, and outlet conditions are discussed in the following section.

The modelling assumes that the conditions at the discharge are expected to be generally well mixed and that any buoyancy effects in the nearfield due to ambient temperature are expected to be minor.

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MODEL PARAMETERS AND SCENARIOS

Modelling Scenarios

The projected flow rates from the Beenyup WWTP are, on average, 120 MLd^{-1}. Three operation scenarios are defined, each with a different total volume sent to the AWRP and thus a different volume of reject flow (approximately to 32% of the total inflow into AWRP). Both pre-recycling (i.e. regular secondary treated wastewater) and post-recycling (i.e. combined water recycling reject stream and secondary treated wastewater) are considered (see Table 1).

Table 1 Operational conditions considered

Operation Scenario	PRE-RECYCLING				POST-RECYCLING
	Beenyup TWW (ML d^{-1})	AWRP (ML d^{-1})			Combined flow (ML d^{-1})
		Inflow	Outflow	Reject flow	
1	120	30	20	10	100
2	120	60	41	19	79
3	120	120	82	39	39

Discharge Characteristics

Discharge temperature and total dissolved solids (TDS) are defined based on measurement collected by the Water Corporation for each of their Beenyup WWTPs. The discharge temperature at the WWTPs is estimated as 27ºC and 25.5ºC, respectively, for summer and autumn. It was assumed that the water recycling reject stream would have a similar seasonal temperature variation to the treated wastewater discharge, so the same summer and autumn temperatures were used in the modelling.

TDS data for the Beenyup WWTP collected on an approximately monthly basis between 2000 and 2005 show a variation between 650-810 mgL^{-1}. There is no seasonal trend present in the TDS data and therefore the worst case of 810 mgL^{-1} has been used in the modelling for the secondary treated wastewater discharge. The TDS of the water recycling reject stream has been estimated at approximately 2,574 mgL^{-1}. For modelling of the blended discharge stream, the concentration of TDS in the water recycling reject stream and the secondary treated wastewater stream have been proportionally combined to give a blended TDS of approximately 982, 1242, and 2574 mgL^{-1}, for operational scenario 1, 2, and 3 respectively.

Physical Conditions

Two seasonal cases, summer and autumn, are considered. The average ambient surface and bottom temperature and salinity for each season have been determined using data from the Perth Long-term Ocean Outlet Monitoring (PLOOM) Programme from year 2003 to 2005 (Oceanica 2005a, 2005b), and are summarised in Table 2.

Table 2 Ambient temperature and salinity conditions during summer and autumn in the vicinity of the Ocean Reef ocean outlets

Season	Temperature (°C)		Salinity	
	Surface (1,2)	Bottom (1,3)	Surface (1,2)	Bottom (1,3)
Summer	22.10	21.75	36.35	36.33
Autumn	21.27	20.67	36.43	36.42

Notes: 1. Site ORR1, an 'Intensive Summer' monitoring reference site located approximately 3,000 m south of the Ocean Reef ocean outlets, and site N1, a 'Seasonal' monitoring site located approximately 4,000 m south of the Ocean Reef ocean outlets were used to determine average ambient conditions.
2. *Surface* water column readings were taken at 0.5 m below water level.
3. *Bottom* water column readings were taken at 9.5 m below water level.

Current Conditions

Three current speeds, 0 ms^{-1}, 0.12 ms^{-1}, and 0.3 ms^{-1}, have been considered. The value of 0 ms^{-1} is to represent a 'worst case' calm condition. The value of 0.12 ms^{-1} is obtained based on the average of the surface current measurements that have been recorded during 11 summers from 1996-2006 as part of the PLOOM Programme. A more energetic condition with a current of 0.3 ms^{-1} has also been considered.

Outlet Conditions

There are two discharge outlets, with 30 ports on Outlet A and 48 ports on Outlet B. Flow volumes are split evenly between two outlets and the two diffusers are sufficiently far apart such that the initial mixing zones do not overlap. The plume from each outlet, thus, has been modelled separately. The set-up parameters used to represent the Ocean Reef ocean outlets are shown in Table 3.

Table 3 Ocean Reef ocean outlets diffuser characteristics

Diffuser Characteristics	Outlet A	Outlet B
Port diameter	0.125 m	0.16 m
Port elevation	0.758 m	0.843 m
Number of open ports	30	48
Port spacing [1]	3.7 m	4.05 m
Port orientation	Alternating horizontal	Alternating horizontal
Water depth	10 m	10 m

Note: 1. In the case of alternate ports, they are all assumed to be on one side of the diffuser and 'port spacing' is the distance between each port irrelevant of the actual position on either side of the diffuser.

Near-field Modelling

Near-field is defined as within the immediate vicinity of the outfall, where the effluent characteristics of the initial outfall (such as momentum and buoyancy) have an influence on mixing while far-field is defined outside this region where environmental forcing such as the ocean current plays a more important role. For this study, near-field modelling only was undertaken.

The near-field modelling was completed using the UM3 (Updated Merge three-dimensional) sub-model within the Visual Plumes framework (Davis, 1999). Visual Plumes is a USEPA released modelling package that allows the user to simulate single and multiple port submerged discharge in a range of configurations (Frick et al., 2003). Arbitrary ambient conditions can be specified, including temperature, salinity, concentration of solubles, current speed and direction. Far-field dilution is also approximated using empirical plume dispersion relationships; however the primary use of the modelling package is to estimate near-field dilution. Visual Plumes has been applied widely to similar environmental outfall assessments in Western Australia, and is familiar framework to the WA Environmental Protection Authority.

UM3 is a Lagragian model that features the projected-area-entrainment (PAE) hypothesis (Winiarski and Frick, 1976; Frick, 1984). The established hypothesis (Rawn, Bowerman, and Brooks, 1960) quantifies forced entrainment, the rate at which mass is incorporated into the plume in the presence of current. In UM3 it is assumed that the plume is in steady state.

RESULTS

Table 4 and Table 5 show the results for the pre- and post-recycling wastewater streams for Ocean Reef Outlet A and B, respectively, under different ambient current speeds and two different seasonal conditions. The results show that the initial dilution was slightly higher at Outlet B than at Outlet A. In terms of seasonal differences in initial dilution, there was no to negligible difference between the summer and autumn conditions for Outlet A for both the pre-recycling and post-recycling dilutions. The same finding is shown for Outlet B, with the exception of scenario 3 with current speed of 0.3 ms^{-1}, in which the dilution under the autumn condition is 15-20% lower than that under the summer condition.

Under all current conditions, for both Outlet A and B, initial dilutions increase for scenarios with increasing ratio of reject flow to pre-recycling flow. Comparing scenario 3 with the pre-recycling case, the increase may be more than 200%.

Higher dilutions are shown under the presence of higher background current, however, once the plume moves beyond approximately 10-20 m from the discharge point; other factors may become important in determining how the plume is diluted and thus results from initial dilution models may not be accurate. The distance where the plume is predicted to reach the surface increases with increasing background current, as well as with the ratio of reject flow to pre-recycling flow.

Table 4 Initial dilution modelling results for pre- and post-recycling wastewater streams for Ocean Reef Outlet A under different ambient current speeds and two different seasonal conditions.

	Current: 0.00 ms^{-1}	Current: 0.12 ms^{-1}	Current: 0.30 ms^{-1}
SUMMER			
(a) Pre-recycling, 60 ML/day			
Average initial dilution	1:69	1:178	1:434
Centreline initial dilution	1:36	1:95	1:199
Horizontal distance for edge of plume to reach surface	~3.5 m	~9.5 m	~30 m
(b) Post-recycling, 50 ML/day (Scenario 1)			
Average initial dilution	1:73	1:208	1:518
Centreline initial dilution	1:38	1:111	1:237
Horizontal distance for edge of plume to reach surface	~3 m	~9.5 m	~32 m
(c) Post-recycling, 39.5 ML/day (Scenario 2)			
Average initial dilution	1:79	1:254	1:644
Centreline initial dilution	1:41	1:132	1:293
Horizontal distance for edge of plume to reach surface	~2.5 m	~9.5 m	~36 m
(d) Post-recycling, 19.5 ML/day (Scenario 3)			
Average initial dilution	1:106	1:489	1:1290
Centreline initial dilution	1:55	1:236	1:582
Horizontal distance for edge of plume to reach surface	~1 m	~12 m	~52 m
AUTUMN			
(c) Pre-recycling, 60 ML/day			
Average initial dilution	1:69	1:178	1:433
Centreline initial dilution	1:36	1:95	1:199
Horizontal distance for edge of plume to reach surface	~3.5 m	~9.5 m	~30 m
(d) Post-recycling, 50 ML/day (Scenario 1)			
Average initial dilution	1:73	1:204	1:518
Centreline initial dilution	1:38	1:107	1:236
Horizontal distance for edge of plume to reach surface	~3 m	~9.5 m	~32 m
(d) Post-recycling, 39.5 ML/day (Scenario 2)			
Average initial dilution	1:78	1:254	1:644
Centreline initial dilution	1:40	1:130	1:293
Horizontal distance for edge of plume to reach surface	~2.5 m	~9.5 m	~36 m
(d) Post-recycling, 19.5 ML/day (Scenario 3)			
Average initial dilution	1:105	1:489	1:1290
Centreline initial dilution	1:55	1:233	1:581
Horizontal distance for edge of plume to reach surface	~1 m	~12 m	~55 m

Table 5 Initial dilution modelling results for pre- and post-recycling wastewater streams for Ocean Reef Outlet B under different ambient current speeds and two different seasonal conditions.

	Current: 0.00 ms^{-1}	Current: 0.12 ms^{-1}	Current: 0.30 ms^{-1}
SUMMER			
(a) Pre-recycling, 60 ML/day			
Average initial dilution	1:74	1:268	1:725
Centreline initial dilution	1:38	1:121	1:329
Horizontal distance for edge of plume to reach surface	~2.5 m	~8.5 m	~35 m
(b) Post-recycling, 50 ML/day (Scenario 1)			
Average initial dilution	1:80	1:316	1:867
Centreline initial dilution	1:42	1:140	1:393
Horizontal distance for edge of plume to reach surface	~2 m	~9 m	~40 m
(c) Post-recycling, 39.5 ML/day (Scenario 2)			
Average initial dilution	1:90	1:405	1:1094
Centreline initial dilution	1:47	1:181	1:494
Horizontal distance for edge of plume to reach surface	~1.5 m	~10 m	~45 m
(d) Post-recycling, 19.5 ML/day (Scenario 3)			
Average initial dilution	1:134	1:825	1:2213
Centreline initial dilution	1:70	1:375	1:996
Horizontal distance for edge of plume to reach surface	~0.5 m	~15 m	~70 m
AUTUMN			
(c) Pre-recycling, 60 ML/day			
Average initial dilution	1:74	1:268	1:725
Centreline initial dilution	1:38	1:120	1:329
Horizontal distance for edge of plume to reach surface	~2.5 m	~8.5 m	~35 m
(d) Post-recycling, 50 ML/day (Scenario 1)			
Average initial dilution	1:80	1:315	1:867
Centreline initial dilution	1:42	1:139	1:392
Horizontal distance for edge of plume to reach surface	~2 m	~9 m	~40 m
(d) Post-recycling, 39.5 ML/day (Scenario 2)			
Average initial dilution	1:90	1:402	1:1091
Centreline initial dilution	1:47	1:178	1:492
Horizontal distance for edge of plume to reach surface	~1.5 m	~10 m	~45 m
(d) Post-recycling, 19.5 ML/day (Scenario 3)			
Average initial dilution	1:134	1:819	1:1921
Centreline initial dilution	1:70	1:369	1:804
Horizontal distance for edge of plume to reach surface	~0.5 m	~15 m	~ 70 m

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Report QA/QC Form

Section A: Author to complete

Project No. and Name:	906_001 Beenyup Advanced Water Recycling Plant
Client:	Water Corporation
Report Title:	Impact Assessment of Water Recycling Reject Stream Discharge
Report Revision:	Rev0
Author:	Mark Bailey
Technical Reviewer:	Tara Amrita
Editorial Reviewer:	Tara Amrita
Admin Reviewer:	Rachael Hillman

Section B: Author checklist

	YES	NO	N/A
General			
Is an editorial review required? (Consultant has confirmed with PD)	☑	☐	
Cover page details match Title Page	☑	☐	☐
Agreed report title	☑	☐	☐
Correct client name/spelling	☑	☐	☐
Oceanica report number issued by Caroline	☑	☐	☐
Report history & distribution up to date	☑	☐	☐
Front page photo credits are correct	☑	☐	☐
Contents page matches content	☑	☐	☐
Main report/document			
Consistent with Oceanica Style Manual	☑	☐	☐
List of abbreviations/terms included if appropriate	☐	☐	☑
Executive Summary consistent with main report	☑	☐	☐
Methods/approaches used are justified	☑	☐	☐
Site location GPS co-ordinates (incl. projection & datum) are tabulated	☐	☐	☑
Critical results/analyses double-checked	☑	☐	☐
All figures and tables checked for errors	☑	☐	☐
All citations included in References	☑	☐	☐
Appendices complete and with standalone reference list where appropriate	☑	☐	☐

Comments

Sign-off	**Author: Mark Bailey** **Date: 01/11/2011**	

Section C: Technical reviewer checklist

	YES	NO	N/A
Executive Summary			
Content consistent with main report	☑	☐	☐
No new material introduced	☑	☐	☐
Recommendations agree with main report	☑	☐	☐
Main report/document			
Report/project objectives clearly described	☑	☐	☐
Report addresses objectives of project	☑	☐	☐
Report complies with any specific client requirements	☑	☐	☐
Background literature appropriate and sufficient	☑	☐	☐
Methods			
Methods/approaches used are justified	☑	☐	☐
Statistical analyses/data manipulation techniques are appropriate and correct	☑	☐	☐
Results			
Results compared with any prelim data/data reports/field reports	☑	☐	☐
Results consistent with figures/tables	☑	☐	☐
Figures/tables add to report content	☑	☐	☐
Results consistent with Executive Summary	☑	☐	☐
Interpretations valid and appropriate	☑	☐	☐
Discussion/Conclusion			
Consistent with results	☑	☐	☐
Consistent with Executive Summary	☑	☐	☐
All key/relevant references are cited	☑	☐	☐
Concluding statements are justified and appropriate	☑	☐	☐
Appendices			
Appendices are appropriate to report	☑	☐	☐

Comments

Sign-off	**Technical reviewer: Tara Amrita** **Date: 02/11/2011**	

Section D: Editorial reviewer checklist

	YES	NO	N/A
Main report/document			
Report history table up to date	☑	☐	☐
Exec Summary clear and logical structure	☑	☐	☐
Figure/table captions informative and succinct	☑	☐	☐
All figures & tables placed after first text reference	☑	☐	☐
Figure/table notes & source references appropriate and correct	☑	☐	☐
All figures & tables are standalone	☑	☐	☐
All citations included in reference list	☑	☐	☐
Reference list format correct	☑	☐	☐
Appendices checked and standalone	☑	☐	☐

Overall			
Document structure is clear and logical	☑	☐	☐
Document style and content appropriate for audience	☑	☐	☐
Document is consistent with Style Guide	☑	☐	☐
Correct use of abbreviations, etc	☑	☐	☐
Spelling & punctuation correct—edited if not	☑	☐	☐
Grammar & sentence structure correct—edited if not	☑	☐	☐

Comments

Sign-off	**Editorial reviewer: Tara Amrita** **Date: 02/11/2011**	

Section E: Admin reviewer checklist

	YES	NO	N/A
QA/QC - reviews			
Author checklist completed and signed off	☑	☐	☐
Technical review completed and signed off	☑	☐	☐
Editorial review completed and signed off	☑	☐	☐
Cover page			
Correct Oceanica format (Font/style, images correct size and position)	☑	☐	☐
Title page			
Author & director signatures inserted in Rev0	☑	☐	☐
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Figures, tables & appendices listed and TOC fields updated	☑	☐	☐
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Executive Summary			
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Main report			
Correct Oceanica format/style	☑	☐	☐
Page numbers checked	☑	☐	☐
Client name & report title in footer	☑	☐	☐
Figures & tables			
Oceanica figures inserted are correctly sized (A3/A4/A5) and rotated	☑	☐	☐
All captions correctly formatted	☑	☐	☐
All notes/source references correctly formatted and correct placement	☑	☐	☐
Fields			
Fields updated before PDFing	☑	☐	☐
Report checked for broken cross references	☑	☐	☐
Appendices			
All appendices added to report pdf before printing	☑	☐	☐
Multiple digital versions (print/email/etc.)			
Content of all versions identical	☑	☐	☐
QA/QC - documentation			
This form completed and attached to Rev0 pdf for hardcopy printing	☑	☐	☐

Comments

Sign-off	**Admin reviewer: Rachael Hillman** **Date: 02/11/2011**	Rachael Hillman

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