4. Stakeholder engagement

4.1 Key stakeholders

Key stakeholders have been identified in relation to the Proposal by Water Corporation including:

- EPA
- DWER
- DoEE
- Department of Health
- Department of Biodiversity, Conservation and Attractions
- Department of Primary Industries and Regional Development
- Department of Treasury, Western Australia
- Department of the Premier and Cabinet (Ministers for Water and Environment)
- Western Australian Planning Commission
- City of Wanneroo (including Elected Members)
- Western Australian Planning Commission (WAPC)
- Main Roads Western Australia
- Lendlease
- LandCorp
- WA Fishing Industry Council
- Recfishwest
- Western Rock Lobster Council
- Alkimos Beach Surf Lifesaving Association
- Alkimos Beach Progress Association
- Conservation Council of Western Australia
- Alkimos Eglinton Landowners Group
- Public Transport Authority – Metronet.

Due to the concurrent engagement approach with investigations completed for the PSDP2, stakeholders were briefed on both proposals where appropriate. An overview of the stakeholder consultation which has been conducted for the Proposal to date is provided in Appendix A. Further consultation is ongoing and will continue as the Proposal progresses through detailed design, approvals, construction and commissioning phases.

4.2 Stakeholder and community engagement process

Stakeholder and community engagement for the Proposal commenced in 2017 and has been conducted in several formats, including: face to face meetings with state and local government agencies, corporations and public interest groups; participation in community events; and drop in sessions in public spaces i.e. cafes, to promote general awareness and stimulate public feedback.

An online community with feedback capabilities was established in early 2018, which provided regular updates on progress. Additionally, Water Corporation has placed advertisements in the local newspaper which were syndicated on social media.

Engagement for the investigations has resulted in:

- more than 50 meetings with stakeholders
- more than 2,000 unique visitors to the online community with 42 feedback surveys received
- more than 300 conversations with community at four local events (hosted by the City of Wanneroo, Lendlease and the Public Transport Authority)
- two briefings at the Alkimos Beach Progress Association
- four drop in information sessions at a local cafe
- completion of a Social Impact Assessment
- engagement with marine stakeholders (undertaken by WA Fishing Industry Council) prior to offshore investigations.

More than 15 media articles have been published in relation to the engagement, with frequent sharing of information via social media channels to local community groups and stakeholder networks.

Key feedback from stakeholders and community included:

- impacts of the Proposal on nearby homes and businesses (primarily visual amenity, property value, odour and noise)
- impacts to Alkimos Beach access and brine impacts on the marine environment
- construction impacts.

Feedback from the community and stakeholders has been used in the design of the Proposal including:

- lowering the height of the buildings and site improvements so the plant cannot be seen by existing and proposed residential development
- completion of noise assessment for ultimate site planning to understand likely noise and inform noise management
- mitigating beach impacts through tunnelling of marine pipelines.

In addition, in December 2018 and early January 2019 the following stakeholders were presented with Proposal overviews to summarise key findings and in response to stakeholder specific items of interest:

- City of Wanneroo
- Recfishwest
- Lendlease
- LandCorp.

5. Environmental principles and factors

5.1 Identification of key factors and their significance

The EPA lists a number of environmental factors which need to be considered in the Environmental Impact Assessment (EIA) process (EPA 2018b). The key factors relevant to this Proposal are considered in Table 5-1.

Table 5-1: Key environmental factors, their significance and relationship to the Proposal

EPA theme	EPA factor[1]	Significance	Relationship to Proposal
Sea	**Benthic Communities and Habitats**	Key environmental factor	The Proposal comprises the construction of marine infrastructure which will require the removal of benthic habitat. Construction and operation of the Proposal may result in changes to marine water quality, which can impact on benthic communities and habitats.
	Coastal Processes	Other environmental factor	The Alkimos coastline supports a number of wide sandy beaches which are utilised frequently for recreational purposes. Public access to the beaches may be temporarily restricted for safety reasons during the tunnelling process.
	Marine Environmental Quality	Key environmental factor	Marine construction activities may temporarily affect water quality due to increased turbidity and the release of any nutrients and contaminants in sediments. During operation of the Proposal, return seawater and process chemicals may affect water quality in the receiving environment.
	Marine Fauna	Key environmental factor	Potential direct impacts through loss of habitat and the construction and operation of the intake and outfall pipelines (e.g. marine fauna entrained into the intake). Potential introduction of invasive marine species through marine plant during construction and operational maintenance.
Land	**Flora and Vegetation**	Key environmental factor	The Proposal will require clearing of native vegetation, including listed and threatened vegetation communities and conservation areas (including *Bush Forever*).
	Landforms	Key environmental factor	Potential impact on the existing landforms (Quindalup Dune system and small portion of Cottesloe unit of the Spearwood Dunes) due to earthworks.
	Subterranean Fauna	Other environmental factor	Potential impacts during construction due to de-watering.
	Terrestrial Environmental Quality	Other environmental factor	Potential for the construction and operation of the proposal to disturb or generate contamination or acid sulfate soils causing risk to the environment.

EPA theme	EPA factor[1]	Significance	Relationship to Proposal
	Terrestrial Fauna	Key environmental factor	Clearing and fragmentation of fauna habitat. Disturbance of fauna during construction and operations.
Water	Inland Waters	Other environmental factor	Potential for the construction and operation of the Proposal to alter ground and surface water systems and values associated with the Proposal. Local hydrological flows and wetlands may be impacted by the construction and permanent installation of the pipeline.
Air	Air Quality (Greenhouse Gas Emissions)	Other environmental factor	Generation of greenhouse gas from the operation of the facility.
People	**Social Surroundings**	Key environmental factor	Potential construction impacts to the amenity of residents and recreational users in the surrounding area and to heritage values from traffic noise, emissions and congestion; noise and vibration; dust; odour; and installation of the pipeline. Potential operational impacts to the amenity of residents and recreational users in the surrounding area and to heritage values from noise, odour, traffic, and light pollution.
	Human Health	Other environmental factor	Storage and use of chemicals.

[1] Key environmental factor are shown in bold.

5.2 Consistency with environmental principles

The EP Act identifies a series of principles for environmental management. The environmental principles are the highest assessment level that a Proposal or scheme must meet in order to be found environmentally acceptable by the EPA. Water Corporation has considered these principles in relation to the development and implementation of the Proposal (Table 5-2).

Table 5-2: EP Act principles

Principle	Consideration
<u>*The precautionary principle*</u> *Where there are threats of serious irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.* *In the application of the precautionary principle, decisions should be guided by:* *a) careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and* *b) an assessment of the risk-weighted consequences of various options.*	Water Corporation has identified several environmental factors that are relevant to the Proposal. The Proposal has been designed to avoid, as far as practicable, any serious environmental harm. Specialist studies have been undertaken (e.g. hydrodynamic modelling, flora and fauna surveys) and used to supplement information from existing surveys/ investigations, to inform the understanding of the existing environment and identify the potential impacts from the Proposal. Where there were areas of uncertainty regarding potential impacts, conservative assumptions were made. Management actions to address residual impacts and ensure impacts are as predicted are addressed within the construction and operations environmental management frameworks and plans. Water Corporation considers that the Proposal meets the application of the precautionary principle.
<u>*The principle of intergenerational equity*</u> *The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.*	The Proposal is part of a larger water resource development program by Water Corporation that includes multiple options based around supply requirements and environmental sustainability. The Proposal is not predicted to have long-term adverse effects on the health, diversity or productivity of the environment outside of the defined LEPA. Water Corporation considers that the Proposal meets the principle of intergenerational equity.
<u>*The principle of the conservation of biological diversity and ecological integrity*</u> *Conservation of biological diversity and ecological integrity should be a fundamental consideration.*	Water Corporation has identified seven key environmental factors relevant to the Proposal. Detailed investigations have been undertaken to identify potential impacts and mitigation options to minimise the impact of the Proposal and align with the EPA objective for each environmental factor. No long-term impact on environmental values of the marine or terrestrial environment are expected to occur (outside of the defined LEPA for marine environment). Water Corporation considers that the Proposal meets the principle of conservation of biological diversity and ecological integrity.

Principle	Consideration
Improved valuation, pricing and incentive mechanisms 1) *Environmental factors should be included in the valuation of assets and services.* 2) *The polluter pays principle – those who generate pollution and waste should bear the cost of containment, avoidance or abatement.* 3) *The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any waste.* *Environmental goals, having been established, should be pursued in the most cost-effective way, by establishing incentive structures, including market mechanisms, which benefit and/or minimise costs to develop their own solutions and responses to environmental problems.*	Water Corporation accepts that costs for environmental mitigation and management are part of the overall Proposal costs. This includes identified rehabilitation and/or residual impact management actions as addressed within the construction and operations EMFs. Water Corporation considers that the Proposal meets the principle of improved valuation, pricing and incentive mechanisms.
The principle of waste minimisation *All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.*	The Proposal's approach to waste is consistent with the waste management (avoid, recover, disposal) principles. The key ongoing waste item for the Proposal is the discharge of brine to the marine environment. The mitigation hierarchy has been applied to this waste stream to reduce the impact of this discharge. Waste management for the Proposal is addressed within the relevant construction and operations EMFs. This also includes consideration of reusing natural materials (e.g. excavated dune sediments) where practicable. Water Corporation considers that the Proposal meets the principle of waste minimisation.

5.3 Relevant policy and guidance

Assessment of the environmental impacts of the Proposal is based on various Western Australian position statements and guidance statements. Standards, guidelines and policies related to specific environmental factors or individual aspects of the Proposal are listed and discussed in the individual sections relevant to the environmental factor being addressed. The documents generally considered relevant to assessment by the EPA for the Proposal are listed in Table 5-3.

Table 5-3: EPA policy and guidelines relevant to the Proposal

Environmental Protection Authority Policy or Guideline	Relevant Proposal aspect
Statement of Environmental Principles, Factors and Objectives (EPA 2018a)	Significance assessment of potential environmental impact.
Environmental Factor Guideline – Benthic communities and habitats (EPA 2016a) Environmental Factor Guideline – Coastal Processes (EPA 2016b) Environmental Factor Guideline – Marine environmental quality (EPA 2016c) Environmental Factor Guideline – Marine Fauna (EPA 2016d) Technical Guidance – Benthic communities and habitats (EPA 2016e) Technical guidance – EIA of Marine Dredging proposals (EPA 2016f) Technical Guidance – Protecting the quality of Western Australia's marine environment (EPA 2016g) Perth's Coastal Waters Environmental Values and Objectives (EPA 2000)	Potential impacts on the marine environmental quality, benthic communities and habitats and marine fauna through the construction and operation of the intake and outfall pipelines.
Environmental Factor Guideline – Flora and Vegetation (EPA 2016h) Technical Guidance – Flora and vegetation surveys (EPA 2016i)	Potential impact on significant flora and vegetation values from clearing vegetation.
Environmental Factor Guideline – Subterranean Fauna (EPA 2016j) Technical Guidance – Subterranean fauna surveys (EPA 2016k) Technical Guidance – Sampling methods for Subterranean Fauna (EPA 2016l)	Potential impact on significant subterranean fauna habitats during construction.
Factor Guideline – Landforms (EPA 2018c)	Potential impact to coastal dune values during construction and operation.
Environmental Factor Guideline – Terrestrial Environmental Quality (EPA 2016m) Environmental Factor Guideline – Terrestrial Fauna (EPA 2016n) Technical Guidance – Terrestrial Fauna surveys (EPA 2016o) Technical Guidance – Sampling methods for terrestrial vertebrate fauna (EPA 2016p) Technical Guidance – Sampling of short range endemic invertebrate fauna (EPA 2016q)	Potential impact on terrestrial fauna from clearing habitat and impacting on fauna during construction.
Environmental Factor Guideline – Inland Waters (EPA 2018d)	Potential impact from groundwater abstraction and surface water/drainage management during construction and operation.
Factor Guideline – Air Quality (EPA 2016r)	Potential impact from scope 2 greenhouse gas emissions during operation.

Environmental Protection Authority Policy or Guideline	Relevant Proposal aspect
Environmental Factor Guideline – Social Surroundings (EPA 2016s) Environmental Factor Guideline – Human Health (EPA 2016t)	Potential impact associated with Aboriginal and cultural values, greenhouse gases production and dust emissions.
Perth's Coastal Waters Environmental Values and Objectives (EPA 2000)	Sets water quality objectives.
Alkimos Coastal Node – Local Structure Plan	Planning and amenity considerations.

6. Marine Environmental Quality

6.1 EPA objective

The EPA's environmental objective for marine environmental quality is:

"To maintain the quality of water, sediment and biota so that environmental values are protected" (EPA 2018b).

6.2 Policy and guidance

The relevant EPA policies and guidelines for marine environmental quality and the scope of each of these as relevant to the Proposal are outlined in Table 6-1.

Table 6-1: Policies and guidelines

Policy or guidance	Consideration
Environmental Quality Criteria Reference Document for Cockburn Sound (EPA 2017)	The thresholds examined by the modelling were generally derived from EPA (2017), which provides comprehensive advice regarding the setting of triggers, even when the area of interest is outside of Cockburn Sound. Other thresholds are as per Table 6-13.
Perth's Coastal Water – Environmental Values and Objectives (EPA 2000)	EPA (2000) provides the environmental quality plan for Perth's coastal waters and defines the Environmental Values and Objectives for Ecosystem Health, Fishing and Aquaculture, Recreation and Aesthetics, and Industrial Water Supply.
Factor Guideline – Marine Environmental Quality (EPA 2016c)	EPA (2016c) provides guidance on Marine Environmental Quality, including factors which can impact the marine environment. Marine Environmental Quality is assessed based on levels of contaminants in water, sediments or biota, or to changes in the physical or chemical properties of waters and sediments relative to a natural state.
Technical Guidance – Protecting the quality of Western Australia's Marine Environment (EPA 2016g)	EPA (2016g) provides guidance on the environmental quality management frameworks for protecting Western Australia's marine environment and defines the environmental values and objectives for ecosystem health, fishing and aquaculture, recreation and aesthetics, industrial water supply and cultural and spiritual values, as well as the approach to setting levels of ecological protection. The studies executed in support of the Proposal, including hydrodynamic and water quality modelling, were designed and executed in the context of EPA (2016g).
Other policy or guidance	
Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy No. 4 (ANZECC & ARMCANZ 2000)	These document and the assessments of impacts contained herein are based on guidance in the relevant EPA documents (cited above), which are in turn based on the high-level guidance provided in ANZECC & ARMCANZ (2000) and ANZG (2018).
Australian Water Quality Guidelines for Fresh and Marine Waters (ANZG 2018)	

6.3 Overview of studies

Water and sediment quality data at Alkimos are well documented following approximately 15 years of monitoring. Figure 6-1 outlines the spatial and temporal extent of monitoring undertaken to:

- support the approvals process for the Alkimos WWTP (approved 2007 under Ministerial Statement 755)
- satisfy the commitments contained within the Alkimos Marine Treated Wastewater Discharge Monitoring and Management Plan (MTWDM&MP, Water Corporation 2016)
- inform the potential impacts of the Proposal.

In addition, a seawater quality program was conducted over 2017-18 on a quarterly basis to gain comprehensive water quality data and depth profiling information for SDP design purposes. The purpose and extent of the studies undertaken between 2005 and 2018 are described in Table 6-2.

Table 6-2: Marine environmental quality studies

Relevant study / monitoring program	Scope
Alkimos WWTP: Marine water quality baseline assessment (Oceanica 2005a)	Undertaken to establish baseline knowledge and inform the Alkimos WWTP approvals process.
Alkimos WWTP: Marine sediment quality baseline assessment (Oceanica 2005b)	
ASOOM 5 yearly sediment quality assessments (Oceanica 2012, BMT Oceanica 2016a)	Undertaken to satisfy commitments in the MTWDM&MP (Water Corporation 2016).
ASOOM annual reports (Oceanica 2012, 2013; BMT Oceanica 2014a, 2015, 2016b, 2017, BMT 2018a)	Undertaken to satisfy commitments in MS 755 and the MTWDM&MP (Water Corporation 2016).
Alkimos Desalination Plant Discharge Modelling: Model Calibration Report (DHI 2019)	Describes the comprehensive hydrodynamic model calibration process and provides an overview of local metocean and water quality results.
Alkimos Desalination Plant Discharge Modelling: Modelling Scenarios Report (DHI 2018)	Describes the results of the hydrodynamic and dispersion modelling with respect to different operational scenarios.
Alkimos Desalination Plant Discharge Modelling: Peer Review Panel Report (Lord et al 2019)	Outlines the results of the peer review panel's assessment of the hydrodynamic model calibration process as well as the approach to the scenario modelling.
Alkimos baseline water quality sampling (BMT 2019)	Describes the results of a comprehensive baseline water quality monitoring program conducted between October 2017 and October 2018.
Alkimos metocean data (April 2017 to March 2018) summary report (BMT 2018b)	Describes local metocean conditions following the deployment of the AWAC instruments to determine local current speeds & direction. AWAC instruments were deployed at four sites A, B, C and D.
Estimate of drill cutting particle fall and trajectory (BMT, unpublished data)	Desktop assessment to determine the likely fall and trajectory of particles released from the drilling of intake and outlet foundations.

Figure 6-1: Historical water and sediment sampling sites at Alkimos

N

Scale 1:40,000 at A4

0 500 1,000 m

Coordinate System:
GDA 1994 MGA Zone 50

Date: 18/03/2019

Legend

- Alkimos WWTP Outlet
- Alkimos WWTP Diffuser
- Desal Baseline
- WWTP Baseline
- WWTP Operation
- WWTP Reference Site
- WWTP Beyond Influence of Plume

BMT
WATER CORPORATION

G:\SpatialData\Client\WaterCorp\1334_11Alkimos EIA\005_ModellingSummary\GIS_Requests\005_02\005_02alkhisA4_20190218.mxd

environment.env@bmtglobal.com | www.bmt.org

Data source: Digital Globe December 2016. Client: Water Corporation, 3/2019. Created by: BMT

6.4 Receiving environment

6.4.1 Environmental values

Western Australia's coastal waters are managed under the EPA's Environmental Quality Management Framework (EQMF) (EPA 2016c). The EQMF is based on the National Water Quality Management Strategy (ANZG 2018), which represents an agreed, Australia-wide approach to protecting water quality and associated environmental values.

For regional management purposes, Alkimos lies within the sub-region of 'Perth's coastal waters', located between Yanchep and Dawesville. EPA (2000) sets out the Environmental Quality Plan (EQP) for Perth's coastal waters, which includes four environmental values (EVs) and seven environmental quality objectives (EQOs) (Table 6-3).

Table 6-3: Environmental values and environmental quality objectives

Environmental Values	Environmental Quality Objectives
Ecosystem health	Maintain ecosystem integrity at a maximum level of ecological protection. There are three levels of ecological protection: • high level of ecological protection • moderate level of ecological protection • low level of ecological protection.
Recreation and aesthetics	Water quality is safe for primary contact recreation (e.g. swimming and diving). Water quality is safe for secondary contact recreation (e.g. fishing and boating). Aesthetic values of the marine environment are protected.
Fishing and aquaculture	Seafood (caught or grown) is of a quality safe for eating. Water quality is suitable for aquaculture purposes.
Industrial water supply	Water quality is suitable for industrial use.

6.4.2 Marine environmental quality

The subsections below describe the metocean, water and sediment quality conditions at Alkimos based on data collected under the MTWDM&MP and the results of contemporary studies undertaken in support of the Proposal. Given the proximity of the SDP outfall to the existing WWTP outfall, the cumulative impacts of both sources have been considered in the assessment. The existing WWTP outfall has also been considered in the context of the SDP intake.

Existing WWTP influence on marine environmental quality

The Alkimos Strategic Ocean Outlet Monitoring (ASOOM) program, conducted between 2011 and 2018, provides a comprehensive record of local water quality and sediment quality, as well as a detailed census of local macroalgal community assemblages (with the latter covered in Section 7).

In addition to monitoring, comprehensive hydrodynamic modelling (DHI 2018) has been carried out to understand the trajectory, dilution and behaviour of the treated wastewater (TWW) plume from the WWTP, as well as the effect of the plume on dissolved oxygen (DO) concentrations. The trajectory of the TWW plume differs depending on the ambient conditions. The TWW plume typically rises directly to the surface of the water column, but may under some conditions exhibit forced entrainment, or 'bottom attachment' (DHI 2018), resulting in highly variable dilution performance (Table 6.4).

Modelling simulations based on maximum flows of 80 ML/d[1] predicted near-field centreline dilutions of 1:153 to 1:733 (Table 6-4) (DHI 2018). Initial dilution modelling examining the performance of the diffuser under current flows (13 ML/d), showed comparable values of 1:193 to 1:370 (Oceanica 2012, 2013, BMT Oceanica 2014a, 2015, 2016b, 2017, 2018). These dilutions are sufficient to ensure the EPA's high ecological protection guidelines are achieved at the edge of the mixing zone (Table 6-5) (DHI 2018).

Table 6-4: Minimum centreline dilution at the end of the near field dilution zone as a function of ambient current speed and density difference

Ambient current	0 m/s	0.043 m/s	0.078 m/s	0.12 m/s	0.2 m/s
Ambient density difference					
0.0 (unstratified)	279	214	387	610	986
0.1 kg/m^3	352	341	459	576	733
0.2 kg/m^3	249	241	325	407	518
0.3 kg/m^3	203	197	265	333	423
0.4 kg/m^3	176	171	229	288	366
0.5 kg/m^3	158	153	205	258	328

Table 6-5: Extent of predicted near field region (m) as a function of ambient current speed and density difference

Ambient current	0 m/s	0.043 m/s	0.078 m/s	0.12 m/s	0.2 m/s
Ambient density difference					
0.0 (unstratified)	18m	23m	41m	65m	106m
0.1 kg/m^3	31m	50m	90m	141m	229m
0.2 kg/m^3	22m	35m	63m	100m	162m
0.3 kg/m^3	18m	29m	52m	82m	132m
0.4 kg/m^3	16m	25m	45m	71m	114m
0.5 kg/m^3	14m	22m	40m	63m	102m

The performance of the diffuser is also reflected in monitoring of dissolved inorganic nutrients, conducted at fortnightly intervals over the summer period under the MTWDM&MP. Sampling at fixed distances down-current of the outlet shows that dissolved nutrients, nitrite+nitrate [NOx] and ortho-phosphate, achieve background levels within 300 m of the outlet (Oceanica 2012, 2013, BMT Oceanica 2014a, 2015, 2016b, 2017 2018).

[1] Noting that the WWTP is licenced to 160 ML/d, but the present pipe and diffuser is only engineered to maximum capacity of 80 ML/d.

The dynamic and typically buoyant nature of the plume also appears to limit its contact with the benthic environment. Sediment sampling conducted on two occasions at the edge of the low ecological protection area (LEPA) found organic carbon, nutrient and heavy metal concentrations were comparable to nearby reference sites (Oceanica 2012, BMT Oceanica 2016a) – suggesting that under present flows, the TWW has a negligible impact on the surrounding benthic environment.

Hydrodynamic modelling

A three-dimensional hydrodynamic model was developed to determine:

- the dispersion of brine and TWW from the proposed SDP and the existing Alkimos WWTP
- the potential interaction of the brine and TWW plumes with the SDP intake infrastructure
- the potential cumulative effects of the combined plumes on the marine environment.

The relevant software packages are described in DHI 2019(Appendix B).

Regional hydrodynamic modelling

The regional hydrodynamic model (MIKE FMHD) provided the critical forcing data to drive the local 3D hydrodynamic model, incorporating both tidal and non-tidal forcings and the stratified conditions of southwestern WA. It also informed the boundary conditions of the model, and ensured the complex mechanisms which dominate medium-term water levels and flows on the shelf were captured. The spatial extent of the regional 3D hydrodynamic model is shown in Figure 6-2, with intermediate and fine details shown in Figure 6-3.

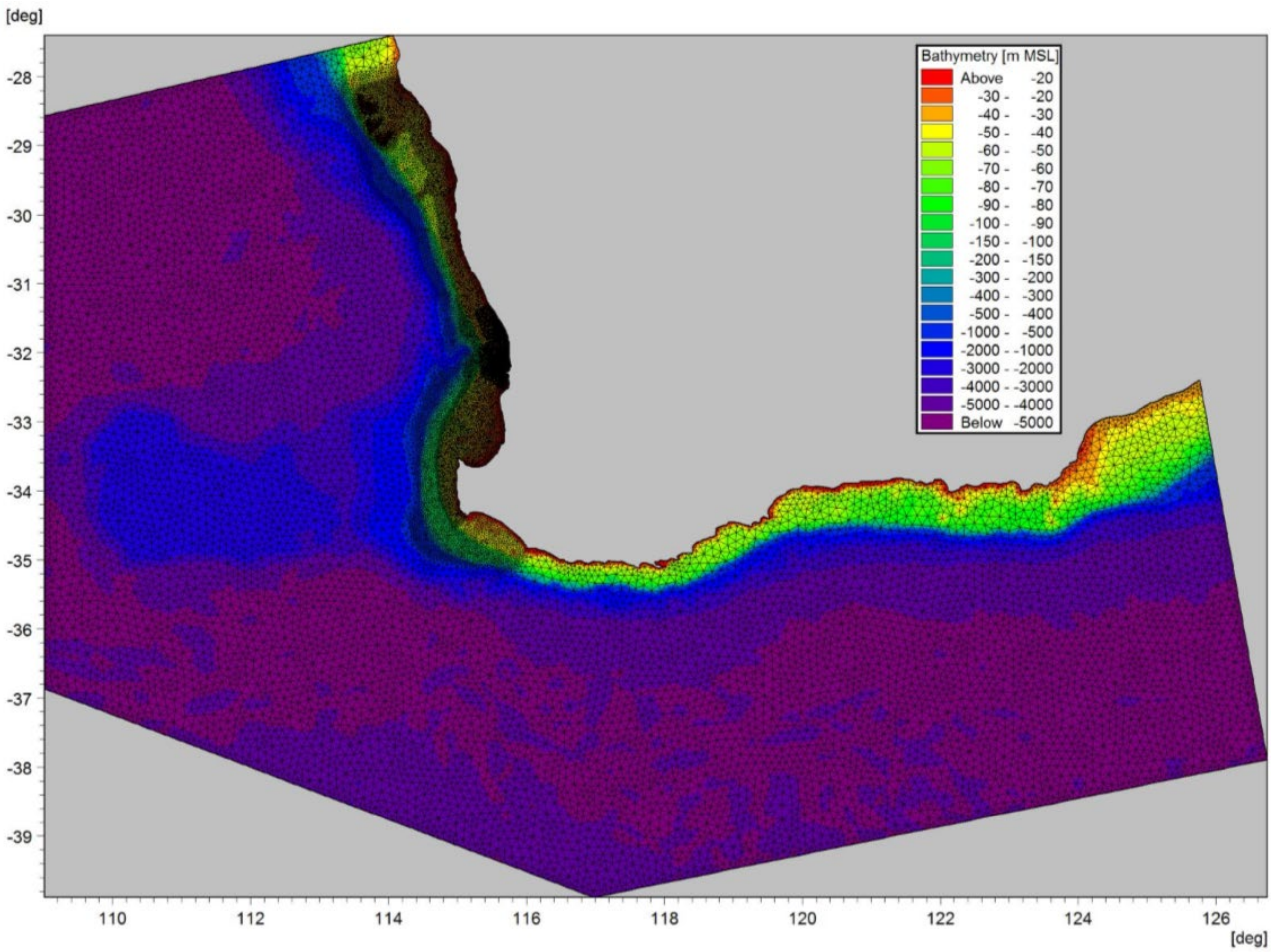

Figure 6-2: Unstructured mesh of regional 3D hydrodynamic model

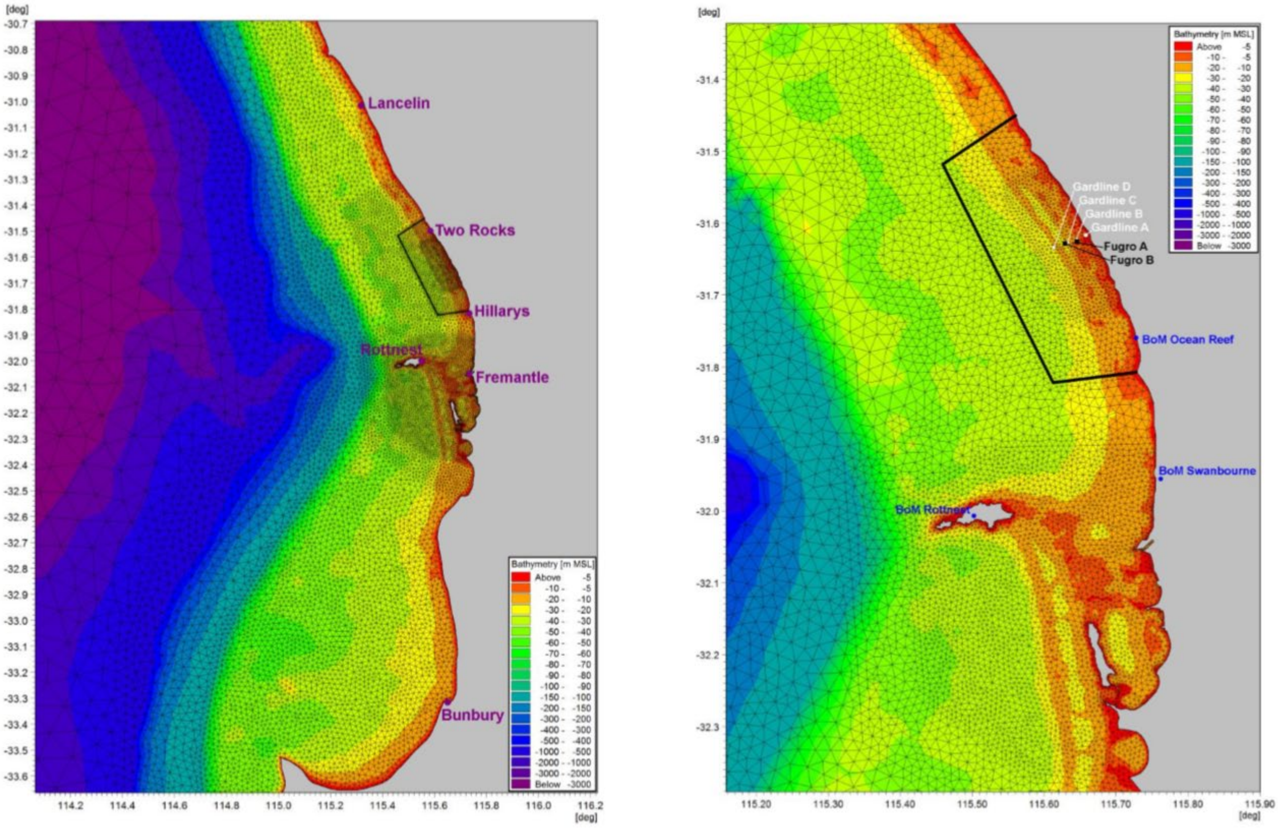

Figure 6-3: Unstructured mesh of the regional 3D hydrodynamic model (Left). Detailed view indicating the instrumentation and BoM met stations (Right). The black line indicates extent of local wave and 3D hydrodynamic models

<u>Local hydrodynamic and wave modelling</u>

As the critical decision-making tools in this assessment, much of the calibration effort was focussed on the local 3D hydrodynamic and wave models. Local hydrodynamics together with local bathymetry and features (water depths and bottom rugosity) influence the movement, dilution and trajectory of the plume after discharge. In a high energy environment (such as at Alkimos), it is also necessary to assess the effects of wave forcings, which play a significant role in driving circulation within the inner portion of the nearshore reef when waves are large (DHI 2018, 2019).

A common calibration mesh was applied to both the local wave model and the local 3D hydrodynamic model (Figure 6-4). The majority of the calibration was performed using a nominal mesh resolution of 50 m in the area of interest, coarsening to 400 m at the open boundaries. As with any numerical model study, the mesh size was driven by achieving a balance between the ideal spatial resolution and that which is practicable from the perspectives of computational runtime (DHI 2018, 2019).

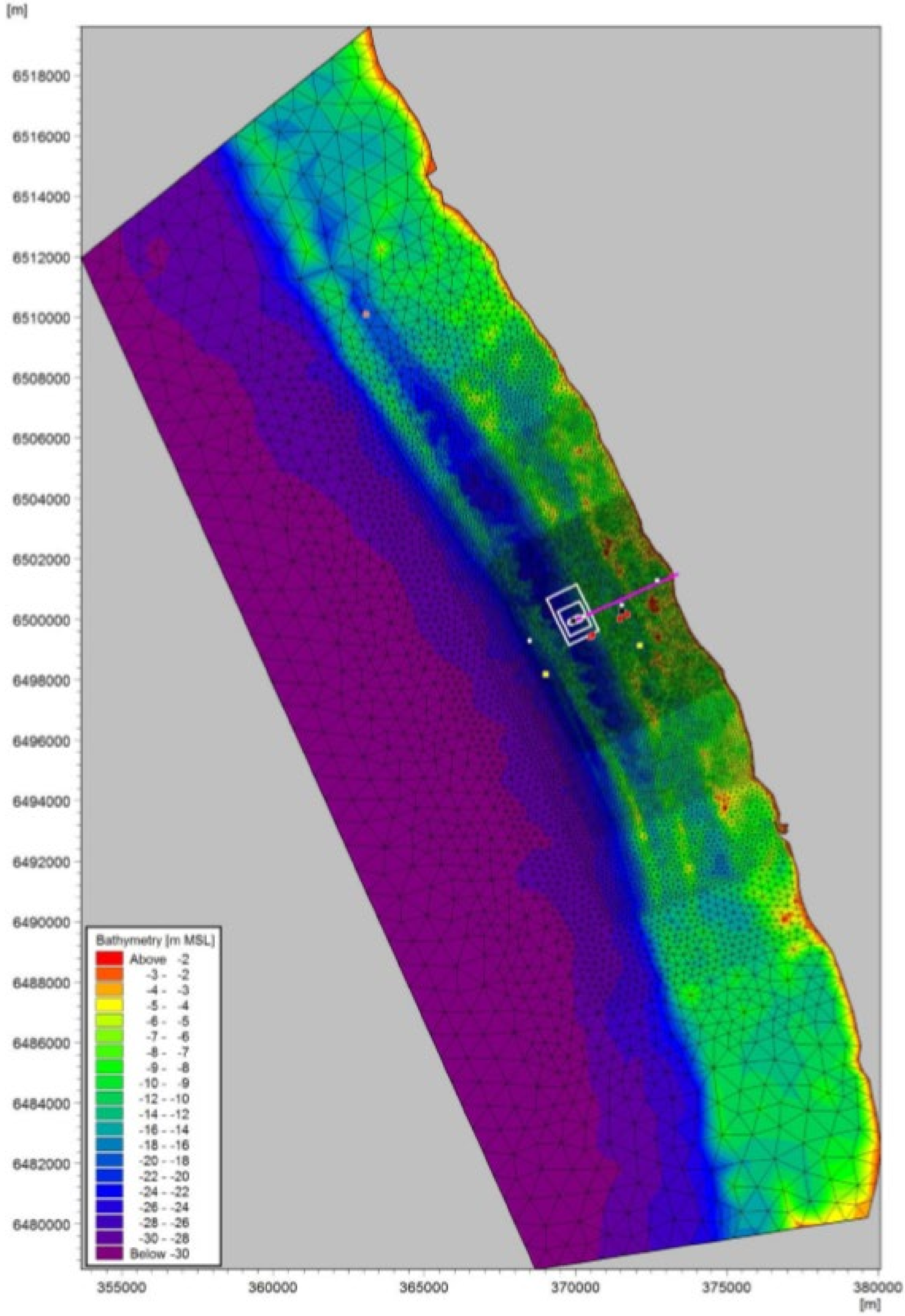

Figure 6-4: Unstructured mesh applied to the wave model and local 3D hydrodynamic model

Water quality modelling

The potential for the SDP to effect ocean DO levels was determined using DHI's ECO Lab model coupled with MIKE 3. DO processes simulated in the ECO Lab model included: boundary fluxes from the regional ocean model; atmospheric exchange and sediment oxygen demand (SOD).

Boundary fluxes from the regional ocean model were set to saturation based on ambient water temperatures. Atmospheric exchange was simulated as a function of water column DO, wind speed, water depth and flow velocity (DHI 2018).

SOD levels were estimated based on in situ measurements from nearby Marmion Lagoon. Recent measurements in winter and summer recorded mean SOD values of 0.19 and 0.36 $g/m^2/d$ respectively, with standard deviations of 0.07 and 0.14 $g/m^2/d$ (BMT 2019). Taking the average of the SOD values, yielded an input SOD value of 0.28 $g/m^2/d$.

ECO Lab uses a Michaelis-Menton equation to describe the sediment oxygen demand as a function of overlying DO concentration and water temperature. Fitting the above data based on water temperatures of 17 and 22°C, for winter and summer respectively, resulted in the following parameters: background SOD (20°C, saturation) = 0.28 $g/m^2/d$; Arrenhius temperature multiplier = 1.14 and a half saturation constant of 0.1 mg/L.

Modelling scenarios

The trajectories and dilution generated by the existing Alkimos WWTP and the proposed SDP plumes, were examined based on the scenarios detailed in Table 6-6.

Table 6-6: SDP modelling scenarios

Modelling scenario	Discharge (ML/d)			
	SDP	GWTP	WWTP	AWRP[2]
1a WWTP outlet baseline	0	0	80	0
1b WWTP outlet with AWRP	0	0	39	30
1c WWTP outlet (abnormal operation)[1]	0	0	80	0
2a 2.3 km outlet, 10 m depth	337	2	1a or 1b	1a or 1b
2b 3.8 km outlet, 18 m depth	337	2	1a or 1b	1a or 1b

1. Using full primary effluent.
2. Advanced Water Recycling Plant.

The Alkimos WWTP outlet includes a staged linear diffuser located 3.8 km offshore as indicated in Figure 3-3. The TWW discharge incorporates a diurnal variation in flow which is based on the established Alkimos WWTP operations. Given the WWTP discharges wastewater originating from a range of terrestrial sources, the WWTP discharge temperature varies.

Based on a review of the measured TWW temperatures at the Alkimos WWTP from 2011 to 2017, a characteristic annual profile of the monthly averaged discharge temperature was determined. The monthly averaged WWTP discharge temperature is typically 3 to 5 °C warmer than the equivalent monthly averaged seawater temperature.

The salinity of the TWW is nearly fresh, at 650 mg/L TDS. For the present assessment, the discharge is assumed to be devoid of dissolved oxygen. Alkimos WWTP scenarios were run based on maximum production levels (80 ML/d) under normal and abnormal treatment scenarios, using the parameters described in Table 6-7.

Table 6-7: Parameters simulated with respect to the Alkimos WWTP

Parameter	Value
Coordinates (inshore to offshore ends)	(370127,6500036) to (369850,6499911)
Effective diffuser length	300 m
Water depth over diffuser length	19.6 to 22.2 m; nominally 21 m
Number of ports	100
Port spacing	3 m
Port diameter	0.1 m*
Port elevations above seabed	~1.0 m
Port arrangement	Perpendicular to feeder, alternating (155.8°,335.8°)
Vertical discharge angle	Parallel with seabed
Mean daily flow rate	80 ML/day (0.926 m^3/s)**
Port exit velocity	1.18 m/s
Discharge TDS	650 mg/L
Discharge temperature	Variable
Discharge DO	0 mg/L
Bacterial load (Total TTC)	100,000 CFU / 100 mL
Bacterial load (*Enterococci* spp.)	20,000 MPN / 100 mL

*Drawings show slightly larger D=0.106m for offshore 60 ports; **with diurnal variation.

The SDP consists of a reverse osmosis plant capable of generating 330 ML/d of potable water and 340 ML/d (3.90 m^3/s) of associated reject brine. These values were treated as constants over the 12 month model simulation.

The SDP scenarios were run initially using different combinations of outlet and intake pipe lengths, and differing diffuser configurations (Table 6-6). All subsequent modelling scenarios were run using the optimal combination, as follows:

- Intake A (1.9 km in length, situated in 10 m water depth) (Figure 3-3)
- Outlet B (3.8 km in length, situated in 18.4 m water depth) (Figure 3-3).

The final parameters for this configuration are described in Table 6-8.

Table 6-8: Parameters simulated with respect to the SDP

Parameter	Value
Rosette midpoint coordinates	(370508, 6499408) and (370556, 6499438)
Separation between rosettes	50 m
Water depth at rosettes	-18.8 and -18.0 m (MSL)
Number of Ports	4 ports x 2 rosettes = 8
Port spacing	Equidistant (90°)
Port diameter	0.336 to 0.351 m
Port elevations above seabed	1.75 to 3.25 m
Vertical discharge angle	45 to 60°
Mean daily flow rate	340 ML/day (3.90 m3/s)
Port exit velocity	5.04 – 5.5 m/s
Discharge salinity	Sout = 1.925 x Sin
Discharge temperature	ΔT = 4°C (Tout = Tin + 4°C)
Discharge DO	100% saturation
Bacterial load (Total TTC)	0
Bacterial load (*Enterococci* spp.)	0

For modelling purposes, it was necessary to define the starting salinity concentrations and the starting water temperatures. Salinities were estimated based on field measurements, and application of 1 standard deviation above the average.

Using this approach, the reference intake salinity was set as 36.0 to 37.0 psu, and the discharge salinity as 69.3 to 71.2 psu. For context, these are marginally higher than the background values used in the original modelling (35.3 to 36.5 psu) (Worley Parsons 2005). The brine stream was modelled at a temperature 4°C above ambient.

Rosette designs

Several rosette designs were investigated by DHI (2018), including the partial burial of the rosette superstructure, as well as reductions in vertical discharge angles and altered port geometries. Consequently, some entries in Table 6-8 are shown as ranges. The final rosette design is expected to achieve a near-field dilution of 1:30 (supported by modelling), and this has been used in the far-field modelling assessment.

Model simulations

Modelling was used to simulate the extent, duration and intensity of potential impacts under a range of climatic conditions. A review of long-term wind, residual current and wave data (measured and hindcast) was carried out to identify seasonally representative design periods. This resulted in the identification of the following seasonal 30 day screening periods:

- autumn: 16 Apr – 15 May 2017
- winter: 23 Jun – 22 Jul 2017
- summer: 17 Nov – 16 Dec 2017.

The above 30 day periods were applied for model calibration and validation in DHI (2018). The final scenario consisted of a full 12 month simulation for the preferred ASDP arrangement, in combination with the planned expansion of the WWTP facility. The 12 month simulation was performed for the period of 1 April 2017 through 31 March 2018. This aligns with the AWAC deployment period which formed the primary physical baseline dataset.

Peer review process

To ensure the model was suitably robust, an independent peer review panel (PRP) was established to critically evaluate the performance of the model. The PRP, consisting of industry experts[2], assessed the model through its development, calibration, validation and later its performance with respect to the 'trustworthiness' of the outputs. The process resulted in several upgrades to the model, to deliver the most comprehensive modelling study at Alkimos (DHI 2018, 2019). The PRP's final report on the validation and calibration of the model (Lord et al 2019) is included in Appendix D.

Conceptual hydrodynamic and particle transport modelling

To determine the rise, fall and distribution of sediment particles during the tunnel drilling process, BMT built a conceptual hydrodynamic and sediment transport model using TUFLOW FV. The model estimated sediment dispersion and advection using estimated background current speeds derived from measured data.

While the model predicted the extent of sedimentation around the intake and outlet construction sites, the scope did not extend to the prediction of TSS or its effect on light attenuation. The effects of these parameters were instead assessed based on precedent.

The model was developed based on the following assumptions:

- the full volume of excavated material is discharged at the sea surface
- the sediments particles within the vicinity of the intake and outlet sites are predominantly medium sands (~64–82%), with smaller proportions of coarser material (i.e. coarse sands and gravels; ~1–10%) and finer material (i.e. fine sands, silts and clays; ~17–27%) (Oceanica 2005a)
- a constant current speed of 0.1 m/s (based on BMT 2019)
- settling velocities based on Stoke's Law for particles >130 μm; and on published values for particles <130 μm (Kemps and Masini 2017)
- the model does not consider changing currents, flocculation of particles, or intermittent discharges.

Two scenarios were investigated:

- discharge and spread of particles assuming all particles were reduced to <130 μm diameter during the drilling process
- discharge and spread of particles assuming no change to native particle sizes during drilling.

[2] Professor Chari Pattiaratchi (University of Western Australia), Dr Murray Burling (RPS) and Dr Desmond Lord (Chair).

Metocean

Broader-scale circulation in the region is dominated by the Leeuwin Current, a warm boundary current which flows southwards along the edge of the continental shelf (DHI 2019). Inshore of the Leeuwin Current, the Capes Current flows northward as a result of upwelling and northward wind stresses and is therefore strongest in spring and summer months. Owing to its location on the inner coastal shelf, as well as proximity to the Leeuwin Current and the inshore Capes Current, nontidal residual flows contribute to the current energy on the shelf near the Alkimos site. Continental shelf waves induce long-period modulations in water level which can reach the same order of magnitude as the tide (Gallop et al, 2012, Mihanovic et al 2016, and references contained within).

The area is exposed to persistently high swell conditions. Annual mean wave conditions approaching the outer reef have been measured at Hs=1.8m with an associated peak period of Tp=12.2s (DHI 2019). Wave direction was typically restricted to a narrow directional band between W–WSW and WSW–SW. Wave direction tended to turn in a clockwise direction from SW–WSW at Site D (offshore) to W–WSW at Site A (inshore). The transition was attributed to wave refraction in shallow waters. Several extreme wave and strong current events occurred between July 2017 and October 2017 as measured at AWAC Sites C and D (see Figure 6-1).

Current directions at Alkimos are predominantly north-westerly between October and March but variable between April and October (Figure 6-5). The transition to north-westerly currents occurs in October at Sites A-C, but is delayed until February at Site D. Current speeds at Sites C and D (0.2-0.5 m/s) were higher than at Sites A and B (<0.2 m/s). Sites C and D experienced strong south-easterly currents between April and October. Median depth-averaged current speeds range from 7.8 cm/s at the existing WWTP outlet (21 m depth) to 4.3 cm/s within the inshore reef (10 m depth) (DHI 2019) (Figure 6-5).

Water quality

Baseline studies focussed on the environmental parameters most likely to be affected by the SDP: salinity, temperature and DO. Salinity and temperature affect the density of seawater, which in turn may affect hydrodynamic processes. Effects to DO occur further along the cause-effect pathway, and in response to prolonged (density induced) stratification together with high levels of biological or sediment oxygen demand (BOD or SOD).

Density differences between the brine and the receiving water affect the near-field behaviour of the plume, while variable densities (stratification) in the receiving water affect both near-field and far-field plume characteristics. Baseline data from various sources indicates that salinity fluctuates seasonally between 34.6 and 36.6 psu (delta 2 psu) (BMT 2018), temperatures between 15.7 and 25.0°C (BMT 2018) and DO between 85% and 100% saturation (Oceanica 2012, 2013, BMT Oceanica 2014a, 2015, 2016b, 2017 2018).

On a spatial and vertical scale, salinity measurements were not substantially different between inshore and offshore locations (sites A and C respectively). Historical CTD measurements indicate subtle differences between the surface and the bottom of the water column (typically 0.1- 0.5 psu) (Oceanica 2012, 2013, BMT Oceanica 2014b, DHI 2019). Inshore sites were typically 1 to 2°C warmer than offshore sites, and subject to greater diurnal variability (Figure 6.6). Temperature gradients between the surface and bottom of the water column, when present, were circa 1°C.

Light attenuation

Light attenuation coefficient values range typically between 0.05–1.5 log^{10} per metre, but may exceed 100 NTU under periods of high wind, particularly in the winter months. Higher turbidity readings were generally accompanied by elevated TSS concentrations.

Sediment quality

Sediment sampling was first completed in 2005. Samples were analysed for particle size, total organic carbon, nutrients, metals, carbonate, pesticides and herbicides, at 6 sites above the inner reef line (~10 m depth) and 6 in the channel between the inner and outer reefs (~20 m depth). Further analyses for grain size, total organic carbon, nutrients and metals were also undertaken in March 2011 and February 2016 (Figure 6-6). Sampling was undertaken at the edge of the low ecological protection area (LEPA), and at the reference sites. For purposes of describing baseline conditions, the description of sediment characteristics is limited to the reference sites.

Sediment particle size fractions varied between sites. Near-shore sediments were dominated by coarse to medium grain particles. Large fractions were also present, with large to very coarse grain sizes present in some samples. Offshore sediments were generally finer, with a higher fraction of medium to fine grained sands (Figure 6-6). None of the samples contained silt or clay fractions (<63 µm).

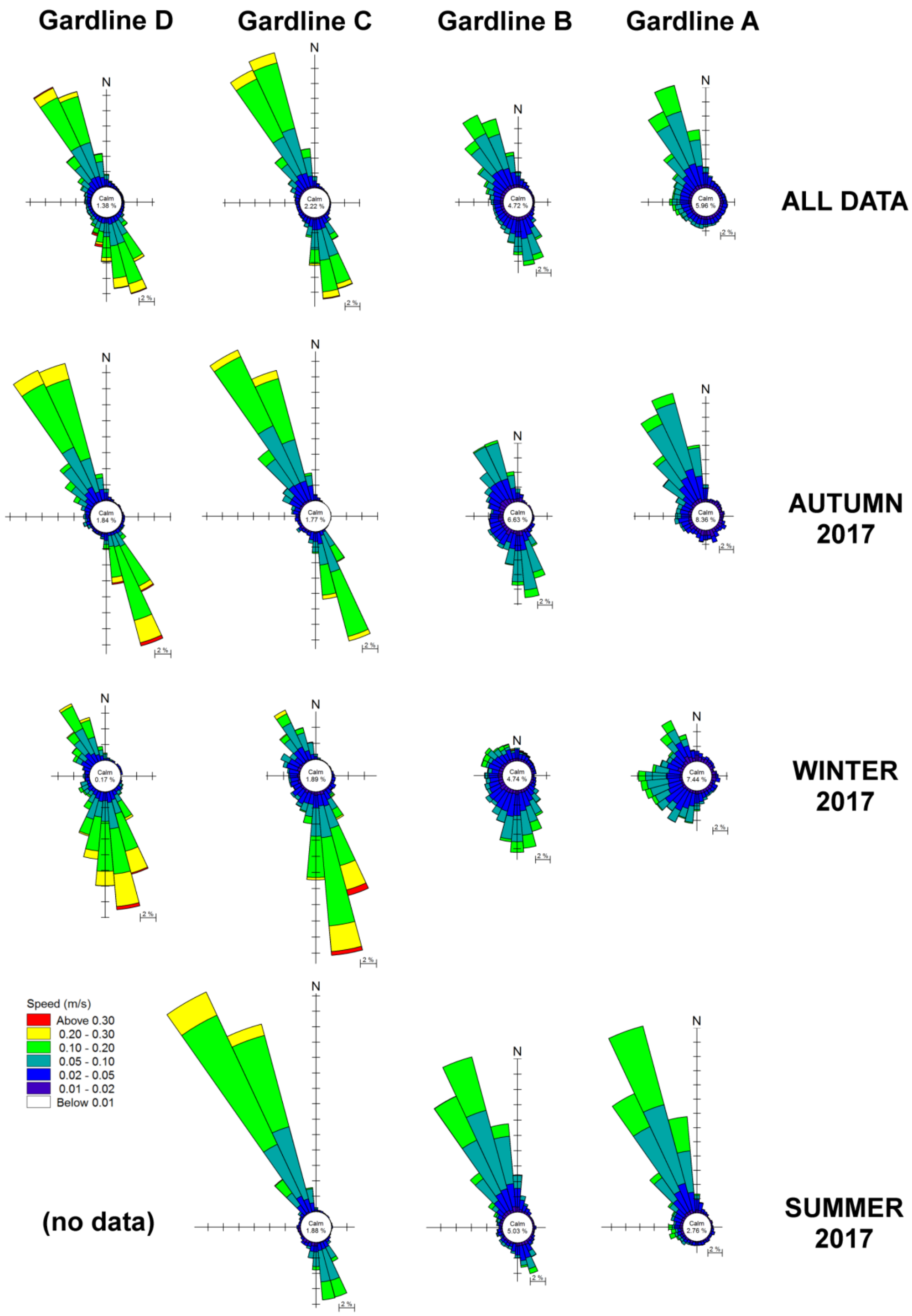

Figure 6-5: Matrix of depth-integrated current roses for the four (AWAC sites) Gardline instruments (columns) and for different time periods (rows)

Figure 6-6: Distribution of sediment particle sizes

N

Scale 1:35,000 at A4

0 500 1,000 m

Coordinate System:
GDA 1994 MGA Zone 50

Date: 18/03/2019

Legend

- Alkimos WWTP Outlet
- Alkimos WWTP Diffuser
- % Composition by weight
- Very Fine Sand
- Fine Sand
- Medium Sand
- Coarse Sand
- Very Coarse Sand
- Gravel

BMT

WATER CORPORATION

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Data source: Digital Globe December 2016. Client: Water Corporation, 3/2019. Created by: BMT