Environmental Impact Assessment (EIA) for a 670 MW CCGT on Jurong Island

EIA Report

PREPARED FOR

PLM Power Pte Ltd

DATE
26 March 2026

REFERENCE
0768379

DOCUMENT DETAILS

DOCUMENT TITLE	Environmental Impact Assessment (EIA) for a 670 MW CCGT on Jurong Island
DOCUMENT SUBTITLE	EIA Report
PROJECT NUMBER	0768379
DATE	26 March 2026
VERSION	07
AUTHOR	Various
CLIENT NAME	PLM Power Pte Ltd

DOCUMENT HISTORY

				ERM APPROVAL TO ISSUE		
VERSION	REVISION	AUTHOR	REVIEWED BY	NAME	DATE	COMMENTS
Draft	01	Various	Ella Li	Mark Eisenegger	23 September 2025	Draft to Client
Draft	02	Various	Ella Li	Mark Eisenegger	17 November 2025	Draft To Technical Agencies
Draft	03	Various	Ella Li	Mark Eisenegger	19 December 2025	Draft To Technical Agencies
Draft	04	Various	Ella Li	Mark Eisenegger	6 January 2026	Draft To Technical Agencies (for Public Disclosure)
Draft	05	Various	Ella Li	Mark Eisenegger	9 January 2026	Draft To Technical Agencies (for Public Disclosure)
Draft	06	Various	Ella Li	Mark Eisenegger	30 January 2026	Final To Technical Agencies (for Public Disclosure)
Final	07	Various	Ella Li	Mark Eisenegger	26 March 2026	Final To Technical Agencies (for EIA Approval)

SIGNATURE PAGE

Environmental Impact Assessment (EIA) for a 670 MW CCGT on Jurong Island

EIA Report

0768379

Mark Eisenegger

Partner

Environmental Resources Management (S) Pte Ltd

20 Collyer Quay, #15-01/02

Singapore 049319

T +65 6324 9636

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

Acronym	Description
AOI	Area of Influence
BESS	Battery Energy Storage System
BIA	Biodiversity Impact Assessment
BOD	Biochemical Oxygen Demand
CCGT	Combined Cycle Gas Turbine
COPPC	Code of Practice for Pollution Control
CPO	Chlorine-Produced Oxidants
CR	Critically Endangered
DCS	Distributed Control System
DD	Data Deficient
DGV	Default Guideline Value
DIN	Dissolved Inorganic Nitrogen
DIV	Dutch Intervention Values
DO	Dissolved Oxygen
ECB	Erosion Control Blankets
ECO	Environmental Control Officer
ECM	Erosion Control Measures
EIA	Environmental Impact Assessment
EMA	Energy Market Authority
EMMP	Environmental Monitoring and Management Plan
EN	Endangered
EPC	Engineering, Procurement, and Construction
EPHA	Environmental Public Health Act
EPMA	Environmental Protection and Management Act
EQO	Environmental Quality Objective
ERM	Environmental Resources Management (S) Pte Ltd
ESA	Environmental Site Assessment
GT	Gas Turbine
GV-H	Guideline Value – High
HRSG	Heat Recovery Steam Generator
IA	Impact Assessment
IUCN	International Union for Conservation of Nature
JPUT	Jurong Port Universal Terminals

Acronym	Description
JTC	Jurong Town Corporation
LC	Least Concern
LED	Light Emitting Diode
LFP	Lithium-iron Phosphate
LIT	Line Intercept Transect
LOR	Limit of Reporting
MPA	Maritime and Port Authority of Singapore
MPN	Most Probable Number
MW	Megawatt
MWQC	Marine Water Quality Criteria
NBSAP	National Biodiversity Strategy and Action Plan
NCMP	Nature Conservation Master Plan
ND	Not Detectable
NE	Northeast
NEA	National Environment Agency
NGs	Nature Groups
NGOs	Non-Government Organisations
NParks	National Parks Board
NT	Near Threatened
NTU	Nephelometric Turbidity Unit
PAHS	Polycyclic Aromatic Hydrocarbons
PAR	Photosynthetically Active Radiation
PCBs	Polychlorinated Biphenyls
PCS	Pollution Control Study
PLM	PLM Power Pte Ltd
PO_4	Phosphate
PUB	Public Utility Board
QECP	Qualified Erosion Control Professional
RDB3	Singapore Red Data Book
RFP	Request for Proposal
SDSs	Safety Data Sheets
SFA	Singapore Food Agency
SLA	Singapore Land Authority
SW	Southwest

Acronym	Description
TA	Technical Agencies
TMSI	Tropical Marine Science Institute
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TPH	Total Petroleum Hydrocarbons
TPZ	Tree Protection Zones
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
UV	Ultra-Violet
VLCCs	Very Large Crude Carriers
VU	Vulnerable
WSHO	Workplace Safe and Health Officer

1. INTRODUCTION

This document presents the Environmental Impact Assessment (EIA) for the proposed development of a new 670 MW Combined-cycle Gas Turbine (CCGT) and Battery Energy Storage System (BESS) located at Meranti Road, Jurong Island, Singapore (hereafter referred to as the "Project"). The assessment covers the construction and operation phases of the Project. PLM Power Pte Ltd (hereafter referred to as "PLM" or the "Client"), a 100% owned subsidiary of PacificLight Power Pte Ltd (PacificLight), has commissioned Environmental Resources Management (S) Pte Ltd ("ERM") to conduct the EIA for this Project.

This EIA report comprises the following:

- Description of the Project to be assessed in the EIA;
- Outline of the administrative framework;
- An overview of the EIA methodology and scoping process in relation to Project activities and identification of potential impacts;
- Description of the stakeholder engagement process;
- Assessment of the potential impacts on environmental aspects; and
- Formulation of the Environmental Management and Monitoring Plan (EMMP) for the proposed Project phases.

1.1 OVERVIEW OF PROJECT

The Energy Market Authority ("EMA") issued a request for proposal (RFP) on 4 June 2024 for the development of a new combined-cycle gas turbine (CCGT) generating unit with a minimum capacity of 600 MW, targeted to be operational by 2029. PacificLight submitted a bid under the RFP to build, own, and operate a 670 MW facility that integrates a CCGT and a Battery Energy Storage System (BESS). PacificLight was subsequently awarded the Project in December 2024.

1.2 OBJECTIVES OF THE EIA

The EIA aims to assess the pre-construction baseline environmental conditions at the Project sites. It also evaluates potential impacts arising from construction and operational activities, in accordance with the relevant legislation and guidelines. The specific objectives of the EIA are:

- To identify and describe elements of the environment likely to be affected by the Project's construction and operational activities;
- To describe the existing baseline environmental conditions of the Project site and surrounding areas;
- To identify, quantify and assess potential impacts and determine the significance of impacts on sensitive receptors and potentially affected uses according to the defined criteria;
- To propose mitigation measures that minimise any significant impact due to the Project's activities;
- To identify, predict and evaluate residual environmental impacts (after practicable mitigation), and the cumulative effects expected to arise during Project activities and other known concurrent projects in the immediate vicinity of the Project sites (see Section 4.6.5 in relation to the sensitive receptors and potentially affected land uses; and

- To detail the specific mitigation and monitoring measures, as well as the implementation roles and responsibilities for the Project's construction and operational phases, within an EMMP framework.

1.3 SCOPE OF EIA

Consultation during the scoping phase of the EIA was coordinated by EMA, PLM and ERM with various Technical Agencies (TAs) such as the National Environment Agency (NEA), National Parks Board (NParks), Marine Port Authority (MPA) and Singapore Food Agency (SFA). The scope of the EIA was aligned with the TAs[1] (see Section 4.2) for more details on the screening and scoping process of the EIA). During the scoping consultations with TAs, impacts on the following aspects were identified to be taken forward for detailed assessment during the construction and/or operation phases of the Project (see Sections 6 and 7 for further details):

- Marine Water Quality (Operation Phase); and
- Marine Biodiversity (Operation Phase).

The aspects above are not assessed within the regulatory Pollution Control Study (PCS) and Environmental Site Assessment, to be approved by the relevant Government agencies, i.e. National Environment Agency (NEA), Jurong Town Corporation (JTC) and the Singapore Land Authority (SLA).

1.4 LIMITATIONS

1.4.1 ENGINEERING DESIGN AT FEASIBILITY STAGE

This EIA was undertaken at the engineering feasibility stage of the Project and therefore assesses the site layout and features of the plant design available at the time of preparing the EIA. Where detailed engineering design information was not available to inform the study, reasonably conservative assumptions were made, where possible, based on ERM's internal subject matter expertise and in consultation with the Technical Agencies and the Project engineers, drawing on experience from similar projects. Where information was not available, this EIA has considered a reasonable worst-case scenario in the undertaking of the impact assessment, and the development of mitigation measures and monitoring plans for the construction and operational stages of the Project. Key engineering design measures identified through the EIA process have been conveyed to the engineering team for incorporation into the detailed design stage of the Project.

1.4.2 USE OF PRECAUTIONARY APPROACH FOR BIODIVERSITY

Where appropriate, the Precautionary Principle has been adopted in this EIA report. The Precautionary Principle is an approach that recommends anticipatory action be taken, when an activity has the potential to cause harm and there is scientific uncertainty on the subject, including instances where scientific information is lacking. The principle was adopted to overcome the lack of local or international standards/guidelines or scientific studies/data to allow for a quantitative assessment of impacts, such as impacts to biodiversity due from Project activities. This may result in the adoption of a conservative approach in undertaking the assessment and assigning residual (post-mitigation) impact significance. For example, in some

[1] NEA had confirmed that while an EIA is not required, a Pollution Control Study (PCS) will need to be conducted for the plant. PLM will submit a PCS directly to the NEA for their review and approval.

instances, the pre-mitigation impact significance level may be retained even after mitigation measures are applied. This typically occurs when baseline or study data are limited, or when there are uncertainties about the potential impacts over the longer term. Residual impact significance levels are to be validated through the establishment of an extensive long-term EMMP requiring monitoring and data analysis through pre-construction, during construction and post-construction (see Section 8*, Environmental Management and Monitoring Plan Framework)*.

1.5 REPORT STRUCTURE

The remainder of this report is structured as follows:

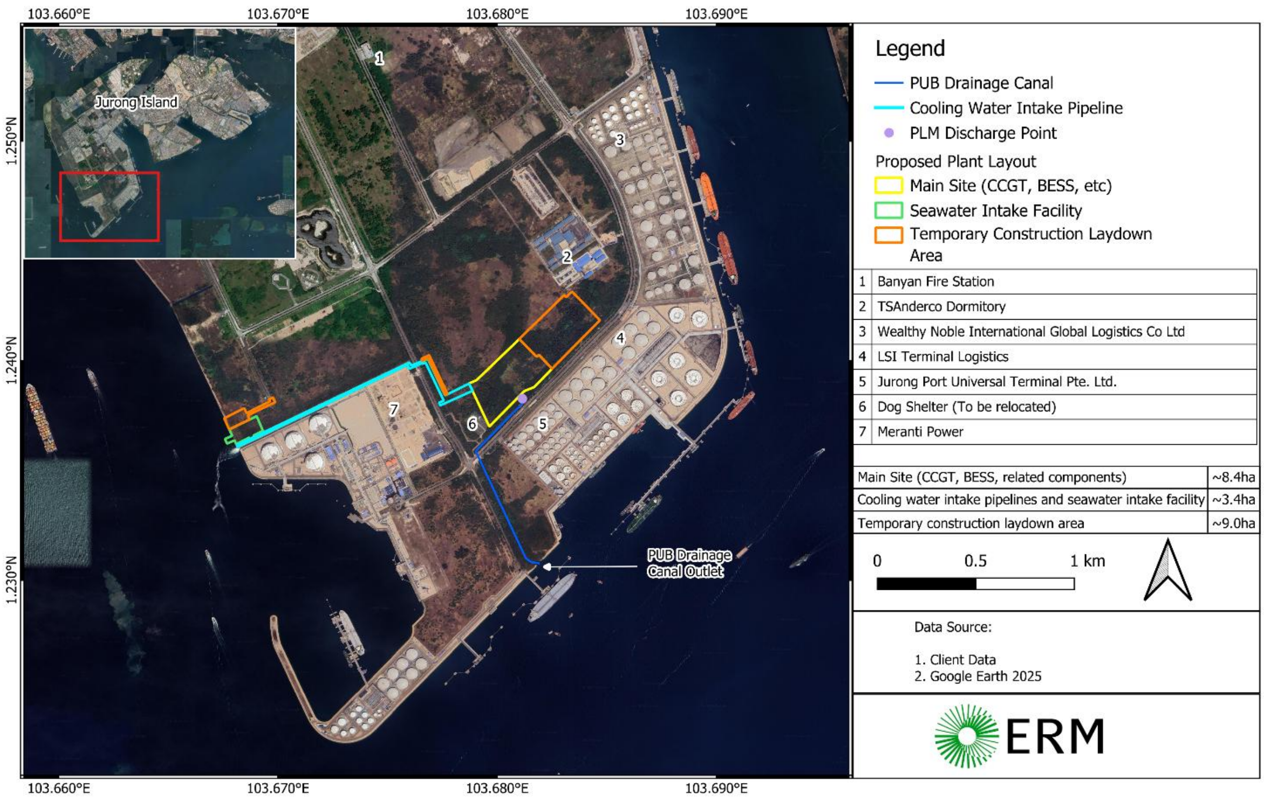
- Section 2: Project Description;
- Section 3: Administrative Framework;
- Section 4: Overview of EIA Methodology and Scoping;
- Section 5: Stakeholder Engagement;
- Section 6: Marine Water Quality;
- Section 7: Marine Biodiversity;
- Section 8: Environmental Management and Monitoring Plan (EMMP);
- Section 9: Conclusion; and
- Section 10: References

2. PROJECT DESCRIPTION

2.1 PROJECT SITE AND SURROUNDINGS

The Project consists of a single 670MW CCGT power generating unit and associated cooling water intake infrastructure with an 80 MW BESS located on reclaimed land at a greenfield site, located at Meranti Road, Jurong Island per Figure 2-1. The operational Project site will occupy a total of 11.8ha with additional temporary construction laydown areas of 9.0ha.

FIGURE 2-1: PROJECT SITE AND SURROUNDINGS



The Project site consists of:

- The main site, which will include the CCGT, Battery Energy Storage System (BESS) and related components (in an area of approximately 8.4ha);
- Cooling water intake and discharge infrastructure (approximately 3.4ha); and
- Temporary construction laydown areas (approximately 9.0ha).

Further details on these Project components can be found in Section 2.2.

During the construction phase various components will be built to support operation of the CCGT and BESS including the seawater intake and outfall structures, a cooling water intake pipe and a vehicle access road.

During operation, the Project will use natural gas as the primary fuel for the gas turbine (GT). Exhaust heat from the GT will be used to generate steam via a heat recovery steam generator (HRSG) which is then used to drive a steam turbine (ST). An 80MW lithium-iron phosphate (LFP) BESS will also be installed to provide dedicated reserve energy for the plant. Wastewater from the closed seawater cooling system will be directed into an existing PUB drain canal, located south of the main site, along Meranti Crescent. The seawater cooling water discharge will flow through the canal and into the Straits of Singapore near the Singapore Refining Co VLCC Terminal.

The Project, located on Jurong Island, is surrounded by industries, vacant land and a dormitory, as shown in the land use map of the site in Figure 2-2. Details of the facilities located near the site can be found in Table 2-1.

FIGURE 2-2: LAND USE AROUND SITE

TABLE 2-1: LIST OF NEARBY FACILITIES

S/N	Name of facility	Type of Business	Direction	Distance (m) from plant Temporary Construction Laydown Area	Distance (m) from plant Operational Area
1	Banyan Fire Station	Infrastructure	Northwest	1,547	1,609
2	TSAnderco Dormitory	Residential	Northeast	5 (near fence line boundary)	324
3	Wealthy Noble International Global Logistics Co. Ltd.	Store	Northeast	717	1,036
4	LSI Terminal Logistics	Store	Southeast	90	269

S/N	Name of facility	Type of Business	Direction	Distance (m) from plant Temporary Construction Laydown Area	Distance (m) from plant Operational Area
5	Jurong Port Universal Terminal Pte. Ltd.	Infrastructure	South	106	106
6	Dog Shelter [(a)]	Animal Shelter	Southwest	420	0 (at fence line boundary)
7	Meranti Power	Infrastructure	West	630	221

Note:

(a) As per the latest information from the EMA, the Dog Shelter will be relocated in Q1 of 2026, prior to the commencement of PLM's construction.

2.2 PROJECT COMPONENT

The Project will comprise the following key components:

1. Main Site
   - 670MW CCGT power generating unit, which will be the largest and most efficient single CCGT facility in Singapore;
   - 80MW lithium-iron phosphate (LFP) BESS which will provide dedicated reserve capacity; and
   - Main entrance along Meranti Road and an emergency pedestrian exit at Meranti Crescent.
2. Temporary Construction Laydown Area adjacent to the main site
   - Temporary laydown area will be used by the contractor for construction equipment and storage. This area will only be used during the construction stage and will be cleared and reinstated after construction has completed;
   - Storage area will be used for bulk material and key equipment storage, steel structures and civil laydown; and
   - It will house the contractor's site offices.
3. Cooling Water Intake Pipeline and PLM Discharge Point
   - The seawater intake facility will channel and filter seawater from the Straits of Singapore to serve as cooling water for plant. A dedicated pump house will be located within this facility to pump seawater to the main site through a dedicated cooling water pipeline. This facility will be located to the north of existing Singapore LNG (SLNG) Terminal, bounding the Singapore Straits;
   - The cooling water pipeline will be laid above ground along a corridor parallel to the northern fence of SLNG and Meranti Power, to Meranti Road and will transport seawater from the intake facility to the main site;
   - The seawater outfall infrastructure includes a culvert that will cross an empty parcel of land, that is designated as a service corridor, at Meranti Crescent. Seawater from the

once-through cooling system will be discharged via this culvert, into the existing PUB canal that runs parallel to Meranti Crescent and then Meranti Road, discharging at the coast next to Singapore Refining Co VLCC Terminal; and

- Temporary laydown area will be established next to the seawater intake facility.

2.3 PROJECT ACTIVITIES

The subsequent sections outline the main project activities during pre-construction, construction, and operation and maintenance phases of the Project. The final design and construction approaches have been determined by considering the boundary limits established in this EIA and other regulatory studies, consultations with government agencies, and detailed engineering design studies. These efforts aim to optimise the Project while minimising impacts on the nearby surroundings, biodiversity, and marine water quality, and ensuring compliance with all relevant local regulations and approvals.

2.3.1 PRE-CONSTRUCTION AND CONSTRUCTION PHASE

2.3.1.1 ONSHORE CONSTRUCTION

The activities which will take place on land during the construction stage will include the following items at the Main Site and Temporary Construction Laydown Areas:

- Pre-construction Site Surveys
  - Soil investigation and CCTV sewerage assessment to ensure sewerage systems are functioning well (e.g. no structural defects and abnormalities in manholes and sewers); and
  - Topographic survey, tree tagging as required and tree assessment will be conducted prior to submitting the application for tree cutting.
- General Site Clearance, Ground Improvement Works and Site Office Works
  - Clearing of trees/vegetation, debris and any unwanted structures;
  - Soil stabilization, erosion control, excavation, grading and compaction of the ground via vibro-compaction;
  - Setting up temporary administrative offices and worker facilities with utilities, e.g. rest areas and sanitary points; and
  - Establishment of temporary and permanent access roads and emergency exits.
- Site Hoarding and Erosion Control Measures (ECM) Construction
  - Erection of site hoarding to demarcate the worksite boundary;
  - Temporary earthworks and erosion control measures;
  - Installation of temporary and permanent retaining structures;
  - Construction of decanting structures, such as tanks, platforms, or discharge points; and
  - Utility and drainage provisions within the site.
- Permanent Structural, Piling and Foundation Schemes
  - Structural schemes including multistorey steel, concrete frames, concrete beams and combined foundation systems; and
  - Foundation, piling and reinforcement works for various equipment e.g. heat recovery steam generator (HRSG) and stack, gas turbine, generator and steam turbine. Foundation schemes (shallow, deep or combined foundations) will depend on the strength of the soil on site.
- Seawater Outfall Structure

  - Construction of seal pit and outfall discharge culvert, connecting to the existing open canal along Meranti Crescent.
- Civil and Structural Works
  - Structural interface involves creating connections between different components of the Project e.g. between mechanical, I&C and electrical systems to ensure proper and safe integration;
  - Civil works include establishment of access roads, with site analysis for road alignment considering topography and drainage. This also includes various drainage systems as noted in item 2 above; and
  - Stormwater drainage systems and landscaping. Stormwater from the plant shall be routed and discharged to the PUB drain, located south of the plant (the same discharge point as the cooling water pipe). Stormwater accumulated at the entrance road will be discharged to the PUB drain located west of the plant (Meranti Road).
- Building Construction
  - Constructing formwork, setting up work platforms, assembling structural frameworks, foundations, installing reinforcement bars, erecting scaffolding, fitting doors and windows, installing gates, performing electrical and cable wiring;
  - Construction of buildings, including the 400kV Gas-Insulated Switchgear (GIS) building, local electrical building, central control building, admin building, workshop and warehouse, GT enclosure, turbine hall firewater pump house, wastewater treatment plant (WTP), gas compressor building, fuel oil storage tanks, demineralised water plant and a guard house; and
  - Installation of mechanical, I&C and electrical equipment for the plant will be carried out.

Cooling Water Intake Infrastructure

- Cooling Water Intake Pipeline/ Advanced Works Construction
  - General site clearance and ground preparation works;
  - Installation, pipelines (e.g. cooling water pipelines which include civil, mechanical & electrical works); and
  - Construction of temporary earth retaining structures or sheet piles.

2.3.1.2 OFFSHORE CONSTRUCTION

Cooling Water Infrastructure

- Foreshore Seawater Intake Facility

The foreshore seawater intake facility will pump seawater into the cooling/circulating water system. The seawater will be pumped via a dedicated pipe to the plant along the corridor to the main plant at Meranti Road. Intake structures, including travel screens to prevent debris entering the cooling system, will be installed. The seawater intake facility will consist of an inlet channel, main cooling water pumps, electro chlorination plant, intake electrical building, wash water booster pump and other associated equipment for the cooling water intake infrastructure. The construction of the foreshore seawater intake facility will involve:

- Site Preparation and Surveys
  - Conducting geotechnical and hydrographic surveys.

1. Piling Works (utilising a cofferdam[2]);
2. Establishment, dewatering (if required) and excavation of cofferdam with sheet piles; and
   - Permanent bearing piles or bored piles per design specifications to support the intake structure.
- Foundation and Structure Construction
3. Prepare seabed (e.g. rockfill); and
   - Construct the intake structure foundation and any connecting pipework.

- Testing and Commissioning
  - Testing and commissioning of all equipment will be carried out prior to commencing full operation of the plant.

2.3.2 OPERATION PHASE

During the operation phase the plant will generate electricity for Singapore consumers.

2.3.2.1 POWER GENERATION

1. Gas Turbine (GT)
   - Consists of a high efficiency compressor, combustor, and high efficiency turbine; and
   - Ambient air enters the compressor where it is pressurized, then sent to the combustor to mix with fuel and ignite. The resulting high-temperature gases expand through the turbine, generating mechanical energy to drive the compressor and an electric generator. The exhaust gases are then released into the Heat Recovery Steam Generator.
2. Heat Recovery Steam Generator (HRSG)
   - Uses hot exhaust gases from the gas turbine to heat feedwater and generate superheated steam which drives the steam turbine;
   - Cooled exhaust gases exit via a stack, equipped with a silencer to attenuate noise; and
3. Stack design features a 65-meter single steel flue stack with dampers.
4. Steam Turbine (ST)
   - Turns steam energy from the HRSG into mechanical power to generate electricity; and
   - High-pressure steam enters and expands, losing energy. It is then reheated at the HRSG and further expanded in the intermediate stage. Finally, the steam mixes with the low-pressure steam from the HRSG and is expanded into the low-pressure section of the turbine before entering the condenser.
5. Battery Energy Storage System BESS
   - A BESS will be used as a reserve for unplanned outages and during fuel changeover.
6. The CCGT plant will be 670 MW, with an 80 MW BESS installed to provide dedicated reserve energy

[2] A temporary, sealed-off enclosure built in a body of water to create a dry work environment for construction

- In case of a CCGT trip, the BESS will instantly provide reserve capacity. In addition, the BESS will be used during fuel change over from gas to liquid fuel via an integrated energy management system and distributed control system (DCS).

2.3.2.2 WASTEWATER TREATMENT

Any discharge (including spill, leakage, cleaning water) from the chemical storage area and chemical feed areas will be collected in a chemical storage area equipped with a secondary containment bund in place (sized to be 100% of the largest storage capacity). Collected wastewater will be routed to the neutralization pit to adjust the pH value to between 6 and 9. The pit will be equipped with a level switch to prevent overflow. After adjustment of pH value, the wastewater will be routed to a holding point and eventually discharged to the PUB wastewater network via the PLM discharge point (per Figure 2-1) after meeting regulatory limits.

Oily water discharge (including spills, leakages, overflows, and stormwater) from the Demineralised Water Pump Area, Fuel Oil Area, Compressor Area, Gas Turbine Area, Steam Turbine Area, and HRSG area will first be routed to a plant sump with a level switch to prevent overflow. It will then be routed to an Oil Water Separator to remove oil waste from the water. The Oil waste will be collected by a licensed third-party contractor for off-site treatment, while the water will be discharged to the public stormwater drain at the PLM discharge point (per Figure 2-1) after meeting regulatory limits.

2.3.2.3 COOLING WATER SYSTEM

Seawater will be drawn from a dedicated intake structure and conveyed through a cooling water pipe to the condenser. After passing through the condenser, the cooling water will be discharged via a dedicated line into a seal pit. The discharge characteristics of the cooling water will adhere to NEA’s permissible limits before discharging into the PUB drain canal. The seawater will be discharged into a culvert, which connects to the existing canal that flows beside Meranti Crescent. The canal flows westward along Meranti Road, located to the south of the main site.

2.4 SCHEDULE

2.4.1 PRE-COSTRUCTION AND CONSTRUCTION PHASE

The indicative programme for construction works, along with the anticipated duration and timeframe for these construction activities are summarised in Table 2-2. The pre-construction works of the Project, comprising non-invasive activities, such as surveys, will take place from 2025 to 2026. Construction is expected to take approximately 3 years, continuing until 2029, including testing and commissioning.

TABLE 2-2: INDICATIVE SCHEDULE FOR PRE-CONSTRUCTION AND CONSTRUCTION WORKS

			2025				**2026**				**2027**				**2028**				**2029**			
S/N	Activity	No. of Months	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Pre-construction Site Surveys	8	*																			
2	General Site Clearance/ Ground Improvement Works	2																				
3	Site Hoarding and ECM Construction	2																				
4	Permanent Structural, Piling and Foundational Schemes	27																				
5	Seawater Outfall Structure	8																				
6	Civil and Structural Works	12																				

			2025				**2026**				**2027**				**2028**				**2029**			
7	Building Construction	16																				
8	Cooling Water Intake Pipelines/ Advanced Works	6																				
9	Foreshore Seawater Intake Facility	16																				
10	Testing and Commissioning	29																				

Notes:
Schedule is tentative and based on data provided by PLM at the time of writing. Actual dates may vary.

2.4.2 OPERATION PHASE

Based on the anticipated construction commencement and duration, operation of the CCGT plant is expected to commence in 2029 and operate on a daily basis, except during routine maintenance, with an estimated design lifespan of 25 years.

Decommissioning of the CCGT plant is not included within the scope of this EIA.

2.5 EMBEDDED CONTROLS

Embedded controls are defined as measures (physical or procedural) that are planned to be put in place as part of the Project design, construction and operation from the outset. The Project description presented herein includes a number of embedded controls that will protect against potential impacts to the environment. The embedded controls are predominantly based on the regulatory requirements and industry standards. Embedded controls for environmental impacts that are both scoped in and out of this EIA are available are presented in Appendix A.

3. ADMINISTRATIVE FRAMEWORK

3.1 NATIONAL PLANS

In addition to the Singapore Government plans discussed in Section 1, the following national level plans are also of relevance to this Project and for the management of land use in Singapore:

- **Singapore Green Plan 2030[3]:** sets out goals to achieve the long-term net zero emissions aspiration to tackle climate change, including the "Energy Reset" pillar, which targets increased efficiency of gas-fired power plants to reduce emissions;
- **National Hydrogen Strategy 2022[4]:** Utilising low-carbon fuels such as hydrogen as a future decarbonisation pathway, encouraging the development of CCGTs which are able to combust a blend of hydrogen and natural gas and eventually have the ability to run on 100% hydrogen gas; and
- **Sustainable Singapore Blueprint 2015[5]**: sets out targets to be achieved by 2030 for factors contributing to a sustainable and resource-efficient city. For the energy sector, it aims to reduce air pollution, achieve emission standards, and support the adoption of clean and innovative energy.

3.2 SINGAPORE ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REQUIREMENT

As a requirement by the Singapore authorities, new developments are required to undertake an EIA scoping exercise in consultation with technical agencies to determine the potential risk and environmental impacts before the development is allowed to proceed. Relevant technical agencies including NEA, NParks, SFA, and MPA, have been engaged for this Project and an EIA was determined to be required, with the scope set out in Section 4.

3.3 LOCAL LEGISLATION & STANDARDS

Singapore adopts a systematic framework to determine and mitigate the potential impact of any new development on the environment. A rigorous evaluation process is in place for any new development to identify its impact on traffic, public health, heritage, and the environment. Development projects in close proximity to sensitive nature areas are also subject to thorough reviews, with a requirement for environmental studies to be conducted if necessary. Outcomes of all environmental studies (if deemed necessary) are carefully considered, in order to determine the extent of potential impacts and the adequacy of proposed mitigation and monitoring measures, before a development is allowed to proceed.

Environmental management requirements are interspersed through different Acts and Regulations, such as the protection of natural areas and wildlife (nature conservation laws). The Acts and Regulations, as well as local guidelines that have been reviewed and referenced in the EIA, are summarised in Table 3-1 below. Per Section3, legislation and guidelines for environmental aspects such as air quality, airborne noise, vibration, surface water quality, light, vector control and waste management will be included as part of embedded controls to be

[3] Singapore Green Plan 2030
[4] https://www.mti.gov.sg/Industries/Hydrogen
[5] ssb-2015-(2016-version).pdf

followed within the Environmental Management and Monitoring Plan (EMMP) but will not form part of the impact assessment.

The selection of a standard/guidelines for scoped in environmental aspects (marine water quality and biodiversity) related to the Project, depend on details which have been identified as the studies progressed, such as the environmental baseline; the sensitivities identified; and the engineering design. The relevant regulatory framework for each environmental aspect is described in the relevant impact assessment sections.

TABLE 3-1: SUMMARY OF KEY RELEVANT SINGAPORE LEGISLATION & GUIDELINES

Subject	Legislation/Regulations/ Guidebooks	Responsible Agency
General	• Environmental Protection and Management Act 1999, 2020 revised edition • Environmental Public Health Act 1987, 2020 revised edition • SS 593:2013 Singapore Standard on Code of Practice for Pollution Control • Wildlife Act 1965, 2020 revised edition	• National Environmental Agency (NEA) • National Parks Board (NParks)
Ambient Air Quality	• Environmental Protection and Management (Vehicular Emissions) Regulations (Amendment), 2023 • Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 • Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations, 2012 • Environmental Protection and Management (Prohibition on Use of Open Fires) Order, 2008 revised edition • Environmental Public Health Act (EPHA), (Amendment), 2022 • NEA Code of Practice for Environmental Control Officers for Construction Sites, 2021 • NEA Singapore Ambient Air Quality Targets (AAQTs), 2020	• NEA
Airborne noise pollution	• Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 • Environmental Protection and Management (Control of Noise at Construction Site) Regulations (Amendment), 2011 • Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations, 2008 • Environmental Protection and Management (Vehicular Emissions) Regulations (Amendment), 2023 • Environmental Public Health Act (EPHA), (Amendment), 2022 • NEA's Code of Practice for Environmental Control Officers for Construction Sites, 2021 • Singapore Standards SS602:2014 Code of Practice for Noise Control on Construction and Demolition Sites, 2014 • Singapore Standards SS593: 2013 Code of Practice for Pollution Control (COPPC) • SS 602:2014 Singapore Standard on Code of Practice for Noise Control on Construction and Demolition Sites	• NEA

Subject	Legislation/Regulations/ Guidebooks	Responsible Agency
	• LTA Guidebook for Best Environmental Practices Noise Control at LTA Sites (2013)	
Surface Water Quality	• Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 • NEA Allowable Limits for Trade Effluent Discharge to Watercourse or Controlled Watercourse under the Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 • Environmental Protection and Management (Trade Effluent) Regulations, (Amendment), 2011 • Environmental Protection and Management (Hazardous Substances) Regulations, 2008 • Environmental Public Health Act (EPHA), (Amendment), 2022 • Environmental Public Health (Toxic Industrial Waste) Regulations (Amendment), 2022 • Environmental Public Health (General Waste Collection) Regulations (Amendment), 2019 • Fire Safety Act (Amendment), 2022 • Sewerage and Drainage Act (Chapter 294) (Amendment), 2021 • Sewerage and Drainage (Surface Water Drainage) Regulations, 2007 • Sewerage and Drainage (Trade Effluent) (Amendment) Regulations, 2022 • NEA's Code of Practice for Environmental Control Officers for Construction Sites, 2021 • PUB Code of Practice on Sewerage and Sanitary Works, 2nd Edition, 2019 • PUB Code of Practice on Surface Water Drainage, 7th Edition December 2018 • PUB Guidebook on Erosion and Sediment Control at Construction Sites, 2018 • PUB's Handbook on Managing Urban Runoff, 2nd Edition, 2024 • Singapore Standard SS 593: 2013 Code of Practice for Pollution Control (COPPC), 2013 • Singapore Standard SS 603: 2014 Code of Practice for Hazardous Waste Management, 2014	• NEA • Public Utility Board (PUB) • NParks
Light	• Light Management in Night Works technical note (under Biodiversity Impact Assessment Guidelines, 2024)	• NParks
Soil and Groundwater quality	• Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 • Environmental Protection and Management (Hazardous Substances) Regulations (Amendment), 2021 • Environmental Protection and Management (Trade Effluent) Regulations, 2008 • Environmental Public Health Act (EPHA) (Amendment), 2022 • Environmental Public Health (Toxic Industrial Waste) Regulations (Amendment), 2022 • Environmental Public Health (General Waste Collection) Regulations (Amendment), 2019 • Sewerage and Drainage Act (Surface Water Drainage) Regulations, 2007 • Fire Safety (Petroleum and Flammable Materials) Regulations (Amendment), 2022	• NEA • PUB

Subject	Legislation/Regulations/ Guidebooks	Responsible Agency
	• Fire Safety (Petroleum and Flammable Materials – Exemption) Order (Amendment), 2020 • Singapore Standard SS593: 2013 Code of practice for pollution control (COPPC)	
Waste Management	• Environmental Public Health Act (EPHA) (Amendment), 2022 • Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 • Environmental Protection and Management (Hazardous Substances) Regulations (Amendment), 2021 • Environmental Public Health (Toxic Industrial Waste) Regulations (Amendment), 2022 • Environmental Public Health (General Waste Collection) Regulations (Amendment), 2019	• NEA
Vibration	• N/A	
Vector Control	• Environmental Public Health Act (EPHA) (Amendment), 2022 • Infectious Diseases Act (IDA) (Amendment), 2022 • Control of Vectors and Pesticides Act (Chapter 59) (Amendment), 2021 • NEA's Code of Practice for Environmental Control Officers for Construction Sites, 2021	• NEA
Marine Environment	• Prevention of Pollution of the Sea Act 1990 • Environmental Protection and Management Act 1999 • NEA Allowable Limits for Trade Effluent Discharge to Watercourse or Controlled Watercourse under the Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 • Environmental Protection and Management (Trade Effluent) Regulations, (Amendment), 2011 • MPA General Guidelines on Requirements for Dredging and Dumping Works	• Maritime & Port Authority of Singapore (MPA) • NEA
Parks, tree and flora protection	• Parks and Trees Act (Amendment), 2024 • Public Utilities (Reservoir and Catchment Areas and Waterway) Regulations, 2018 • National Parks Board Guidelines on Greenery Provision and Tree Conservation for Developments, 2018	• NParks
Biodiversity Impact Assessment	• Biodiversity Impact Assessment Guidelines (2024) • Wildlife Act, 1965 (Revised edition 2020) • National Biodiversity Strategy and Action Plan (NBSAP), 2019 • Nature Conservation Master Plan (NCMP), 2015 • Biodiversity Impact Assessment (BIA) Guidelines, 2024 • Singapore Red Data Book (2^{nd} Edition, 2008; and 3^{rd} edition, 2024)	• NParks
Animal/ wildlife/ fauna protection	• Wild Animals and Birds Act (Amendment), Chapter 351, 2020 (Also known as Wildlife Act)	• Animal & Veterinary Service (AVS)

Subject	Legislation/Regulations/ Guidebooks	Responsible Agency
Hazardous chemical	• Environmental Protection and Management (Hazardous Substances) Regulations, 2008 revised edition • Fire Safety Act 1993, 2020 revised edition • Fire Safety (Petroleum and Flammable Materials) Regulations, 2008 revised edition	• NEA, • SCDF

3.4 OTHER GUIDANCE DOCUMENTS

Other international guidance documents that have been reviewed to inform this study are summarised as follows:

- Marine Water Quality and Biodiversity:
  - ASEAN Marine Water Quality Criteria (2008); and
  - US Environmental Protection Agency Quality Criteria for Water (1986).
- Biodiversity:
  - International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN) (2023); and
  - United Nations Convention on Biological Diversity (UNCBD) (1993).

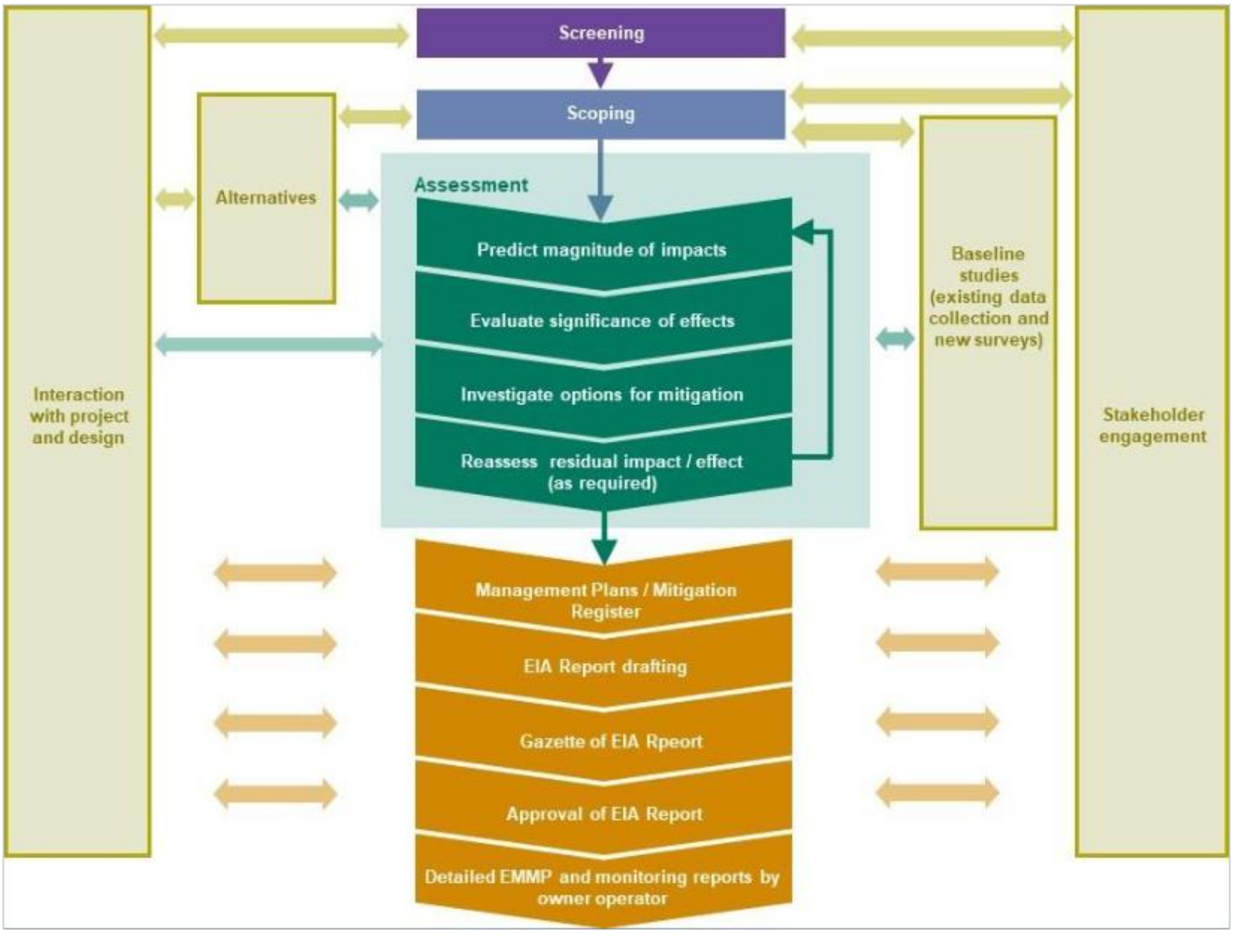
4. EIA METHODOLOGY & SCOPING

4.1 OVERVIEW

This EIA is conducted following ERM's Impact Assessment (IA) Standard. This IA Standard has been developed based on ERM's extensive experience across a wide variety of projects globally, as well as its involvement in developing EIA legislation, frameworks and guidelines for government bodies over the last 50 years. It is generally consistent with most international standards, such as the World Bank and International Finance Corporation (IFC) Performance Standards with regard to environmental, social, and health performance, and is considered best practice. It deliberately provides overarching guiding principles that can be tailored to specific IA cases. Over the last two decades, ERM has successfully applied the ERM IA Standard to numerous project EIAs both globally and within Singapore, including several publicly gazetted EIAs in Singapore.

The IA has been undertaken following a systematic process that predicts and evaluates the potential impacts from the Project on aspects of the physical and biological environment and identifies measures that the Project will take to avoid, minimise/reduce, mitigate, offset or compensate for adverse impacts and to enhance positive effects where practicable. The stages of the IA process from ERM's IA standard which will be applied to the Project are described below in Figure 4-1.

FIGURE 4-1: IMPACT ASSESSMENT STAGES



Note: "Management plans/mitigation register" encompasses a range of environmental management plans *and environmental monitoring plans depending on the assessment outcome and legislative requirements. Source: ERM*

4.2 SCREENING & SCOPING

As mentioned in Section 1.3, consultation with Technical Agencies (TAs) and government agencies including NParks, NEA, SFA, MPA, MND, and URA took place during the screening and scoping stages of the EIA. During the screening phase, it was concluded that a full EIA would be required for this Project. During the scoping phase, it was aligned with the TAs that the scope of the EIA would include the assessment of potential Project impacts on:

- Marine Biodiversity (Operation Phase); and
- Marine Water Quality (Operation Phase).

For environmental aspects not assessed within this EIA (including air quality, airborne noise and vibration), it was agreed by the TAs that a Pollution Control Study (PCS) would be conducted to assess the potential environmental impacts of air pollution, noise pollution, surface water discharge, soil and groundwater contamination, waste management and hazardous chemical management during project operation. Therefore, these environmental aspects have not been included within this EIA study. At the time of writing, the PCS is under development following the Singapore Guidelines for Pollution Control Study (2025). The PCS will be submitted to the NEA for their review and approval.

In relation to terrestrial biodiversity, the site was reclaimed from 1995 and was completed in 2009 (16 years ago) from several offshore islands (Ayer Islands). The site is currently dominated by open grasslands and young exotic-dominated secondary regrowth (e.g. Acacia and Lead trees). Based on a review of the present condition of the vegetation and habitat, as well as the fauna that will likely be present on site, it is considered that potential impacts to terrestrial biodiversity can be managed through the development and implementation of terrestrial biodiversity measures in the environmental management and monitoring plan (EMMP); hence in consultation with TAs, the assessment of impacts to terrestrial biodiversity has been scoped out of this EIA. Nonetheless, to support the development of appropriate EMMP measures for terrestrial biodiversity, PLM and ERM have conducted a rapid terrestrial biodiversity survey which is detailed in Appendix B. The detailed findings have been used to inform the EMMP (see Section 8).

Additionally, it was also agreed with the TAs that the Project would develop a construction-phase environmental management and monitoring plan (cEMMP) prior to the commencement of Project construction. This document will detail the steps to be taken to minimize potential environmental impacts caused by construction activities. The cEMMP will include control measures and monitoring requirements for air emissions (dust), airborne noise emissions, surface water quality, marine water quality, marine biodiversity, waste management and vector control. Therefore, these environmental aspects have been scoped out from further impact assessment but have been included in the Environmental Management and Monitoring Plan (Section 8).

The following environmental aspects, shown in Table 4-1, have been identified that could result in significant impacts during Project construction and/or operation. Further details on the steps to conduct the impact assessment are provided in Section 4.6 below.

TABLE 4-1: ENVIRONMENTAL ASPECTS AND POTENTIAL IMPACTS CONSIDERED IN SCOPING

Environmental Aspects	Project Phase	Potential Impacts
Marine Water Quality	Operation	Treated wastewater/effluent discharge from the outfall during Project operation could potentially result in changes to physical, chemical or biological quality of marine water quality.
Marine Biodiversity	Operation	The outfall discharge during Project operation could potentially influence the health of the surrounding marine ecosystem and potentially affect productivity of aquaculture facilities.

4.3 AREA OF INFLUENCE

The Area of Influence (AOI) is defined broadly as the area that is likely to be affected due to direct, indirect, and cumulative effects from the Project. It is derived for the purpose of baseline establishment and impact assessment on various environmental receptors within the AOI. The AOI and the Project footprint constitutes the Study Area of the EIA, which is used to understand the baseline conditions likely to be affected by the Project.

The AOI (and thus the Study Area) distance varies across different environmental aspects, depending on the nature of specific impacts to potential environmental receptors. For this reason, the EIA Study Area has been defined for each environmental aspect (i.e., marine water quality and marine biodiversity) and assessed respectively in the subsequent chapters (Sections 6 to 8).

4.4 BASELINE ENVIRONMENT

To provide an environmental baseline against which the impacts of the Project can be assessed, this EIA describes the current environmental conditions that are assumed will prevail in the absence of the Project. The baseline includes information on receptors and resources identified as having the potential to be affected by the proposed Project, as defined for each environmental aspect. The description of the baseline has the following objectives:

- To identify the key environmental conditions in areas potentially affected by the Project and highlight those that may be vulnerable to aspects of the Project;
- To describe and, where possible, quantify, their characteristics (such as nature, condition, quality, extent) in the absence of the Project;
- To provide data to aid the prediction and evaluation of possible impacts; and
- To inform ERM’s assessment of the significance of potential impacts.

The baseline environmental setting was developed through gathering and review of existing information (also referred to as secondary information) from various sources and field surveys (primary information). Existing information was gathered from in-house databases, online sources, publications, library resources and Technical Agencies including MPA, NEA and NParks.

Baseline surveys related to the scoped in aspects (conducted over the period July to August 2025) as well as research of publicly available sources were conducted by ERM to understand the characteristics within the Project Study Area related to:

- Marine Biodiversity (plankton and macrobenthos);
- Marine Water Quality;
- Marine Sediment Quality; and
- Terrestrial Biodiversity (flora and fauna such as birds, herpetofauna, and mammals)[6].

Details of the baseline survey methodology were discussed and aligned with the TAs during the EIA scoping exercise. This included survey duration, number of sampling locations/number of transects, sampling parameters, and applicable guidelines. Further details on the baseline are provided within the relevant sections and related appendices of this EIA, alongside the results and analysis of the baseline surveys and desktop research.

4.5 STAKEHOLDER ENGAGEMENT

An effective impact assessment process requires engagement with relevant stakeholders during the EIA stage. This assists in understanding stakeholder views on the Project and in identifying issues that should be taken into account in the evaluation of impacts. It also supports the development of appropriate mitigation and enhancement measures, where appropriate. Section 5 outlines the stakeholder engagement activities carried out for the Project with Government agencies and other stakeholders, such as Nature Groups.

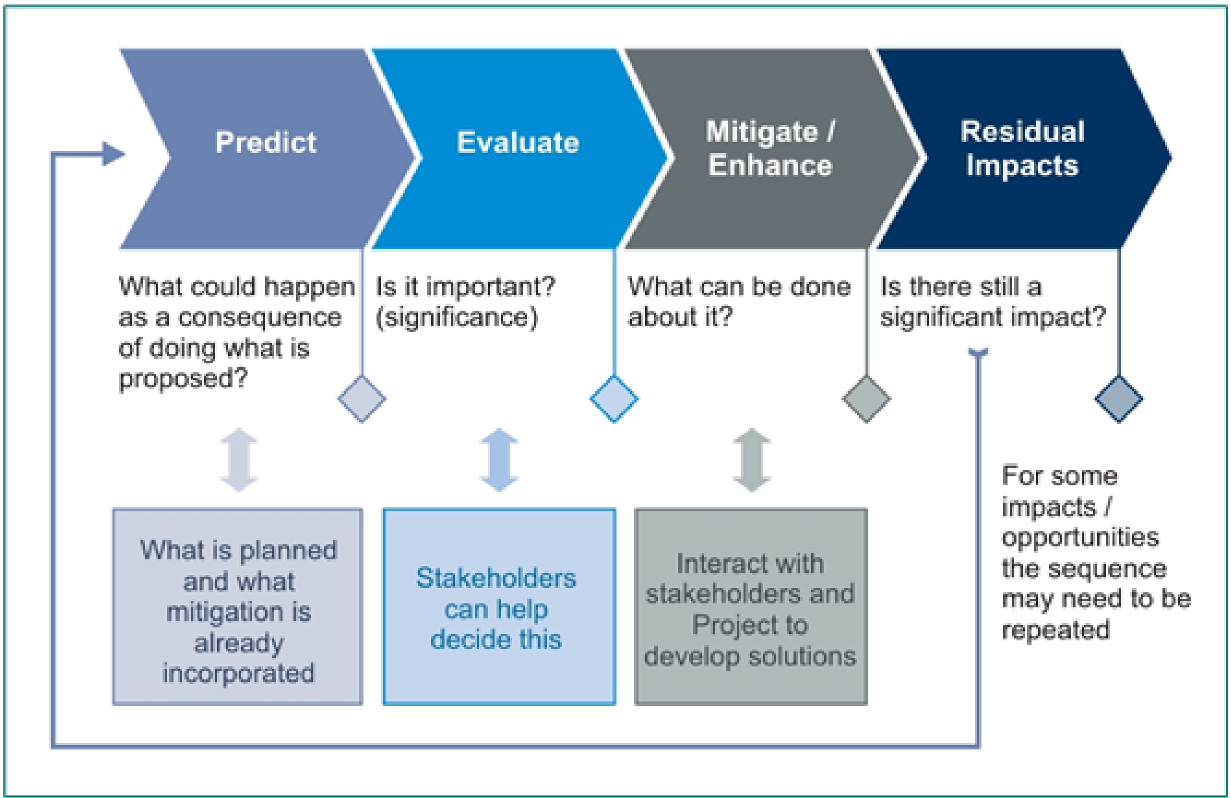
4.6 IMPACT ASSESSMENT

The assessment of impacts involved an iterative process considering four questions as illustrated in Figure 4-2. The following sections describe ERM's standard IA steps, comprising:

- **Impact prediction:** to determine what could potentially happen to resources/receptors as a consequence of the Project and its associated activities;
- **Impact evaluation:** to evaluate the significance of the predicted impacts by considering their magnitude and likelihood of occurrence, and the sensitivity, value and/or importance of the affected resource/receptor;
- **Mitigation and enhancement:** to identify appropriate and justified measures to mitigate negative impacts and enhance positive impacts; and
- **Residual impact evaluation:** to evaluate the significance of impacts assuming effective implementation of mitigation and enhancement measures.

[6] Additional survey conducted beyond the scope of the EIA requirements.

FIGURE 4-2: PROCESS OF PREDICTION, EVALUATION AND MITIGATION OF IMPACTS



4.6.1 PREDICTION OF IMPACT MAGNITUDE

Prediction of impacts is essentially an objective exercise to determine what is likely to happen to the environment as a consequence of the Project and its associated activities. From the potentially significant interactions identified during Scoping, the impacts on the various resources/receptors are elaborated and evaluated.

The range of potential impacts considered in the impact assessment process resulted in a diverse variety of prediction methods being used, including quantitative, semi-quantitative and qualitative techniques.

During the EIA scoping exercise meetings with the TAs, the proposed prediction methods were discussed and aligned.

4.6.2 EVALUATION OF IMPACT SIGNIFICANCE

The next step in the assessment process was to use the information describing the magnitude of an impact and explain what this meant in terms of its importance to the environment (e.g. biodiversity), by considering the assigned impact magnitude and the sensitivity of potentially impacted receptors.

4.6.2.1 IMPACT MAGNITUDE

Impact magnitude describes the intensity of the change predicted to occur in the resource or receptor as a result of the impact. It is typically a function of a combination (depending on the resource or receptor in question) of the following impact characteristics: type, extent, duration, scale, and frequency. The type designations and definitions are shown in Table 4-2 and Table 4-3 respectively.

TABLE 4-2: IMPACT CHARACTERISTIC TERMINOLOGY

Characteristic	Definition	Designations
Type	A descriptor indicating the relationship of the impact to the Project (in terms of cause and effect).	Direct; Indirect; Induced
Extent	The "reach" of the impact (e.g. Projected for several kilometres, etc.).	Local; Regional; International
Duration	The time period over which a resource / receptor is affected.	Temporary; Short-term; Long-term; Permanent
Scale	The size of the impact (e.g. the size of the area damaged or impacted, the fraction of a resource that is lost or affected, etc.)	No fixed designations; intended to be a numerical value or a qualitative description of "intensity"
Frequency	A measure of the constancy or periodicity of the impact.	No fixed designations; intended to be a numerical value or a qualitative description

TABLE 4-3: IMPACT TYPE DEFINITIONS

Designations	Definition
Type	
Direct	Impacts that result from a direct interaction between the Project and a resource/receptor (e.g. between occupation of a plot of land and the habitats which are affected).
Indirect	Impacts that follow on from the direct interactions between the Project and its environment as a result of subsequent interactions within the environment (e.g. viability of a species population resulting from loss of part of a habitat because of the Project occupying a plot of land).
Induced	Impacts that result from other activities (which are not part of the Project) that happen as a consequence of the Project (e.g. influx of informal business (such as food stalls) resulting from the importation of a large Project workforce).

As discussed above, the magnitude designations adopted are universally consistent, however their designations vary on a resource/receptor-by-resource/receptor basis. The universal magnitude designations are:

- Positive;
- Negligible;

- Small;
- Medium; and
- Large.

In the case of a positive impact (i.e. benefit), no additional magnitude designation (aside from 'positive') is assigned. It is considered sufficient for the purpose of this EIA to indicate that the Project is expected to result in a positive impact, without characterising the exact degree of positive change likely to occur.

4.6.2.2 RECEPTOR SENSITIVITY

In addition to characterising the magnitude of impact, the other principal impact evaluation step is to define the sensitivity, vulnerability or importance of the potentially impacted resource or receptor. A range of factors were considered when defining the sensitivity, vulnerability, or importance of the resource or receptor, such as legal protection, government policy, stakeholder views and economic value. The sensitivity, vulnerability, or importance designations used herein for all resources or receptors are:

- Low;
- Medium; and
- High.

4.6.2.3 IMPACT SIGNIFICANCE

The impact magnitude and sensitivity of a resource or receptor were considered in combination to evaluate whether an impact was significant, and if so, its degree of significance. Impact significance was designated using the matrix shown in Table 4-4, with mitigation measures required when the assessed impact significance is Moderate or higher.

TABLE 4-4: MATRIX FOR EVALUATION OF IMPACT SIGNIFICANCE

		Sensitivity/Vulnerability/Importance of Resource/Receptor		
		Low	**Medium**	**High**
Impact Magnitude	**Negligible**	Negligible	Negligible	Negligible
	Small	Negligible	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major

The matrix applies universally to all resources/receptors, and all impacts on these resources/receptors, as the resource/receptor-specific considerations are factored into the assignment of magnitude and sensitivity/vulnerability/importance designations. Figure 4-3 provides a context for what the various impact significance ratings signify.

FIGURE 4-3: CONTEXT OF IMPACT SIGNIFICANCES

An impact of **Negligible significance** is one where a resource/receptor will essentially not be affected in any way by a particular activity or the predicted effect is deemed to be 'imperceptible' or is indistinguishable from natural background variations.
An impact of **Minor significance** is one where a resource/receptor will experience a noticeable effect, but the impact magnitude is sufficiently small and/or the resource/receptor is of low sensitivity/ vulnerability/ importance. In either case, the magnitude should be well within applicable standards.
An impact of **Moderate significance** has an impact magnitude that is within applicable standards but falls somewhere in the range from a threshold below which the impact is minor, up to a level that might be just short of breaching a legal limit. Clearly, to design an activity so that its effects only just avoid breaking a law and/or causing a major impact is not best practice. The emphasis for moderate impacts is therefore on reducing them to a level that is as low as reasonably practicable (ALARP). This does not mean that impacts of moderate significance have to be reduced to minor, but that moderate impacts are being managed effectively and efficiently.
An impact of **Major significance** is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors. An impact of **Critical significance** has a similar definition but is only applicable to the biodiversity assessment and when large magnitude impacts interact with critical habitats [(1)]. The aim of an impact assessment is to get to a position where the Project does not have any major residual impacts, certainly not ones that would endure into the long-term or extend over a large area. However, for some aspects there may be major residual impacts after all practicable mitigation options have been exhausted (i.e. ALARP has been applied). An example might be the visual impact of a facility. It is then the function of regulators and stakeholders to weigh such negative factors against the positive ones, such as employment, in coming to a decision on the Project.

4.6.3 MITIGATION & ENHANCEMENT

Once the significance of the impacts was characterized, the need for and type of mitigation and enhancement measures required to meet the applicable standards were considered. For the purposes of this EIA, ERM has adopted the following mitigation hierarchy:

- **Avoid at source, reduce at source:** avoiding or reducing at source through the design of the Project;
- **Abate on site:** add something to the design to abate the impact (e.g. pollution control equipment, traffic controls etc.);
- **Abate at receptor:** if an impact cannot be abated on-site, then control measures can be implemented off-site;
- **Repair or remedy:** some impacts involve unavoidable damage to a resource and can be addressed through repair, restoration or reinstatement measures; and

- **Compensate in kind, compensate through other means:** where other mitigation approaches are not possible or fully effective, then compensation for loss, damage and disturbance might be appropriate.

4.6.4 ASSESSING RESIDUAL IMPACTS

Once mitigation and enhancement measures were identified, the next step in the impact assessment process was to assign residual impact significance. This step essentially repeats the impact assessment process discussed above, taking into account the implementation of the proposed mitigation and enhancement measures.

4.6.5 CUMULATIVE IMPACTS

A cumulative impact arises as a result of an impact from the Project interacting with an impact from another activity to create an additional impact. It is noted that the assessment of cumulative impacts is strongly influenced by the status of other developments (already ongoing or committed i.e., approved or proposed) and the availability of data about them.

The impact assessment process itself is broadly similar to that presented herein, i.e., scoping to define the ongoing/committed developments; level of information available; potential interactions; baseline data gathering which is usually captured in the study area of the project; impact assessment to determine the magnitude and significance of impacts considering the vulnerability of the resources and receptors and their limits of acceptable change; and development of any management and monitoring measures to mitigate significant impacts.

Information on other project developments near the Project area was not available at the time of writing. Consequently, cumulative impact assessments have not been included in this EIA due to the lack of data. This Project should be evaluated under the cumulative impact assessments within these other project's EIAs.

4.7 MANAGEMENT & MONITORING

The final stage in the impact assessment process was the definition of basic management and monitoring measures. These were needed to ascertain if impacts or their associated Project components remain in conformance with applicable standards, and if mitigation measures are effectively addressing impacts or reducing effects to the extent predicted. An EMMP was developed accordingly and is presented in Section 8 of this report.

5. STAKEHOLDER ENGAGEMENT

5.1 OVERVIEW

Stakeholder engagement is an integral part of the EIA process. It enables the sharing of information and knowledge and supports a collaborative approach to problem-solving and decision-making.

Stakeholders are defined as "persons or groups who are directly or indirectly affected by a project, as well as those who may have interests in a project and/ or the ability to influence its outcome, either positively or negatively" (IFC, 2007). The primary objectives of stakeholder engagement are to:

- Ensure that adequate information is provided in a timely manner to those interested in or affected by the Project;
- Ensure that identified stakeholders are provided with sufficient opportunities to voice their opinions and concerns; and
- Ensure that stakeholder feedback is received and considered in Project decisions.

For this Project, a systematic process was undertaken to first develop an understanding of the issues, identify selected stakeholders, and allow these stakeholders to participate in the process of developing the EIA.

5.2 STAKEHOLDER ENGAGEMENT

To establish a local context and understanding of stakeholders in Singapore for the Project, a desktop review was undertaken of potentially interested parties related to the Project and its site and surroundings.

5.2.1 IDENTIFIED STAKEHOLDERS

Project stakeholders identified were grouped into the following categories:

- Government Agencies (e.g. URA, MND) and Technical Agencies (e.g. MPA, SFA, NEA, and NParks);

1. Adjacent Facilities, including Jurong Port Universal Terminals (JPUT), Meranti Power and Singapore LNG Corporation Terminal;
2. Local Nature Groups (NGs), Non-Government Organisations (NGOs), Independent Interest Groups, and Independent Academics/ Professionals; and
3. General Public.

5.3 ENGAGEMENT ACTIVITIES

The stakeholder engagement activities and their feedback are summarized in Table 5-1. It also includes cross-references to the relevant Sections within this EIA that address the corresponding concerns.

TABLE 5-1: EXTERNAL STAKEHOLDER CONCERNS AND REPORT REFERENCES SUMMARY

No.	Stakeholder Category	Stakeholder Engagement Description	Feedback/Requirements	Report Reference/Note
1	Government Agencies (e.g. URA, MND) and Technical Agencies (e.g. MPA, SFA, NEA, and NParks)"	EIA scope consultation with TAs were conducted in April to May 2025 to seek TAs' feedback on EIA scope of work and methodology.	• EIA is required to evaluate potential impacts on marine water quality (e.g. chlorine and temperature) and marine biodiversity during project operation. • An EMMP is required and must include pre-felling inspections, Erosion control measures, wastewater and waste management measures, water quality monitoring, and wildlife management. • The Project must consult NParks before the commencement of any work. • Project should comply with trade effluent, noise and air limits. • Mitigation, management and monitoring for the Project. • Engagement of relevant stakeholders (i.e. nature groups) throughout the EIA, and public disclosure of the EIA over a 4-week period.	• Section 1 (Introduction) • Section 2 (Project Description) • Section 6 (Marine Water Quality) • Section 7 (Marine Biodiversity) • Section 8 (EMMP) • Appendix B (Terrestrial Biodiversity Baseline) • Appendix C (Marine Environment Baseline) • Appendix D (Marine Water Quality Assessment Report)
2	Adjacent Landowners on Jurong Island	PLM has conducted general engagements with the adjacent facilities to share project development plans.	No specific environmental related concerns / requirements.	N/A

No.	Stakeholder Category	Stakeholder Engagement Description	Feedback/Requirements	Report Reference/Note
3	Local Nature Groups (NGs), Non-Government Organisations (NGOs), Independent Interest Groups and Independent Academics/ Professionals	ERM and PLM has undertaken one (1) stakeholder engagement with Nature Group representatives, together with representatives from Technical and other Government Agencies on 12 December 2025. The aim of this engagement sessions was to consult with nature group representatives by sharing Project EIA baseline and assessment findings and soliciting feedback on the proposed mitigation measures and monitoring plans to further inform the EIA.	• Marine baseline for Helios Secondary Reef is limited and dated. ERM has agreed with TAs that the currently available information is valid. • Concerns were raised on the marine biodiversity assessment in the vicinity of the PUB drainage canal outlet. Further information is supplemented within the EIA (Section 7). • EMMP measures should consider more robust and detailed measures for concrete and ECM and stockpile management. Further information is supplemented within the EIA (Section 8).	• Section 6 (Marine Water Quality) • Section 7 (Marine Biodiversity) • Section 8 (EMMP) • Appendix B (Terrestrial Biodiversity Baseline) • Appendix C (Marine Environment Baseline) • Appendix D (Marine Water Quality Assessment Report)

5.4 STAKEHOLDER FEEDBACK MECHANISM

The disclosure of this EIA report provides the opportunity to communicate the proposed Project activities, implementation schedules, associated risks, impacts, benefits and mitigation measures with the public. All public feedback will be managed by ERM and PLM, in agreement with the relevant technical and government agencies.

PLM and EPC Contractor will be responsible for addressing project-specific concerns, complaints, comments and feedback during the Project's implementation, and for providing an appropriate forum, e.g. phone number/email address, to receive and respond to such input.

6. MARINE WATER QUALITY

6.1 INTRODUCTION

This Section of the EIA evaluates the potential impact to marine water quality associated with the operation phase of the Project. Where required, the mitigation hierarchy of avoidance, minimisation, reduction or compensation has been applied to potentially significant impacts to reduce impact levels to as low as reasonably practicable. Monitoring recommendations for marine water quality during the operation phase of the Project are also referenced where applicable.

Technical Agencies have been consulted since the early phases of the Project (since October 2024), and Nature Groups have been engaged in December 2025, to understand marine water quality related concerns, and seek feedback in preparing the marine water quality impact assessment for this Project. The discussions and recommendations from the Technical Agencies and engaged stakeholders (including Nature Groups) have been taken into account in the following assessment.

This section summarises and draws upon information from the following technical report:

- Marine Water Quality Baseline Report (Appendix C), encompassing the full methodology and detailed results of a marine water quality survey conducted within August 2025.
- Marine Water Quality Modelling Assessment Report (Appendix D), encompassing the full methodology, data source, modelling scenarios and detailed results of the marine water quality assessment.

6.2 SCOPE OF ASSESSMENT

The Project involves both the construction and operation of the proposed facilities described in Section 2. The potential water quality impacts associated with the construction works will be fully controlled through the implementation of an Environmental Monitoring and Management Plan (EMMP) (Section 8). This is aligned with EMMP requirements from other approved EIAs in Singapore. The following sections cover the operation phase water quality impacts, namely:

- Changes in water temperature at the receiving water, due to thermal discharge; and
- Elevations in chlorine level at the receiving water, due to discharge.

6.3 REGULATORY FRAMEWORK

Section 3 refers to legislation, standards and/or guidelines applicable to governing marine water quality in Singapore relevant to this Project. This includes:

<u>For Industrial Effluent</u>

- Environmental Protection and Management Act (EPMA) 1999 (2020 revised edition);
- Environmental Protection and Management (Trade Effluent) Regulations 1999 (2008 revised edition);
- Prevention of Pollution of the Sea Act 1990 (2020 revised edition);
- Environmental Public Health Act (EPHA) 1987 (2020 revised edition);

- Environmental Public Health (Toxic Industrial Waste) Regulations 1988 (2000 revised edition);
- Guidebook on Erosion and Sediment Control at Construction Sites, 5th Edition 2018;
- Code of Practice on Surface Water Drainage, 7th Edition December 2018;
- Code of Practice on Sewerage and Sanitary Works, 2nd Edition January 2019;
- The Singapore Standard SS 593: 2013 Code of Practice for Pollution Control (COPPC) 2013;
- PUB Guidebook on Erosion and Sediment Control at Construction Sites, 2018; and
- PUB Allowable Limits for Trade Effluent Discharge to Watercourse or Controlled Watercourse.

Additional Legislation for Sewage Discharge

- Sewerage and Drainage Act 1999 (2020 revised edition); and
- Sewerage and Drainage (Trade Effluent) Regulations 1999 (2007 revised edition).

6.4 IMPACT ASSESSMENT CRITERIA

The applicable limits for the listed marine water quality parameters are based on local and international standards, as presented in Table 6-1. The sensitivity and magnitude of potential impacts on marine water quality have been assessed in accordance with ERM's IA Standard, presented in Section 4.6 and Table 6-2. Additionally, an Environmental Impact Significance criterion (also known as Environmental Quality Objective (EQO)) was aligned with technical agencies on the assessment criteria to determine impact levels per the tables below. This criterion has been aligned with SFA for protection of fish farms.

TABLE 6-1: MARINE WATER QUALITY LIMITS

Water Quality Parameters [(a)]	Limit for Marine Water Quality at Point of Discharge [(b)]	Limit for Receiving Environment (Ecological Receptors)
Thermal	Temperature shall not exceed 45°C at the discharge point to the sea	Temperature increase of the surrounding seawater will not be more than 2°C [(c)] above the maximum ambient temperature.
Chlorine	Concentration of free chlorine shall not exceed 1 mg/L at discharge point to the sea	Levels of chlorine should not exceed a one-hour average limit of 13 µg/L [(d)] and a 4-day average of 7.5 µg/L [(d)] to protect aquatic life from short and long-term exposure to chlorine and chlorine-produced oxidants (CPOs)

Notes:

Water Quality Parameters [a]	**Limit for Marine Water Quality at Point of Discharge [b]**	**Limit for Receiving Environment (Ecological Receptors)**

(a) *For all other water quality parameters, limits at point of discharge will adhere to NEA allowable trade effluent discharge limits to watercourse*

(b) NEA allowable trade effluent discharge limits to watercourse https://www.nea.gov.sg/our-services/pollution-control/water-quality/allowable-limits-for-trade-effluent-discharge-to-watercourse-or-controlled-watercourse

(c) *ASEAN 2008 marine water quality management guidelines https://environment.asean.org/public/uploads/repositories/20220725-ASEAN-MarineWaterQualityManagementGuidelinesandMonitoringManual.pdf*

(d) *US Environmental Protection Agency Quality Criteria for Water 1986 https://www.epa.gov/sites/default/files/2018-10/documents/quality-criteria-water-1986.pdf*

TABLE 6-2: SIGNIFICANCE OF IMPACTS ON MARINE WATER QUALITY (DURING OPERATION)

Baseline Sensitivity		Magnitude of Effect on Marine Water Quality			
		Negligible	Small	Medium	Large
		Immeasurable, undetectable or within the range of normal natural variation	Slight change in water quality expected over a limited area with water quality returning to background levels within a few metres and / or Discharges are well within benchmark effluent discharge limits (Table 6-1)	Temporary or localized change in water quality with water quality returning to background levels thereafter and / or Occasional exceedance of benchmark effluent discharge limits (Refer to Table 6-1)	Change in water quality over a large area that lasts over the course of several months with quality likely to cause secondary impacts on marine ecology; and/ or Routine exceedance of benchmark effluent discharge limits (Refer to Table 6-1)
Low	Existing water quality is good	**Negligible**	**Negligible**	**Minor**	**Moderate**
Medium	Existing water quality already shows some signs of stress	**Negligible**	**Minor**	**Moderate**	**Major**
High	Existing water quality is already under stress	**Negligible**	**Moderate**	**Major**	**Major**

6.5 BASELINE CONDITIONS

6.5.1 METHODOLOGY

Marine water quality surveys were conducted on 28 July 2025 (spring tide) and 05 August 2025 (neap tide) at sampling locations WS1 to WS5 (as shown in Figure 6-1). The marine water quality sampling points were chosen to represent:

- WSQ1: Conditions at the cooling water intake;
- WSQ2: Conditions at marine biodiversity sensitive receptor Terumbu Pempang Laut;
- WSQ3: Conditions at the outlet of the PUB drainage canal for cooling water;
- WSQ4: Conditions at marine biodiversity sensitive receptor Sakra Terminal at Jurong Island; and
- WSQ5: Conditions at marine biodiversity sensitive receptor Helios Secondary Reef.

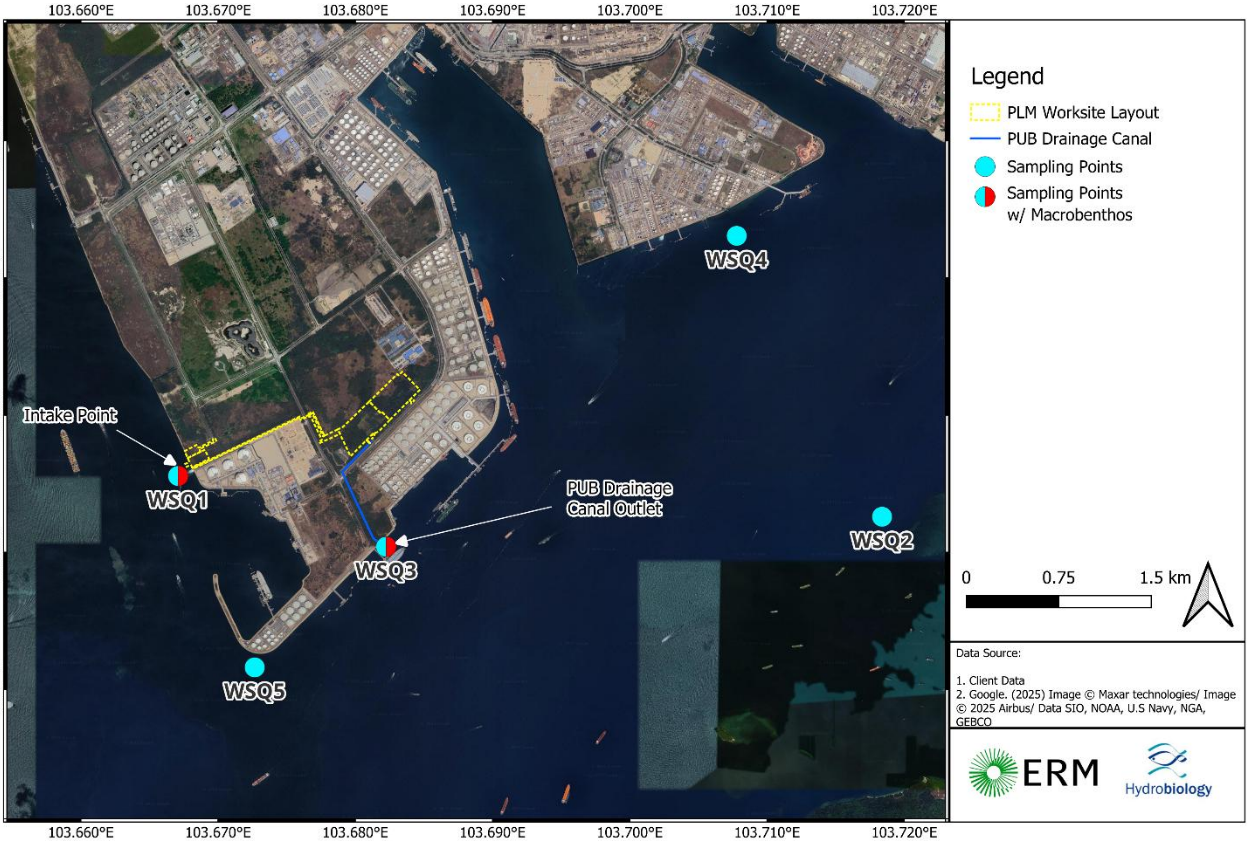
Depth-profiled, in-situ measurements at 1 m interval, including Temperature, Salinity, Turbidity, pH, Dissolved Oxygen, Light (PAR), and Secchi Depth were collected. Mid-depth water samples were collected for laboratory analysis (by Marchwood Laboratory Services Pte Ltd) for Total suspended Solids (TSS), Nitrate as NO_3-N, Nitrite as NO_2-N, Phosphate as PO_4-P, Total Nitrogen (TN), Total Phosphorus (TP), Total Ammonia Nitrogen, Total Organic Carbon (TOC), Total Petroleum Hydrocarbons (TPH), Biochemical Oxygen Demand (BOD), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), Zinc (Zn), Faecal coliforms, and Enterococci.

In addition, sediment samples were collected at the same five (5) locations on 05 August 2025. The corresponding particle size distribution, total organic carbon, total petroleum hydrocarbons, heavy metals / metalloid and polycyclic aromatic hydrocarbons were analysed. The findings of sediment survey are presented below in Section 6.5.2.

Plankton samples were collected at all five (5) sampling locations (WSQ1 to WSQ5) while, macrobenthos samples were collected at two (2) of the sampling locations (WSQ1 and WSQ3). The findings of the plankton and macrobenthos survey are provided under the marine biodiversity section under Section 7.

The surveys were also discussed and agreed with the relevant Technical Agencies during the scoping phase of the Project.

FIGURE 6-1: LOCATIONS OF MARINE WATER QUALITY SAMPLING POINTS



6.5.2 SUMMARY OF BASELINE FINDINGS

The detailed report on the results by Hydrobiology (September 2025) are provided in Appendix C. A high level summary of the water quality and sediment results are provided in text in Table 6-3 to Table 6-5 below.

The results of the water quality survey conducted across all five locations under both flooding and ebb tide conditions on both survey dates (for spring and neap tides) were generally in compliance with the relevant ASEAN Marine Water Quality Criteria (MWQC), with the following noted exceptions:

- For Nitrate-nitrogen (NO_3-N) the corresponding MWQC is 0.06 mg/L. Except for the spring tide at WQS3 and WQS4, recorded NO_3-N levels at all locations were higher than the corresponding MWQC of 0.06 mg/L for all four (4) sampling instances.
- For Faecal Coliforms and Enterococci, the corresponding MWQC are 100 MPN/100 mL and 35 cfu/100 mL respectively. Both criteria were exceeded for the neap ebb tide at WQS4.

For heavy metals including Cadmium, Chromium, Copper, Lead, Mercury, and Zinc, the recorded levels were either not detected (denoted as ND in Table 6-4) or less than 0.5x of the corresponding MWQC. Levels of nutrient species other than nitrate-nitrogen—namely nitrite, ammonia-nitrogen, and phosphate-phosphorus—were either not detected or measured at less than 50% of the corresponding MWQC. Dissolved oxygen concentrations consistently ranged between 6 and 7 mg/L, exceeding the relevant MWQC.

For marine sediment quality, samples were collected at the same locations and analysed in a laboratory for their physical and chemical properties. Sediment samples collected at station WSQR1 were predominantly composed of silt, whereas those from all other stations were primarily sand dominated. The total organic carbon content was generally low at all stations and the levels recorded were all less than 1%. In terms of heavy metal/metalloid contamination, all the contamination levels of sediment samples collected at all stations were low when compared with: (1) Dutch Intervention Values for soil contamination; (2) Maritime and Port Authority of Singapore (MPA) sediment quality guideline; and (3) Default Guideline Value (DGV) and Guideline Value – High (GV-H) of the Australia & New Zealand default guideline values for sediment quality. All the recorded values were lower than all the corresponding applicable soil/sediment quality standards/guidelines mentioned above and showed no sign of sediment contamination. For organic contaminants, a total of 16 polycyclic aromatic hydrocarbons (PAHs) species were tested. All results were at levels below the corresponding limit of reporting at all stations.

TABLE 6-3: SUMMARY OF WATER QUALITY RESULTS MEASURED IN-SITU

Parameter	Unit	MWQC	WSQ1	WSQ2	WSQ3	WSQ4	WSQ5	All
Secchi Disk Depth	m	N/A	2.3 (2.1-2.4)	2.1 (1.6-2.4)	2 (1.9-2.0)	2.2 (2.1-2.2)	2.2 (2.0-2.6)	2.1 (1.6-2.6)
Temperature	°C	Increment <2	30.2 (30.1-30.7)	30.1 (29.8-30.5)	30.3 (30.2-30.5)	30.4 (30.2-31.3)	30.2 (30.1-30.6)	30.2 (29.8-31.3)
Salinity	ppt	N/A	29.3 (28.6-29.8)	29.4 (29.0-29.7)	29.4 (29.1-29.9)	29.4 (29.0-29.8)	29.3 (28.7-29.7)	29.4 (28.6-29.9)
Turbidity	NTU	N/A	2.1 (1.3-4.6)	3.4 (0.9-6.7)	3.5 (1.5-12.9)	3.3 (1.1-6.0)	2.2 (1.3-3.0)	2.9 (0.9-12.9)
pH	-	N/A	7.8 (7.5-7.9)	7.9 (7.5-8.0)	7.9 (7.6-8.1)	7.9 (7.4-8.0)	7.8 (7.2-8.1)	7.8 (7.2-8.1)
Dissolved Oxygen	mg/L	>4	6.3 (6.1-6.9)	6.1 (6.0-6.5)	6.1 (6.0-6.5)	6.2 (5.9-6.6)	6.3 (6.1-7.3)	6.2 (5.9-7.3)
PAR	μmol s^{-1} m^{-2})	N/A	319.62 (0.97-2753.40)	142.83 (0.08-1805.10)	185.79 (0.13-1779.80)	233.98 (0.11-1756.80)	242.42 (0.68-2338.40)	224.93 (0.08-2753.40)

Note: Top values presented are water column averages, values in brackets are range in the entire water column.

TABLE 6-4: WATER QUALITY RESULTS BY LABORATORY ANALYSIS FOR SPRING FLOOD AND EBB TIDES COMPARED AGAINST MWQC

Parameter	**Unit**	**MWQC**	**WSQ1**				**WSQ2**				**WSQ3**				**WSQ4**				**WSQ5**			
			Spring		Neap		Spring		Neap		Spring		Neap		Spring		Neap		Spring		Neap	
			Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb
Cadmium, Cd	µg/L	10	ND	0.11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.13	ND	ND	ND
Chromium, Cr	µg/L	48	0.32	0.42	0.20	0.21	0.41	1.04	0.30	0.19	0.42	0.47	0.25	0.18	0.50	0.53	0.26	0.22	0.67	0.45	0.26	0.19
Copper, Cu	µg/L	2.9	0.81	0.53	1.03	1.15	0.56	1.03	0.96	0.69	0.63	0.83	0.66	0.68	0.65	0.68	0.88	0.72	0.73	0.63	0.53	0.60
Lead, Pb	µg/L	8.5	0.11	ND	ND	0.26	ND	0.16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.10	ND
Mercury, Hg	µg/L	0.16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel, Ni	µg/L	N/A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc, Zn	µg/L	50	1.29	ND	2.12	2.86	ND	ND	6.45	0.89	ND	ND	1.50	1.16	ND	ND	2.13	1.84	ND	ND	1.30	1.72
Nitrite, NO_2–N	mg/L	0.055	ND	ND	0.022	ND	ND	ND	0.016	ND	ND	ND	0.020	0.012	ND	ND	0.020	0.021	ND	ND	0.015	0.017
Nitrate, NO_3–N	mg/L	0.06	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.09**	**0.09**	**0.09**	0.02	**0.08**	**0.11**	**0.11**	0.03	**0.07**	0.01	**0.09**	**0.08**	**0.09**	**0.10**	**0.08**
Total Nitrogen, TN	mg/L	N/A	0.15	0.22	0.19	0.17	0.30	0.15	0.16	0.18	0.18	0.23	0.20	0.19	0.13	0.12	0.18	0.19	0.13	0.18	0.22	0.17
Total Phosphorus, TP	mg/L	N/A	0.013	ND	0.021	0.019	0.021	ND	0.016	0.015	0.018	0.016	0.022	0.017	0.010	ND	0.019	0.023	ND	ND	0.018	0.017
Phosphate, PO_4–P	mg/L	0.015	ND	ND	ND	ND	ND	ND	0.011	ND	ND	ND	0.011	0.010	ND	ND	ND	0.012	ND	ND	ND	ND
Ammonia, NH_3–N	mg/L	0.07	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.019	ND	ND	ND	ND	ND
Total Ammonia, (NH_3 + NH_4)	mg/L	N/A	ND	0.011	ND	ND	0.011	ND	ND	ND	0.010	ND	ND	ND	ND	0.011	0.024	0.011	ND	ND	ND	ND
Total Organic Carbon, TOC	mg/L	N/A	2.29	2.15	2.16	2.27	2.24	2.19	2.02	2.13	2.09	2.38	2.02	2.23	2.12	2.36	2.10	2.15	2.19	2.29	2.20	2.15
Biochemical Oxygen Demand (BOD_5)	mg/L	N/A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Suspended Solids, TSS	mg/L	≤ 10%*	4.20	4.20	2.40	5.40	6.90	3.60	7.70	4.10	7.10	6.80	9.20	8.80	6.80	2.90	8.30	7.80	4.80	9.20	5.70	3.60
Oil & Grease	mg/L	0.14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Faecal Coliforms	MPN/100mL	100.00	ND	ND	20	3	ND	ND	2	1	ND	ND	28	48	ND	ND	24	**110**	ND	ND	6	8
Enterococci	cfu/100mL	35	ND	ND	4	8	ND	ND	6	ND	6	ND	14	20	4	ND	14	**38**	ND	ND	12	18

Notes:

Parameter	**Unit**	**MWQC**	**WSQ1**				**WSQ2**				**WSQ3**				**WSQ4**				**WSQ5**			
			Spring		Neap		Spring		Neap		Spring		Neap		Spring		Neap		Spring		Neap	
			Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb

*1. * Permissible 10% maximum increase over seasonal average concentrations.*

2. “ND” = Not detected.

3. Values in bold indicate levels exceeding MWQC values.

4. “N/A” = Not applicable

TABLE 6-5: SEDIMENT QUALITY RESULTS FOR SAMPLING SITES WSQ1 TO WSQ5

Parameter (unit: mg/kg, unless otherwise specified)		Dutch Intervention Values (DIV)	MPA Guidelines	Australia & New Zealand default guideline values for sediment quality		WSQ1	WSQ2	WSQ3	WSQ4	WSQ5	LOR
				Default Guideline Values	Guideline Values - High						
Particle Size Distribution (%)	Clay (<0.002mm)	N/A	N/A	N/A	N/A	38	5	3	7	2	N/A
	Silt (0.002-0.05mm)	N/A	N/A	N/A	N/A	59	8	3	10	2	N/A
	Sand (0.05-2mm)	N/A	N/A	N/A	N/A	3	47	92	81	94	N/A
	Gravel (>2mm)	N/A	N/A	N/A	N/A	0	40	2	2	2	N/A
Total Organic Carbon (TOC) (%)		N/A	N/A	N/A	N/A	0.51	0.61	0.45	0.59	ND	0.3
Total Petroleum Hydrocarbons (TPH)		N/A	N/A	280	550	52.0	47.5	24.7	24.4	10.9	10
Aluminum, Al		N/A	N/A	N/A	N/A	12,579	5,997	2,646	4,346	1,584	0.15
Arsenic, As		55	30	20	70	8.78	20.70	5.60	7.40	5.66	1.25
Barium, Ba		625	N/A	N/A	N/A	28.0	9.50	4.62	8.08	4.25	0.01
Cadmium, Cd		12	1	1.5	10	0.45	0.46	0.16	0.18	0.15	0.075
Chromium, Cr		380	50	80	370	12.70	12.50	4.97	6.93	4.05	0.05
Copper, Cu		190	55	65	270	17.50	6.14	2.72	4.24	2.59	0.2
Iron, Fe		N/A	N/A	N/A	N/A	22,330	21,903	8,449	10,018	7,272	0.1
Nickel, Ni		210	35	21	52	8.53	6.33	2.87	3.79	1.85	0.25
Lead, Pb		530	65	50	220	21.70	16.50	7.85	9.56	4.75	1
Vanadium, V		N/A	N/A	N/A	N/A	16.50	21.20	6.45	11.60	6.44	0.1
Zinc, Zn		720	150	200	410	85.4	39.0	20.6	29.2	10.1	0.1
Mercury, Hg		10	0.8	0.15	1.0	0.061	0.040	0.023	0.027	ND	0.01
Acenaphthene		N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Acenaphthylene		N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Anthracene		N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Benzo(a)anthracene		N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Benzo(a)pyrene		N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Benzo(b)fluoranthene		N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Benzo(ghi)perylene		N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Benzo(k)fluoranthene		N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Chrysene		N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Dibenz(ah)anthracene		N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1

Parameter (unit: mg/kg, unless otherwise specified)	Dutch Intervention Values (DIV)	MPA Guidelines	Australia & New Zealand default guideline values for sediment quality		WSQ1	WSQ2	WSQ3	WSQ4	WSQ5	LOR
			Default Guideline Values	Guideline Values - High						
Fluoranthene	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Fluorene	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Indeno(1,2,3cd)pyrene	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Naphthalene	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Phenanthrene	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1
Pyrene	N/A	N/A	N/A	N/A	ND	ND	ND	ND	ND	0.1

Note:

1. LOR = Limit of Reporting. This value may also represent Detection Limit required for the project.

2. "ND" = Not detected. The data reported is less than the LOR.

3. "N/A" = Not applicable

6.6 SENSITIVE RECEPTORS

As discussed in Section 6.5.2, the receiving body of water south of Jurong Island were generally in compliance to the corresponding water quality standards, and thus is considered to be of **Low** receptor sensitivity according to Table 6-2. The receiving body of water was assessed for the potential changes in water temperature and elevation in residual chlorine. Findings were then compared against the assessment criteria stipulated in Table 6-1 to determine the level of compliance, which were further evaluated based on the standards stated in Table 6-2 for the level of impact significance.

There are notable marine biodiversity sensitive receptors, including coral sites and seagrass areas, as well as existing and future fish farms, identified in the vicinity of the Project site for assessment under this Study. These sensitive marine biodiversity receptors could be affected by the change in water quality from the Project. Refer to Section 7.6 for the corresponding baseline sensitivity and assessment of potential marine biodiversity impacts.

6.7 EMBEDDED CONTROLS

Various regulations, guidelines, standards and criteria applicable to the Project are listed in detail in Section 2.5, with water quality related measures summarised below. Embedded control measures will be put in place to ensure effluent quality will be controlled and in compliance with these regulations/guidelines/standards/criteria.

6.7.1 OTHER EMBEDDED CONTROLS BASED ON VARIOUS ENVIRONMENTAL REGULATIONS

The following embedded controls based on various environmental regulations would be followed as well:

TABLE 6-6: OTHER EMBEDDED CONTROLS BASED ON ENVIRONMENTAL REGULATIONS

Environmental Regulations	Measures
Environmental Protection and Management (Trade Effluent) Regulations (2008)	• Only runoff, treated and compliant with allowable discharge limits for the Interim Site, will be discharged from the Site. • Water quality of the cooling water will adhere to NEA's trade effluent limits at the point of discharge. • Runoff discharged to a watercourse will be regularly monitored and recorded.
Asean Marine Water Quality Guidelines (2008)	• Temperature increase of surrounding seawater should not be more than 2^{o}C above the maximum ambient temperature.
US Environmental Protection Agency Quality Criteria for Water (1986)	• Levels of chlorine should not exceed a one-hour average limit of 13 µg/L to protect aquatic life from short and long-term exposure of 7.5 µg/L to chlorine and chlorine-produced oxidants (CPOs).

6.8 IMPACT ASSESSMENT

Among the identified key sources of water quality impact, two (2) were quantitatively modelled using the MIKE suite of models. They include:

- Changes in water temperature at the receiving water, due to thermal discharge; and
- Elevations in chlorine level at the receiving water, due to discharge.

The modelling report prepared by Haskonings is provided in Appendix D. Details on data inputs, the model setup and assumptions, model calibration/validation, as well as scenarios and findings are provided in the appendix and are referred to for assessment of the water quality impact during the operation phase. Highlights of the key findings of the assessment of thermal and chlorine impact are presented below. Key assumptions used by Haskonings for the modelling scenarios of both thermal and chlorine impact are summarized below in Table 6-7.

TABLE 6-7: KEY MODELLING ASSUMPTIONS FOR THERMAL AND CHLORINE IMPACT

Parameters	Assumptions
Water abstraction rate at intake	15.75m^3/s
Water discharge rate at condenser outlet/canal inlet	15.75m^3/s
Water discharge temperature at condenser outlet/canal inlet	36.0°C
Chlorine concentration at condenser outlet/canal inlet	Normal level: 0.25 mg/L Once every 8 hrs, shock dosing of 0.5 mg/L will be implemented for 0.5 hr The resulting dosing pattern would consist of repeating on an 8hr basis for 0.5 hr of 0.5 mg/L dosing, followed by 7.5 hr of 0.25 mg/L dosing.

6.8.1 CHANGE IN WATER TEMPERATURE AT RECEIVING WATER DUE TO THERMAL DISCHARGE

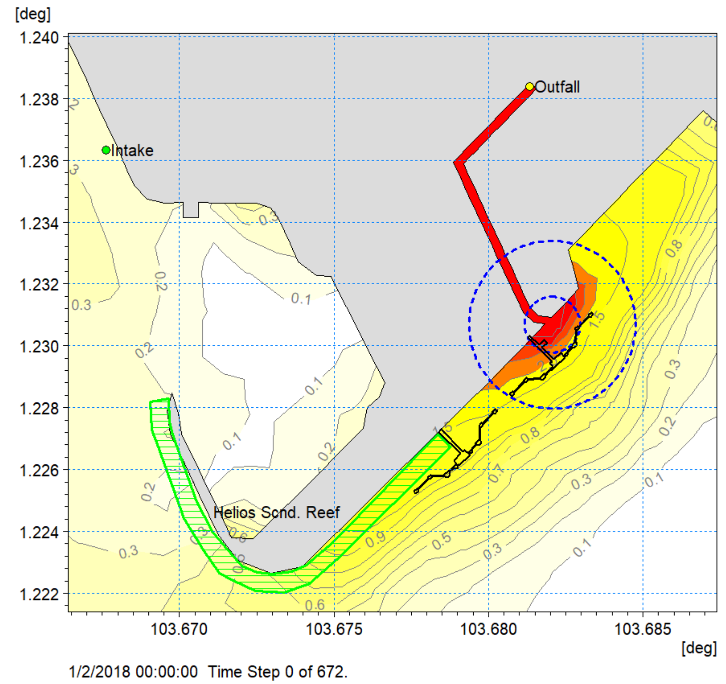
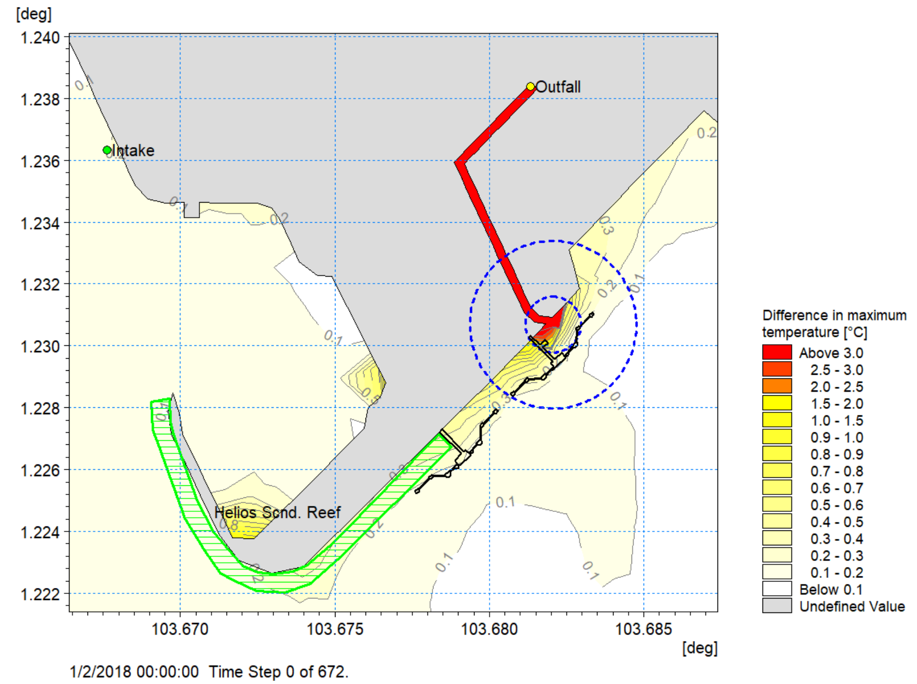
6.8.1.1 IMPACT SIGNIFICANCE

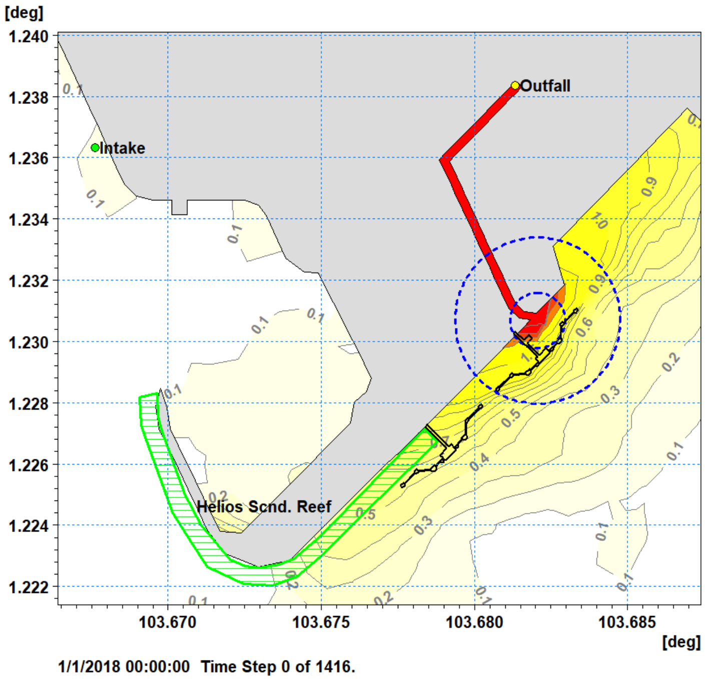
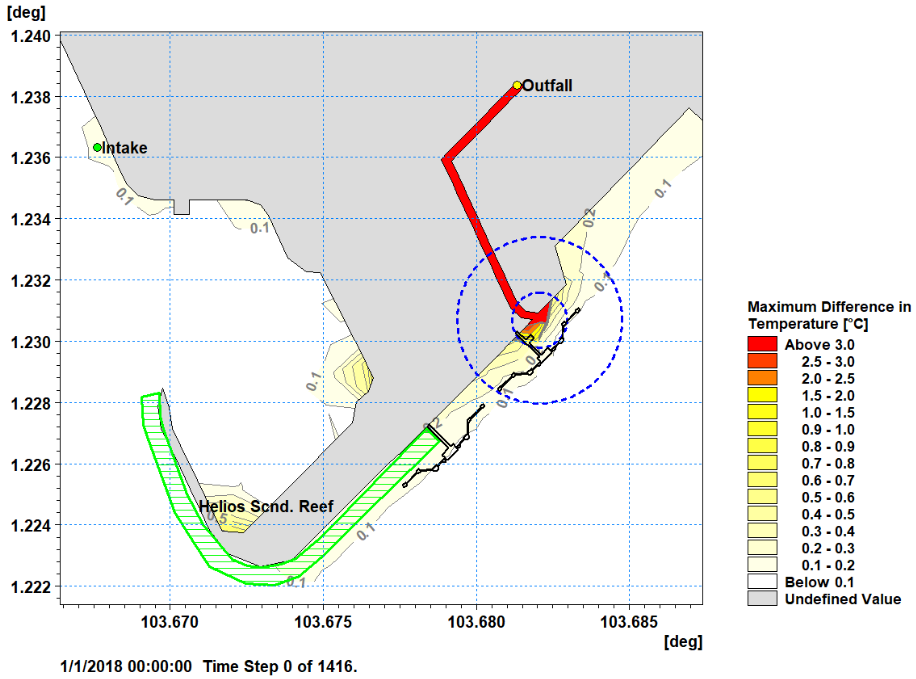
The thermal discharge from the Project would elevate the temperature of the receiving water. Based on the latest available information, a discharge temperature of 36°C has been set for normal operation and 40°C during emergency operation at the Project Boundary, both of which comply with regulatory limits (below 45°C). The MWQC stipulates that the allowable temperature elevation should not be more than 2°C above the maximum ambient temperature. Given the discharge temperature at the condenser outlet/canal inlet would be about 4°C above ambient water, there would be some areas (referred as mixing zone) around the drainage canal outlet that exceeds the MWQC. It should be noted that the cooling water discharge point at the Project boundary is located 1 km from the drainage canal outlet.

To evaluate the potential change of water temperature at the receiving water and determine the extent of the mixing zone, thermal discharge modelling was conducted.

In the thermal discharge modelling exercise, continuous thermal discharge was assumed at a rate of 15.75 m^3/s. The discharge temperature modelled was 36˚C throughout the modelling period. The condenser outlet/canal inlet was assumed to be at the northern end of the drainage canal. The invert level of the drainage canal is at about 2.4 m below mean sea level. Table 6-8 presents the change in maximum water temperature under the post-construction scenario above pre-construction scenario. Table 6-9 shows the percentage of time with predicted temperature under the post-construction scenario exceeding 2˚C above the pre-construction scenario.

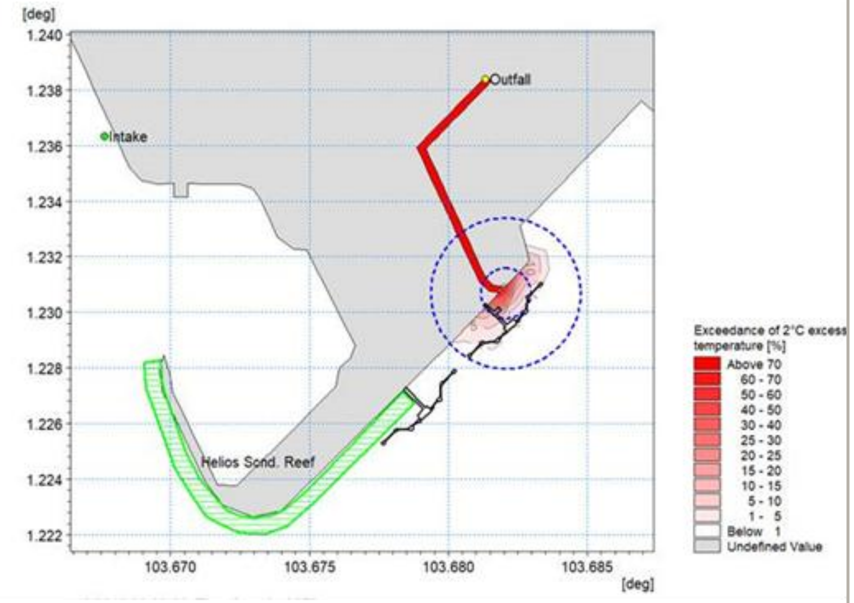
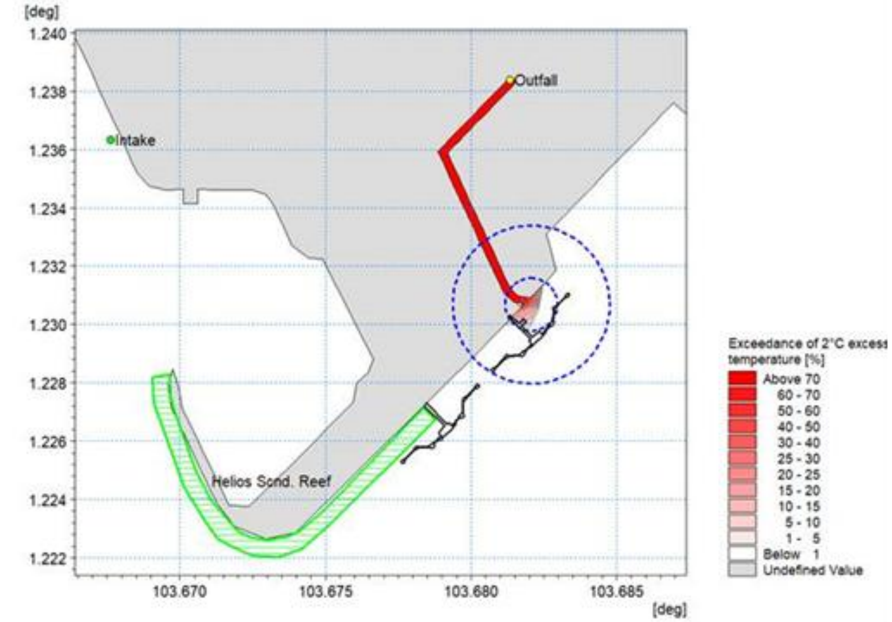
TABLE 6-8: MAXIMUM TEMPERATURE DIFFERENCE BETWEEN BASELINE AND OPERATIONAL FOR NE AND SW MONSOON

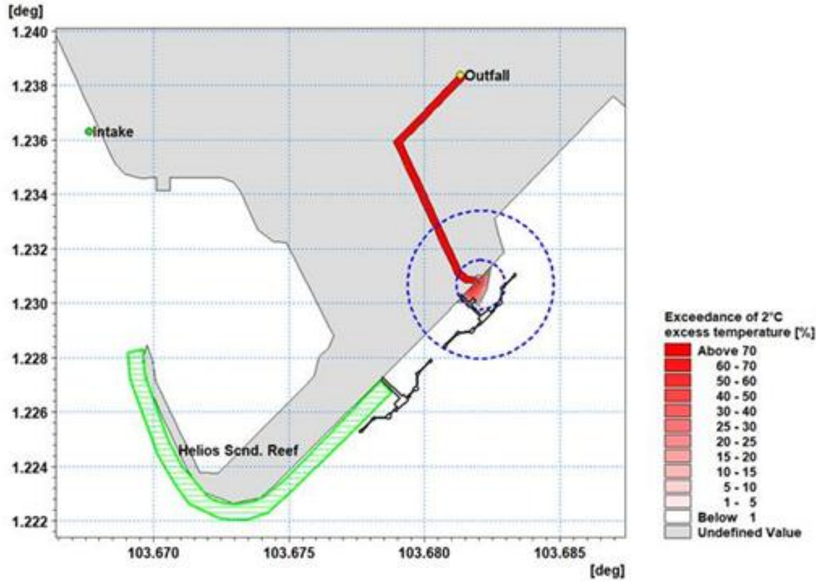
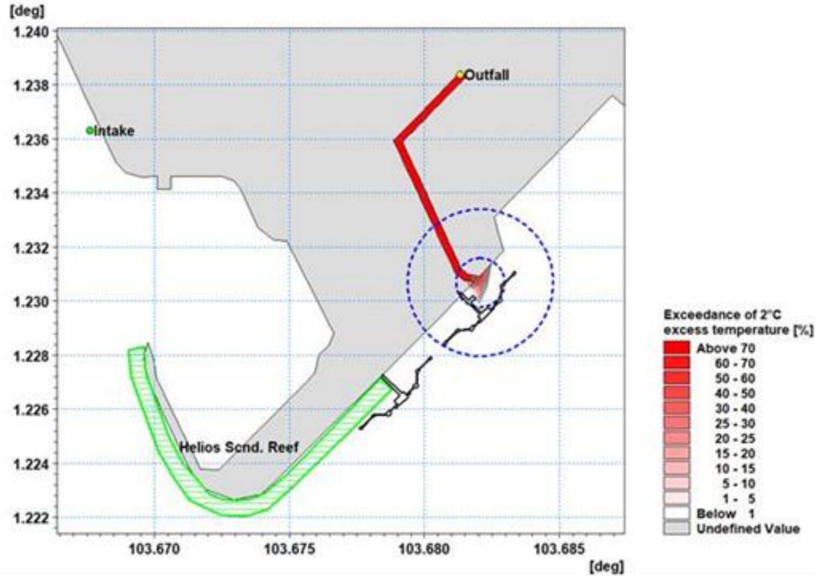
<table>
<tr><th rowspan="2">Monsoon</th><th colspan="2">Depth</th></tr>
<tr><th>Surface</th><th>Bottom</th></tr>
<tr><td>NE</td><td>
</td><td>
</td></tr>
</table>

Monsoon	Depth	
	Surface	Bottom
SW		

Note: Offset distances of 100 m and 300 m from the drainage canal outlet are shown by the blue dashed circles.

TABLE 6-9: PERCENTAGE TIME OF TEMPERATURE EXCEEDANCE OF 2°C EXCESS TEMPERATURE ABOVE BASELINE SCENARIO UNDER OPERATIONAL SCENARIO

Monsoon	**Depth**	
	Surface	Bottom
NE		

Monsoon	Depth	
	Surface	Bottom
SW		

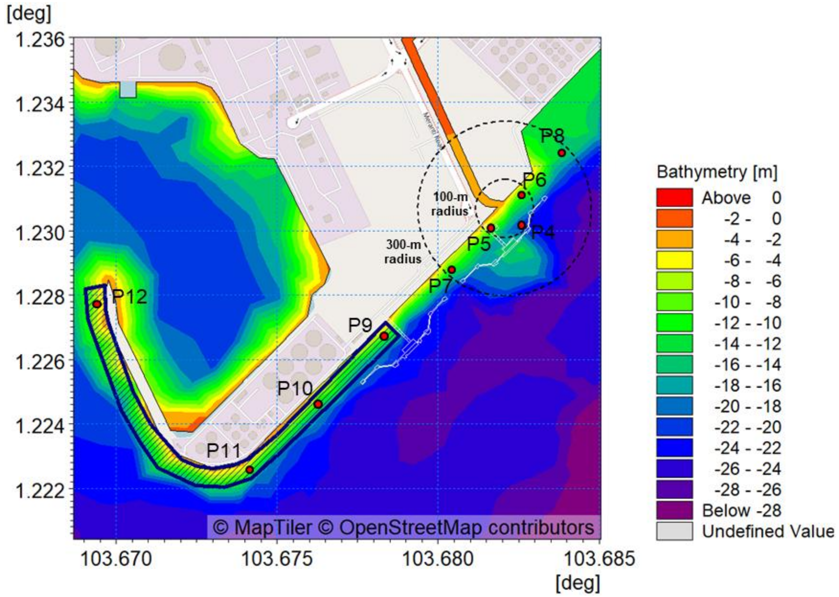
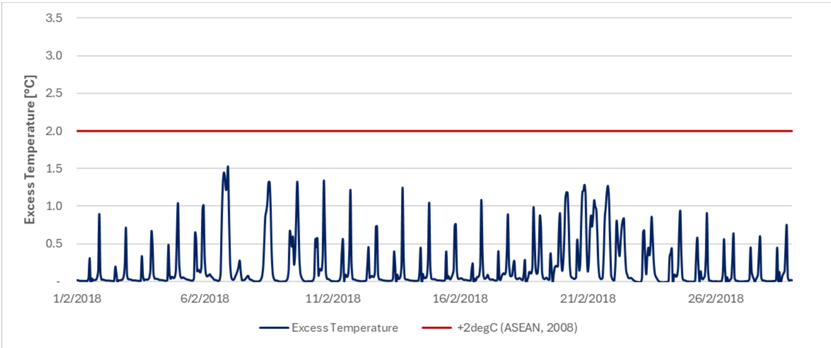
Note: Offset distances of 100 m and 300 m from the drainage canal outlet are shown by the blue dashed circles.

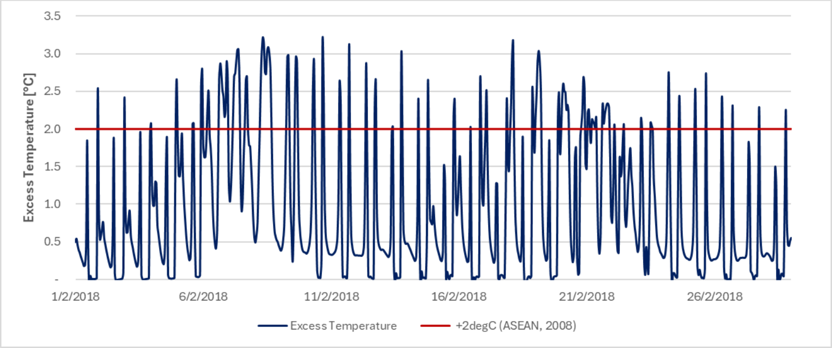
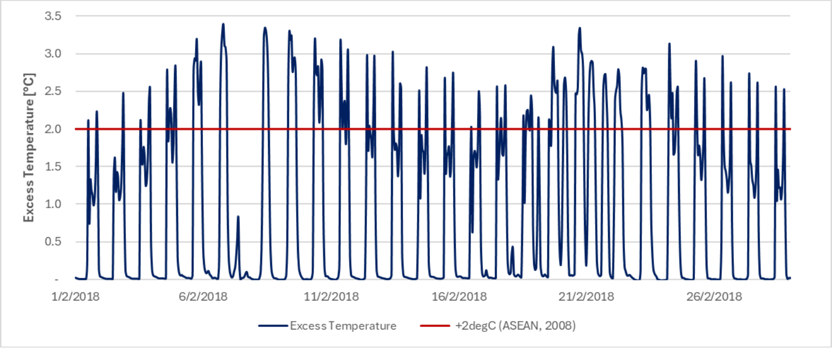
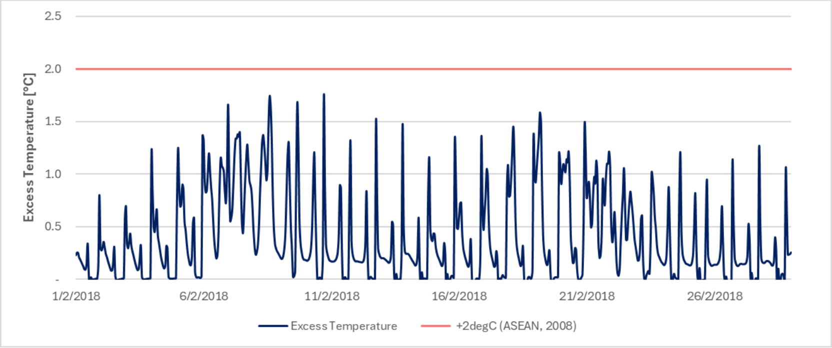
As shown in Table 6-8 above, the plume of elevated water temperature was notably larger near the surface of the water column than near the bottom. This is because the discharge is warmer than the ambient water (thus less dense) and occurs near the surface. Model results indicated the thermal plume / mixing zone is highly localized and attached to the shoreline. Furthermore, the predicted thermal plume with 2°C temperature elevation (shown in orange to red in Table 6-8) is predicted to extend up to about 300 m from the outlet of the drainage canal only in the NE monsoon and about 200 m in the SW monsoon. As shown in Table 6-9, for areas >100 m from the outlet of the drainage canal, temperature elevation exceeding 2°C is predicted to occur less than 15% of the time, whereas at >300 m from the outlet, temperature elevated exceeding 2°C is predicted to occur less than 1% of the time.

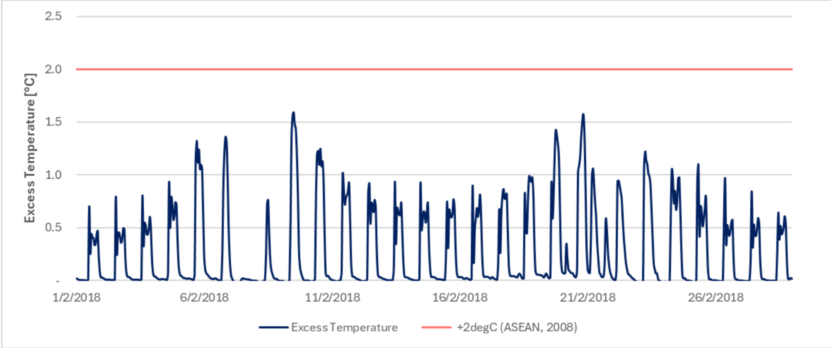
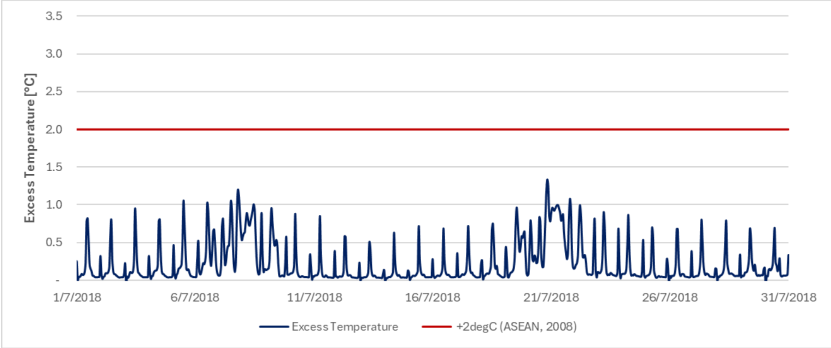
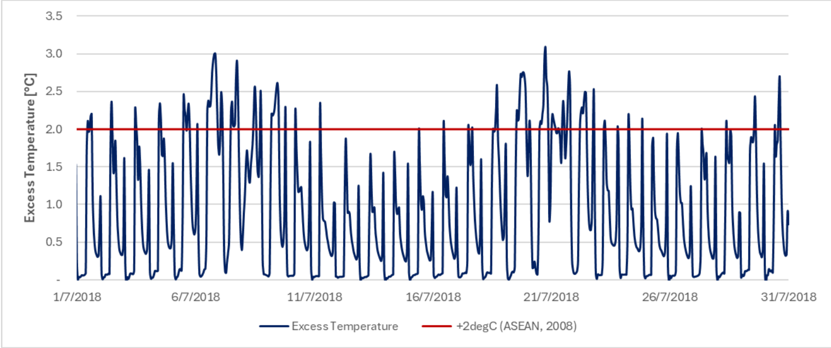
To further assess the predicted temperature elevation at the area surrounding the drainage canal outlet, time series outputs around the outlet were produced and compared against the corresponding MWQC Guideline. Time series outputs of the predicted temperature elevation at 5 observation points are provided, together with the corresponding MWQC. These observation points are shown in Table 6-10 below[7]. P4 to P6 are located at about 100 m from the outlet of the drainage canal, while P7 and P8 are located at about 300 m from the outlet. Note that the area within 300 m from the drainage canal outlet is occupied by an existing jetty without notable beneficial use of water which can be adversely affected by the proposed thermal and chlorine discharge. The selected locations at 100 m and 300 m from the drainage canal outlet are selected for indicative representation of water quality close to the outlet and do not represent any water sensitive receptors.

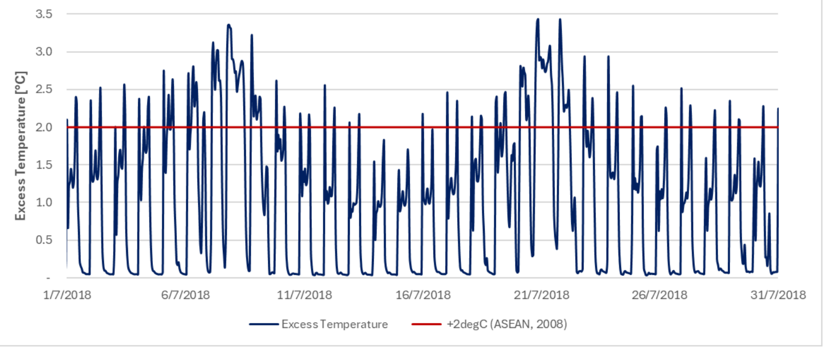
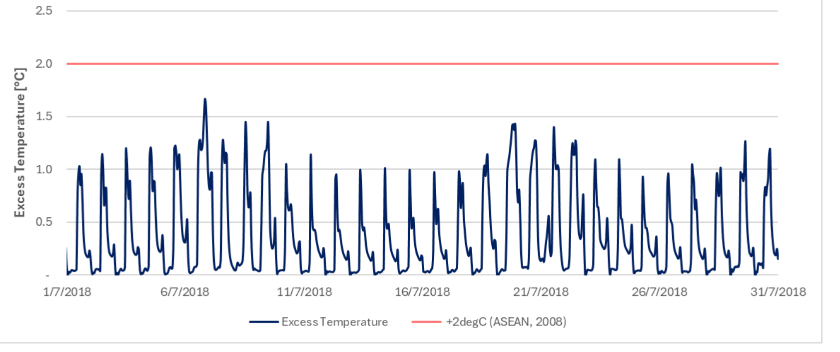
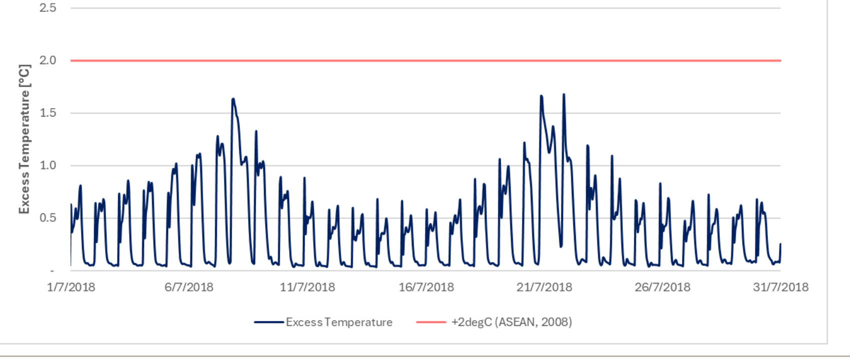
[7] Numbering starts from P4 because P1 to P3 are located within the drainage canal. These three points were used for internal inspection of performance in the drainage canal and their results were not presented in this section nor the modelling report.

TABLE 6-10: LOCATIONS OF TIME SERIES OUTPUT AROUND THE DRAINAGE CANAL OUTLET, TIME SERIES OUTPUT FOR TEMPERATURE ELEVATION NEAR SURFACE

Season	Location	Distance from Outlet	Plot
Cross Section Location	N/A	N/A	
NE	P4	100 m	

Season	Location	Distance from Outlet	Plot
	P5	100 m	
	P6	100 m	
	P7	300 m	

Season	Location	Distance from Outlet	Plot
	P8	300 m	
SW	P4	100 m	
	P5	100 m	

Season	Location	Distance from Outlet	Plot
	P6	100 m	
	P7	300 m	
	P8	300 m	

Note: Offset distances of 100 m and 300 m from the drainage canal outlet are shown as blue dashed circles.

As shown in Table 6-10, the predicted surface water temperature at P5 and P6 would often exceed 3°C above ambient levels, with a maximum exceeding 3.4°C. For P4, which is perpendicular to the dominant flow direction, predicted temperature elevation is limited, with maximum of less than 2°C above ambient temperatures. Overall, this means the predicted surface water temperature elevation cannot fully comply with the corresponding MWQC at 100 m from the drainage canal outlet. For less than 20% of time within a tidal cycle, area >100 m from the drainage canal outlet would experience temperature elevation exceeding 2°C under the post-construction scenario compared to the pre-construction scenario.

For locations P7 and P8, the predicted water temperature elevation near the surface would be less than 1.8°C above ambient. This means full compliance with the MWQC would be expected at around 300 m from the drainage canal outlet, which implies compliance at all other marine sensitive receptors beyond 300 m.

Based on the above findings of the thermal discharge model, the impact significance of the change in water temperature from thermal discharge is considered **Minor**, based on Table 6-11 below. While no mitigation measures are required for this impact, proposed management measures detailed in EMMP (Section 8) will be implemented as part of best practice for environmental management.

6.8.1.2 SUMMARY

TABLE 6-11: IMPACT SIGNIFICANCE – CHANGE IN WATER TEMPERATURE FROM THERMAL DISCHARGE

<table>
<tr><th colspan="2">Impact</th><td colspan="8">Impact Assessment of Change in Water Temperature from Thermal Discharge</td></tr>
<tr><th colspan="2">Impact Nature</th><td colspan="3">Negative</td><td colspan="3">Positive</td><td colspan="2">Neutral</td></tr>
<tr><th rowspan="8">IMPACT CHARACTERISTICS</th><th rowspan="2">Type</th><td colspan="3">Direct</td><td colspan="3">Indirect</td><td colspan="2">Induced</td></tr>
<tr><td colspan="8">Impact is direct.</td></tr>
<tr><th rowspan="2">Extent</th><td colspan="2">Site</td><td colspan="2">Local</td><td>Regional</td><td colspan="2">National</td><td>International</td></tr>
<tr><td colspan="8">The Project will discharge into marine water to the southeast of the site. The extent of predicted change in water temperature is limited to the surroundings of the outlet.</td></tr>
<tr><th rowspan="2">Scale</th><td>Negligible</td><td colspan="2">Small</td><td colspan="3">Medium</td><td colspan="2">Large</td></tr>
<tr><td colspan="8">Discharge temperature would be up to 4°C above ambient water. While the predicted temperature elevation of 2°C extends beyond 100 m from the drainage canal outlet for about 20% of time, the predicted elevation would be less than 1.8°C at and beyond 300 m away from the outlet. This means the predicted temperature elevation would fully comply with the MWQC at 300 m from the outlet for ambient temperature in Table 6-1.</td></tr>
<tr><th rowspan="2">Duration</th><td colspan="2">Temporary</td><td colspan="2">Short-term</td><td colspan="3">Long-term</td><td>Permanent</td></tr>
<tr><td colspan="8">The discharge will be continuous throughout the operation phase (long term), but the discharge will not significantly alter the ambient water temperature beyond the immediate vicinity of the outlet during the period. Temperature elevation exceeding 2°C would only affect water within 300 m from the drainage canal outlet. Therefore, the predicted change over which the receptors may be impacted is temporary.</td></tr>
</table>

	Frequency	The discharge will be continuous throughout the operation phase, but the discharge will not significantly alter the ambient water temperature beyond the 300 m of the outlet during the period. Therefore, the predicted change over which the receptors may be impacted is occasional.			
IMPACT MAGNITUDE		Negligible	Small	**Medium**	Large
		Temporary (occasional frequency) with local-extend at medium scale. Discharges are well within benchmark effluent discharge limits (small impact as per Table 6-2), while compliance to the MWQC of 2°C can be achieved at about 300 m from outlet but not 100 m.			
RECEPTOR SENSITIVITY		**Low**	**Medium**		High
		Existing water quality is generally good and in compliance with the corresponding MWQC Water Quality Standard.			
Impact Significance		Negligible	**Minor**	Moderate	Major

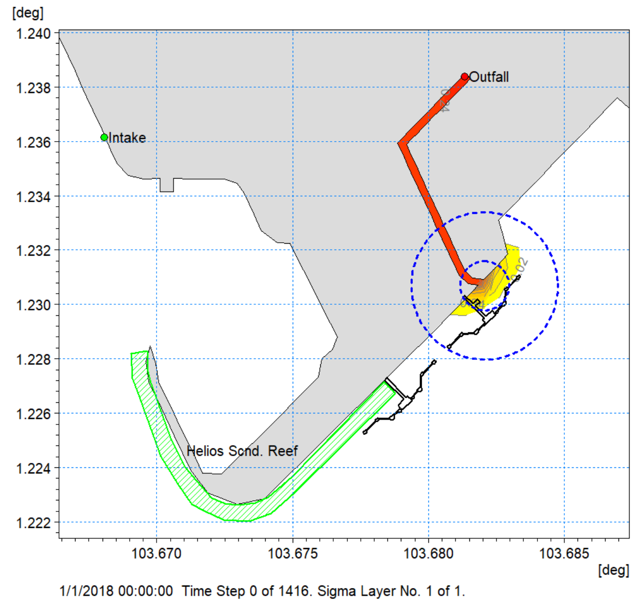
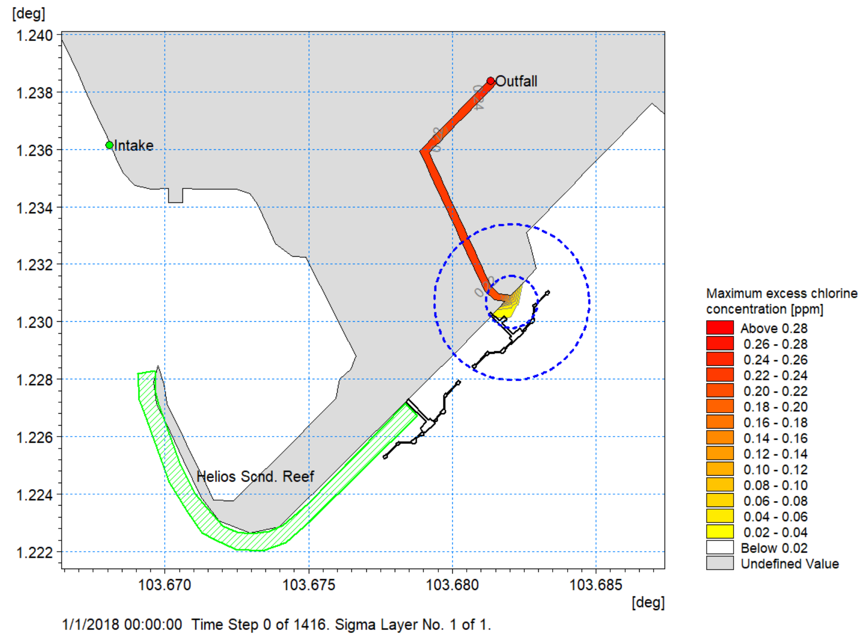
The significance of impacts is expected to be minor. No mitigation measure for this potential source of impact is deemed necessary.

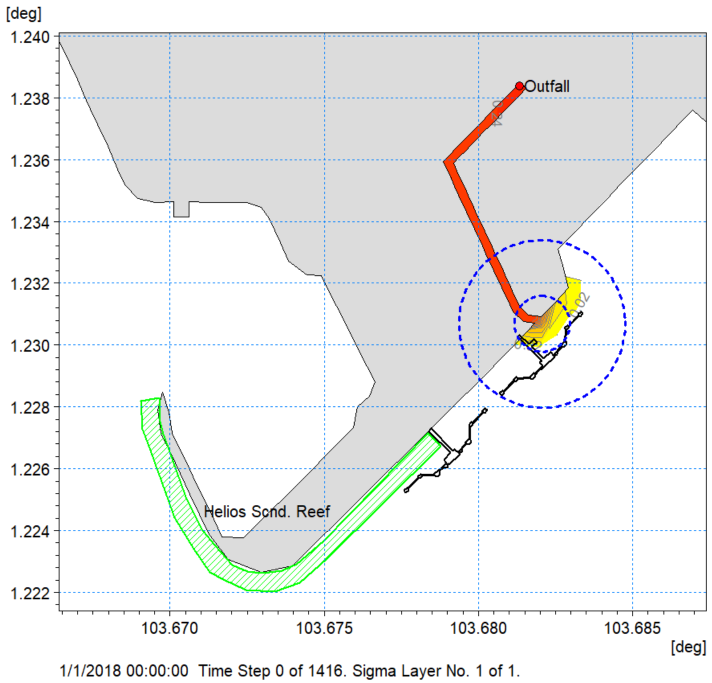
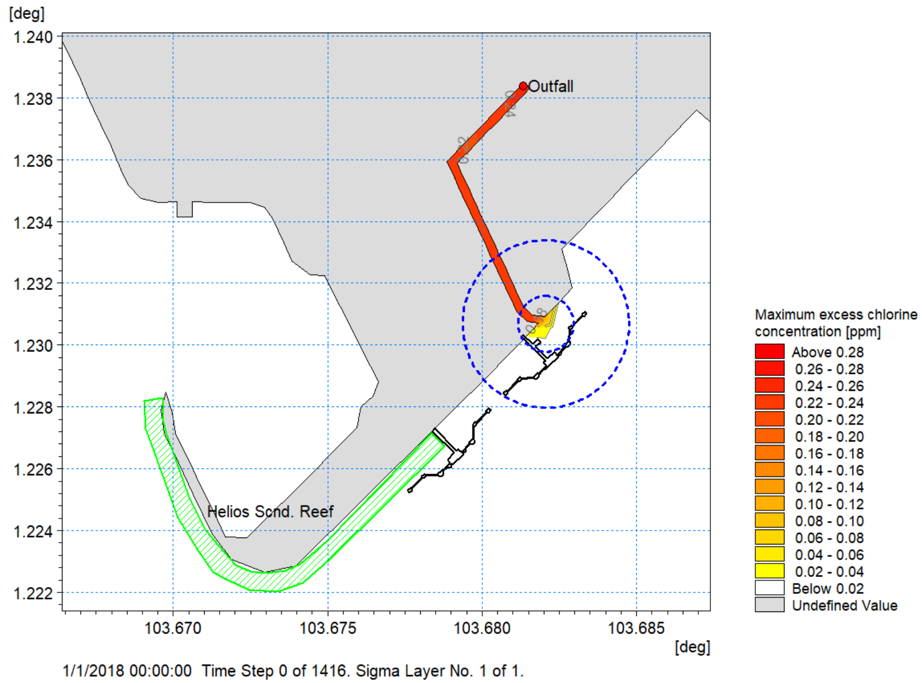
6.8.2 ELEVATION IN CHLORINE LEVEL AT RECEIVING WATER DUE TO DISCHARGE

6.8.2.1 IMPACT SIGNIFICANCE

Chlorine would be used as biocide to control biofouling of the seawater cooling system. Based on the latest design information, the design discharged chlorine concentrations are 0.25 ppm and 0.5 ppm for normal and shock dosing operation, respectively, which is below the regulatory threshold of 1 ppm at discharge. Shock dosing will be implemented every 8 hours (i.e. three times per day) and last for 30 minutes. Discharged residual chlorine could affect marine life and is of water quality concern. The USEPA recommends that levels of chlorine should not exceed a one-hour average limit of 13 µg/L (or 0.013 mg/L) and a four-day average limit. This criterion has been adopted for evaluating the potential impact on marine life at the receiving water from residual chlorine discharge from this Project. Table 6-12 presents the predicted maximum elevation of residual chlorine under operational scenario.

TABLE 6-12: MAXIMUM RESIDUAL CHLORINE ELEVATION UNDER OPERATIONAL SCENARIO

<table>
<tr><th rowspan="2">Monsoon</th><th colspan="2">Depth</th></tr>
<tr><th>Surface</th><th>Bottom</th></tr>
<tr><td>NE</td><td>
</td><td>
</td></tr>
</table>

Monsoon	Depth	
	Surface	Bottom
SW		

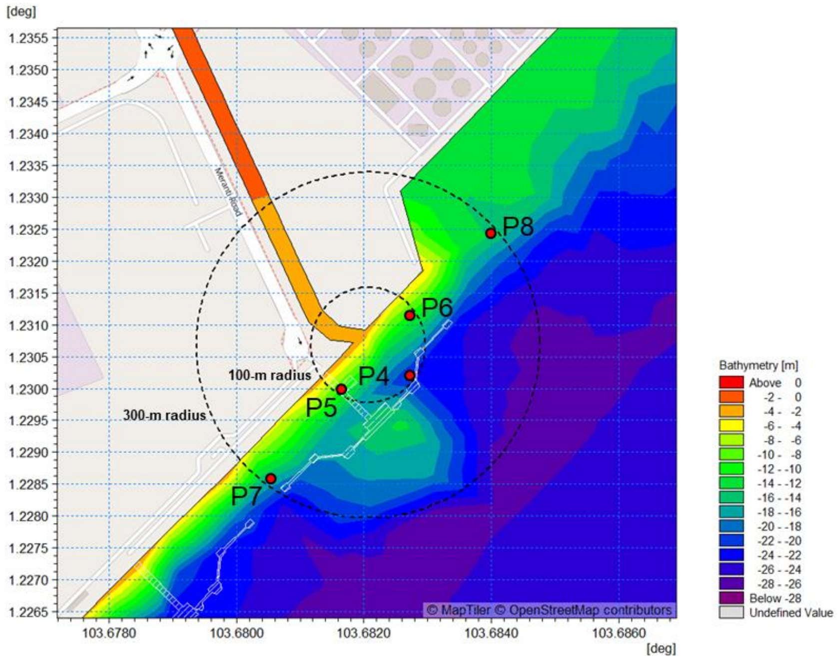
Note: Offset distances of 100 m and 300 m from the drainage canal outlet are shown at blue dashed circles.

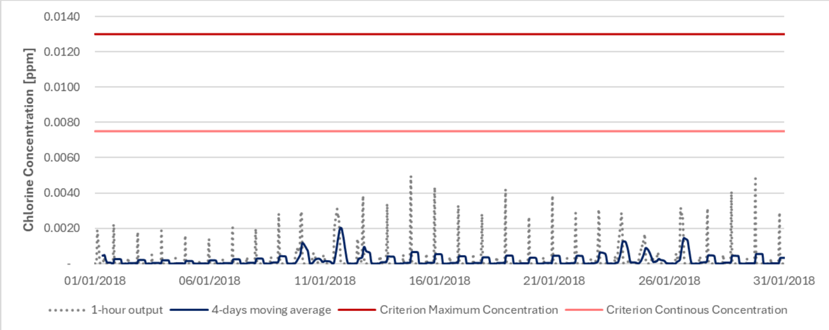
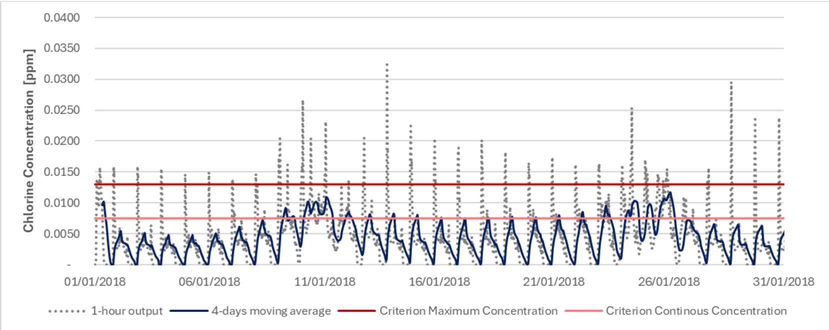
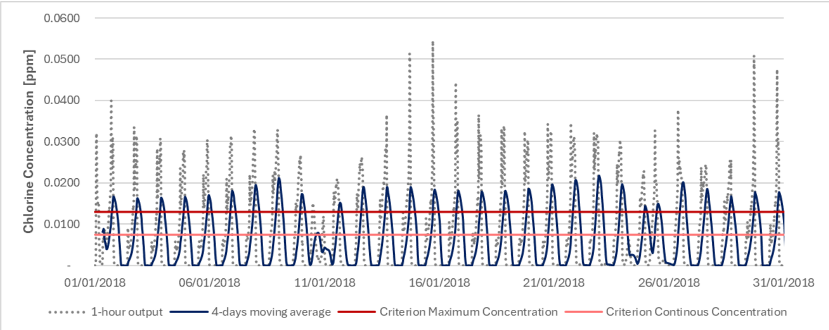
As shown in Table 6-12, the plume of predicted maximum residual chlorine elevation would generally be confined near the surface for the same reasons as the distribution of temperature elevation discussed in Section 6.8.1 (i.e. thermal discharge above water surface does not penetrate into the water column). The maximum chlorine elevation is predicted at about 200 m from the outlet of the drainage canal and is only about 0.02 mg/L near the surface. For predicted maximum chlorine elevation near the bottom, the effluent plume was predicted to be localized within 100 m from the outlet of the drainage canal.

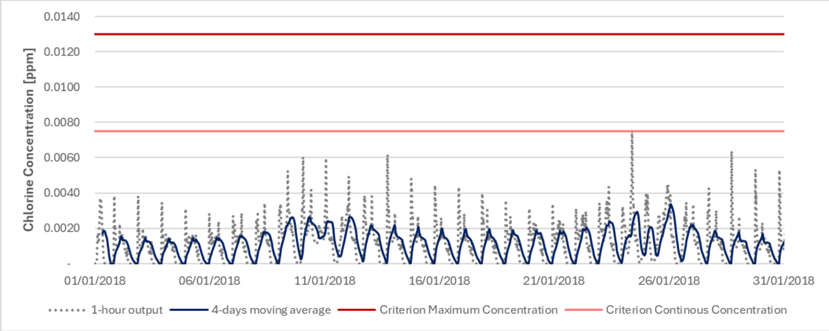
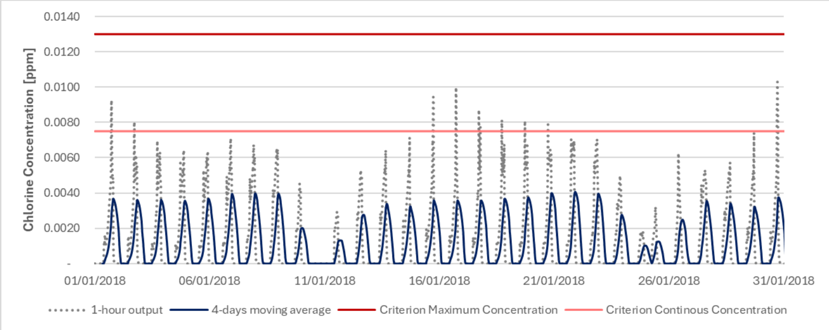
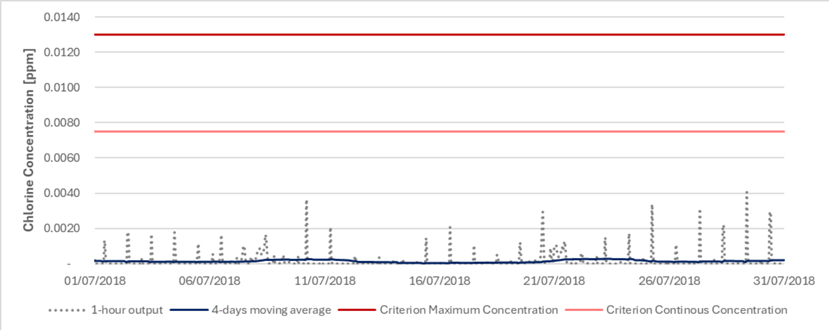
Further analysis was conducted to evaluate the potential chlorine impacts on the surrounding water. As shown in Table 6-13, elevation would be highest at P5 and P6, which are 100 m from the outlet in the SW and NE direction. The predicted chlorine elevation at P5 and P6 is above the corresponding USEPA chlorine criteria for acute (one hour average of 0.013 mg/L) and chronic (4-day moving average of 0.0075 mg/L) exposure. For P4 (which is perpendicular to the direction of dominant flow of the tidal current), the predicted elevation is low and complies with both acute and chronic criteria. This means there will be limited chlorine exposure to marine sensitive receptors on the other side of the channel (i.e. in the direction perpendicular to the tidal current) (refer to Table 6-10). Furthermore, the predicted chlorine elevation at P7 and P8 (300 m from outlet) complies with both acute and chronic criteria. As shown in Table 7-11, all identified marine sensitive receptors are at 700 m from the drainage canal outlet. This means all water sensitive receptors identified, including the Helios Secondary Reef, would not experience chlorine elevation exceeding the corresponding USEPA chlorine criteria.

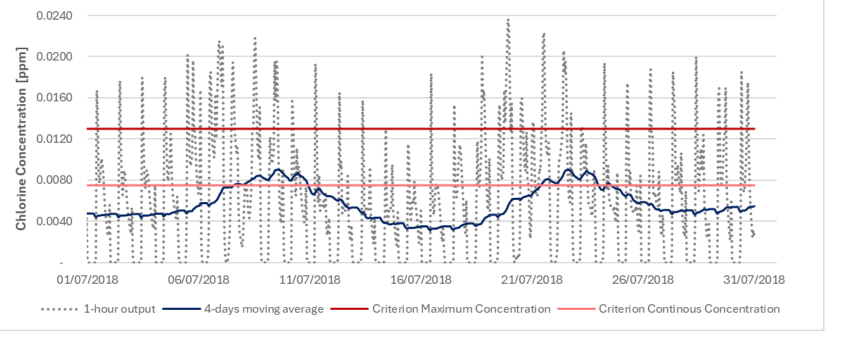
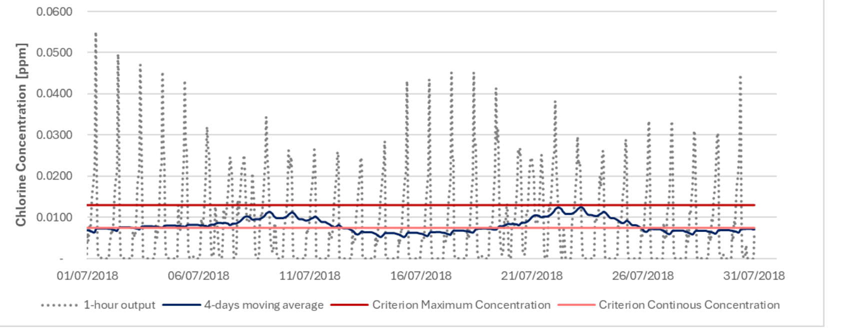
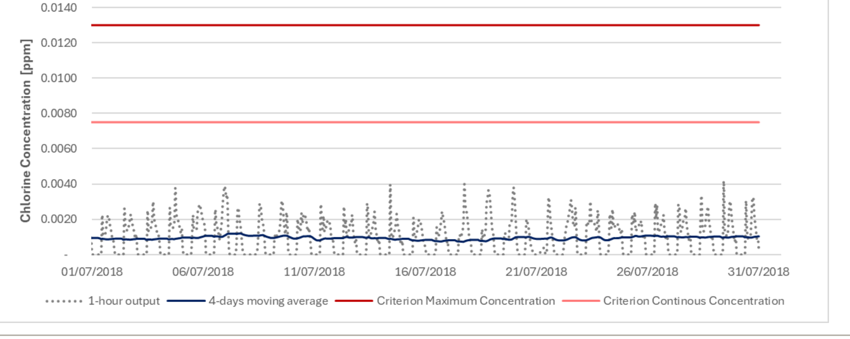
Based on the above findings of the chlorine discharge model, the impact significance of the increase in residual chlorine from project discharge is considered to be **Negligible**, based on Table 6-13 below. While no mitigation measures are required for this impact, proposed management measures detailed in EMMP (Section 8) will be implemented as part of best practice for environmental management.

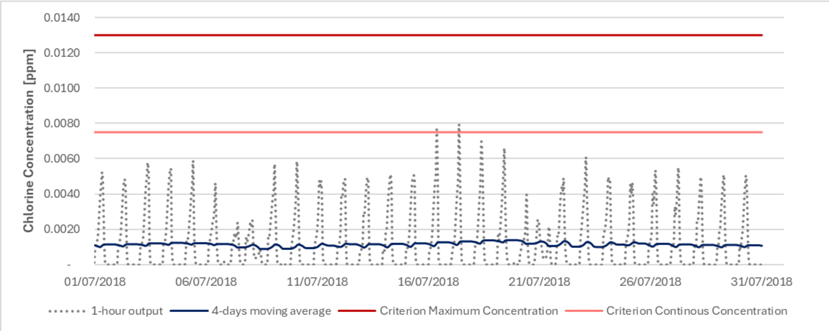
TABLE 6-13: TIME SERIES OUTPUT FOR RESIDUAL CHLORINE ELEVATION NEAR SURFACE AT LOCATIONS P4 TO P8

Season	Location	Distance from Outlet	Plot
Cross Section Location	N/A	N/A	 *Note: Offset distances of 100 m and 300 m from the drainage canal outlet are shown by the blue dashed circles.*

Season	Location	Distance from Outlet	Plot
NE	P4	100 m	
	P5	100 m	
	P6	100 m	

Season	Location	Distance from Outlet	Plot
	P7	300 m	
	P8	300 m	
SW	P4	100 m	

Season	Location	Distance from Outlet	Plot
	P5	100 m	
	P6	100 m	
	P7	300 m	

Season	Location	Distance from Outlet	Plot
	P8	300 m	

6.8.2.2 SUMMARY

TABLE 6-14: IMPACT SIGNIFICANCE – ELEVATION OF RESIDUAL CHLORINE LEVEL FROM PROJECT DISCHARGE

Impact		Impact Assessment of Elevation of Residual Chlorine Level from the Project Discharge				
Impact Nature		**Negative**	Positive	Neutral		
IMPACT CHARACTERISTICS	**Type**	**Direct**	Indirect	Induced		
		Impact is direct.				
	Extent	Site	**Local**	Regional	National	International
		The Project will discharge into marine water to the southeast of the site. The extent of predicted change in water temperature is limited to the localised area surrounding the outlet.				
	Scale	**Negligible**	Small	Medium	Large	
		Residual chlorine elevation would comply with the corresponding acute and chronic criteria of USEPA beyond 300 m from the drainage canal outlet, including at all sensitive receptors.				
	Duration	**Temporary**	Short-term	Long-term	Permanent	
		The discharge will be continuous throughout the operation phase (long term), but the discharge will not significantly increase the residual chlorine levels at any identified marine sensitive receptor locations. Compliance of acute and chronic criteria for residual chlorine is expected beyond 300 m from the outlet. Therefore, the predicted change over which the receptors may be impacted is considered temporary.				
	Frequency	The discharge will be continuous throughout the operation phase and compliance is expected beyond 300 m from the outlet, including at all identified marine sensitive receptor locations. Therefore, the predicted change over which the receptors may be impacted is rare.				
IMPACT MAGNITUDE		Negligible	**Small**	Medium	Large	
		Temporary (rare frequency) with local-extend at negligible scale. Discharges are well within benchmark effluent discharge limits (small impact as per Table 6-2).				
RECEPTOR SENSITIVITY		**Low**	Medium	High		
		Existing water quality is generally good and in compliance with the corresponding MWQC Water Quality Standard.				
Impact Significance		**Negligible**	Minor	Moderate	Major	

The significance of impacts is expected to be negligible. No mitigation measure for this potential source of impact is deemed necessary.

6.9 SUMMARY OF MARINE WATER QUALITY ASSESSMENT FINDINGS

The major sources of marine water quality impact from operational phase discharge, namely, change in water temperature, and elevation in chlorine level at the receiving water, have been assessed quantitatively using computational modelling. Several embedded controls (refer to Section 6.7) have been considered in the Project design and reflected in the modelling/ assessment to minimize the potential impact.

The change in water temperature was assessed based on the MWQC criterion of 2°C elevation. Modelling results indicate that temperature elevation at 100 m from the drainage canal outlet could exceed the 2°C elevation criterion of MWQC for about 15% of time but will fully comply at about 300 m from the drainage canal outlet (and thus at all identified marine sensitive receptors). The impact magnitude of the change in water temperature from thermal discharge is considered **Minor**.

The elevation of chlorine from the Project discharge was assessed against the USEPA's acute (13 µg/L as one-hour average) and chronic (7.5 µg/L as four-day average) criteria. Modelling results indicate that predicted elevation will comply with both the acute and chronic criteria at 300 m from the drainage canal outlet. The impact magnitude of the increase in residual chlorine from project discharge is considered **Negligible**.

In view of the above, the potential water quality impact from the Project's operation is deemed limited with the implementation of embedded controls. Therefore, no additional mitigation measure is deemed necessary. While no mitigation measures are required for the assessed impacts, proposed management measures detailed in the EMMP (Section 8) will be implemented by the Project as part of best practice for environmental management.

7. MARINE BIODIVERSITY

7.1 INTRODUCTION

This Section of the EIA evaluates the potential impacts on marine biodiversity (i.e. marine habitats, flora and fauna) associated with the operational phase of the Project[8]. Where required, the mitigation hierarchy framework of avoidance, minimisation, reduction or compensation has been applied to potentially significant impacts and to look to reduce impact levels to as low as reasonably practicable. Monitoring recommendations for marine biodiversity during the operational phase of the Project are also referenced, where applicable.

Technical Agencies have been consulted since the early phase of the Project (October 2024) and Nature Groups have been engaged in December 2025, to understand biodiversity concerns and seek feedback in preparing the biodiversity impact assessment for the Project. The discussions and recommendations from Technical Agencies and engaged stakeholders (including Nature Groups) have been considered in the following assessment.

This section summarises and draws upon information from the following technical reports:

- Marine Water Quality Baseline Report (Appendix C), which includes the full methodology and detailed results of a marine biodiversity and water quality survey conducted in July and August 2025.
- Marine Water Quality Modelling Assessment Report (Appendix D), which includes the full methodology, data source, modelling scenarios and detailed results of the marine water quality assessment.

7.2 SCOPE OF ASSESSMENT

The Project involves the construction and operational phases of the proposed facilities as described in Section 2. The potential marine biodiversity impacts associated with the construction works are expected to be fully controlled through mitigation with the implementation of the Environmental Monitoring and Management Plan (EMMP) (Section 8). The following sections will cover the operational-phase marine biodiversity impacts, namely on:

- Impact of changes in water quality (thermal and chlorine plumes) on coral habitat;
- Impact of changes in water quality (thermal and chlorine plumes) on the planktonic community;
- Impact of changes in water quality (thermal and chlorine plumes) on the macrobenthos community;
- Impact of changes in water quality (thermal and chlorine plumes) on seagrass habitat; and
- Impact of changes in water quality (thermal and chlorine plumes) on marine species.

7.3 REGULATORY FRAMEWORK

The collection of ecological baseline data and impact assessment referred to the administrative framework as outlined in Section 3. Section 3 refers to legislation, standards and/or guidelines applicable to biodiversity governance in Singapore relevant to this Project. This includes:

---

[8] As agreed with the Technical Agencies, assessment of impacts to marine biodiversity during the construction phase has been scoped out of this EIA, however, embedded controls to ensure minimisation of any impact is included in Section 8, EMMP.

- Parks and Trees Act (Amendment), 2017;
- Public Utilities (Reservoir and Catchment Areas and Waterway) Regulations, 2018;
- National Parks Board Guidelines on Greenery Provision and Tree Conservation for Developments, 2018;
- NParks Biodiversity Impact Assessment (BIA) Guidelines, 2024;
- Wildlife Act, 1965 (Revised edition 2020);
- National Biodiversity Strategy and Action Plan (NBSAP), 2019;
- Nature Conservation Master Plan (NCMP), 2015;
- Singapore Red Data Book (3rd edition), 2024; and
- Singapore Blue Plan, 2018

7.4 IMPACT ASSESSMENT CRITERIA

The sensitivity and magnitude of potential impacts on habitats and species have been assessed in accordance with ERM's IA standards, per the criteria presented in Table 7-1 and Table 7-2. The ERM impact assessment approach set out in Section 4 and below aligns with, and follows, the same principles as the NParks BIA Guidelines. Additionally, an Environmental Impact Significance criterion (also known as Environmental Quality Objective (EQO)) was aligned with Technical Agencies regarding the assessment criteria to determine impact levels per the tables below considering the water quality criteria for limits for ecological receptors in Section 6.4, Table 6-1.

Reference is made throughout this section to the Species Conservation Status, with reference to the Singapore Red Data Book (RDB3)[9] and international IUCN status[10].

[9] Davison GWH, Gan JWM, Huang D, Hwang WS, Lum SKY & Yeo DCJ (eds.) (2024) The Singapore Red Data Book: Red Lists of Singapore Biodiversity. 3rd ed. National Parks Board, Singapore.
[10] Obtained from https://www.iucnredlist.org/es

TABLE 7-1: SIGNIFICANCE OF IMPACTS ON HABITATS

Baseline Habitat Sensitivity/Value		**Magnitude of Effect on Baseline Habitats**			
		Negligible	**Small**	**Medium**	**Large**
		Effect is within the normal range of natural variation	*Affects only a small area of habitat, such that there is no loss of viability / function of the habitat*	*Affects part of the habitat, but does not threaten the long-term viability / function of the habitat.*	*Affects the entire habitat, or a significant proportion of it, and the long-term viability / function of the habitat is threatened.*
Negligible	Habitats with negligible interest for biodiversity.	**Negligible**	**Negligible**	**Negligible**	**Negligible**
Low	Habitats with no, or only a local designation / recognition, habitats of significance for species listed as of Least Concern (LC) on Singapore's Red Data Book and/or IUCN Red List of Threatened Species, habitats which are common and widespread within the region, or with low conservation interest based on expert opinion.	**Negligible**	**Negligible**	**Minor**	**Moderate**
Medium	Habitats within nationally designated or recognised areas, habitats of significant importance to locally and/or globally Vulnerable (VU) Near Threatened (NT), or Data Deficient (DD) species, habitats of significant importance for nationally restricted range species, habitats supporting nationally significant concentrations of migratory species and / or congregatory species, and low value habitats used by species of medium value.	**Negligible**	**Minor**	**Moderate**	**Major**
High	Habitats within internationally designated or recognised areas; habitats of significant importance to locally and/or globally Critically Endangered (CR) or Endangered (EN) species, habitats of significant importance to endemic and/or globally restricted-range species, habitats supporting globally significant concentrations of migratory species and / or congregatory species, highly threatened and/or unique ecosystems, areas associated with key evolutionary species, and low or medium value habitats used by high value species.	**Negligible**	**Moderate**	**Major**	**Major**

TABLE 7-2: SIGNIFICANCE OF IMPACTS ON SPECIES

Baseline Species Sensitivity/Value		**Magnitude of Effect on Baseline Species**			
		Negligible	**Small**	**Medium**	**Large**
		Effect is within the normal range of variation for the population of the species.	*Effect does not cause a substantial change in the population of the species, or other species dependent on it.*	*Effect causes a substantial change in abundance and / or reduction in distribution of a population over one, or more generations, but does not threaten the long-term viability / function of that population, or any population dependent on it.*	*Affects entire population, or a significant part of it causing a substantial decline in abundance and / or change in and recovery of the population (or another dependent on it) is not possible either at all, or within several generations due to natural recruitment (reproduction, immigration from unaffected areas).*
Negligible	Species with no specific value or importance attached to them	**Negligible**	**Negligible**	**Negligible**	**Negligible**
Low	Species and sub-species of LC on the IUCN Red List, or not meeting criteria for medium or high value. Species which are not sensitive to changes in water quality.	**Negligible**	**Negligible**	**Minor**	**Moderate**
Medium	Species on IUCN Red List as VU, NT, or DD, species protected under national legislation, nationally restricted range species, nationally important numbers of migratory, or congregatory species, species not meeting criteria for high value, and species vital to the survival of a medium value species. Species that are under pressure and/or are slow to adapt to changing environments. Species which could be sensitive to change in water quality.	**Negligible**	**Minor**	**Moderate**	**Major**
High	Species on IUCN Red List as CR, or EN. Species having a globally restricted range (ie endemic to a site, or found globally at fewer than 10 sites, fauna having a distribution range of less than 50,000 km2), internationally important numbers of migratory, or congregatory species, key evolutionary species, and species vital to the survival of a high value species. Species that are under significant pressure and/or highly sensitive to changing environments. Species which are very sensitive to change in water quality	**Negligible**	**Moderate**	**Major**	**Major**

7.5 BASELINE CONDITIONS

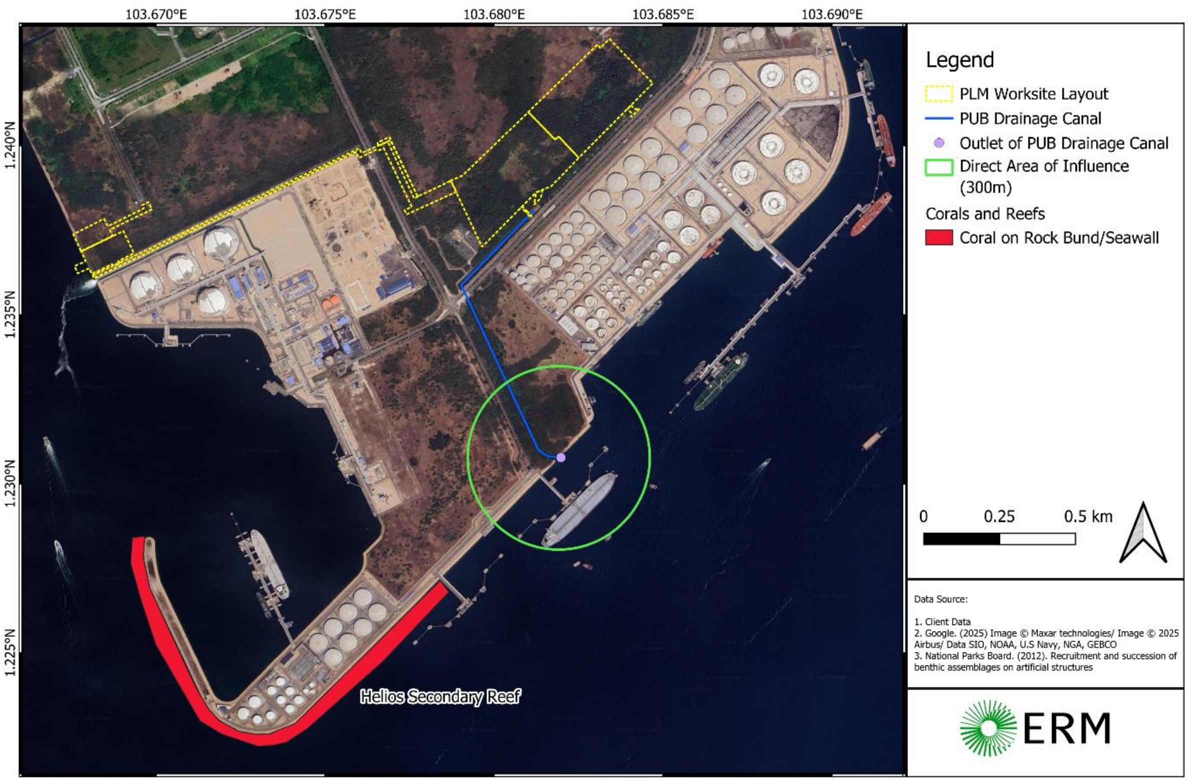
7.5.1 METHODOLOGY

For the purpose of establishing the marine biodiversity baseline and conducting an impact assessment of water quality discharge from the CGGT, two distinct Project AOIs have been defined: a Direct AOI and an Indirect AOI. This approach allows for a focused assessment of direct impacts on nearby sensitive receptors, while also considering broader, indirect ecological effects in a precautionary manner.

Direct AOI

Direct AOI refers to the primary impact zone where the changes in marine water quality (due to the thermal and chlorine plume) are predicted to cause direct physiological stress, or even mortality, to marine organisms. For this assessment, the direct AOI is based on the results of the Marine Water Quality Assessment Report (Appendix D), which presents the outcomes of modelling scenarios illustrating the extent of thermal and chlorine plume dispersion with variables such as monsoon seasons and depths. Given that thermal plume extends over a greater area than chlorine, the direct AOI was determined based on the maximum increase in temperature that would exceed the threshold of coral stress. Hence the direct AOI is defined as an area within 300 m from the outlet of the drainage canal.

FIGURE 7-1: DIRECT AOI (300 M) AND NEARBY MARINE HABITATS[11]



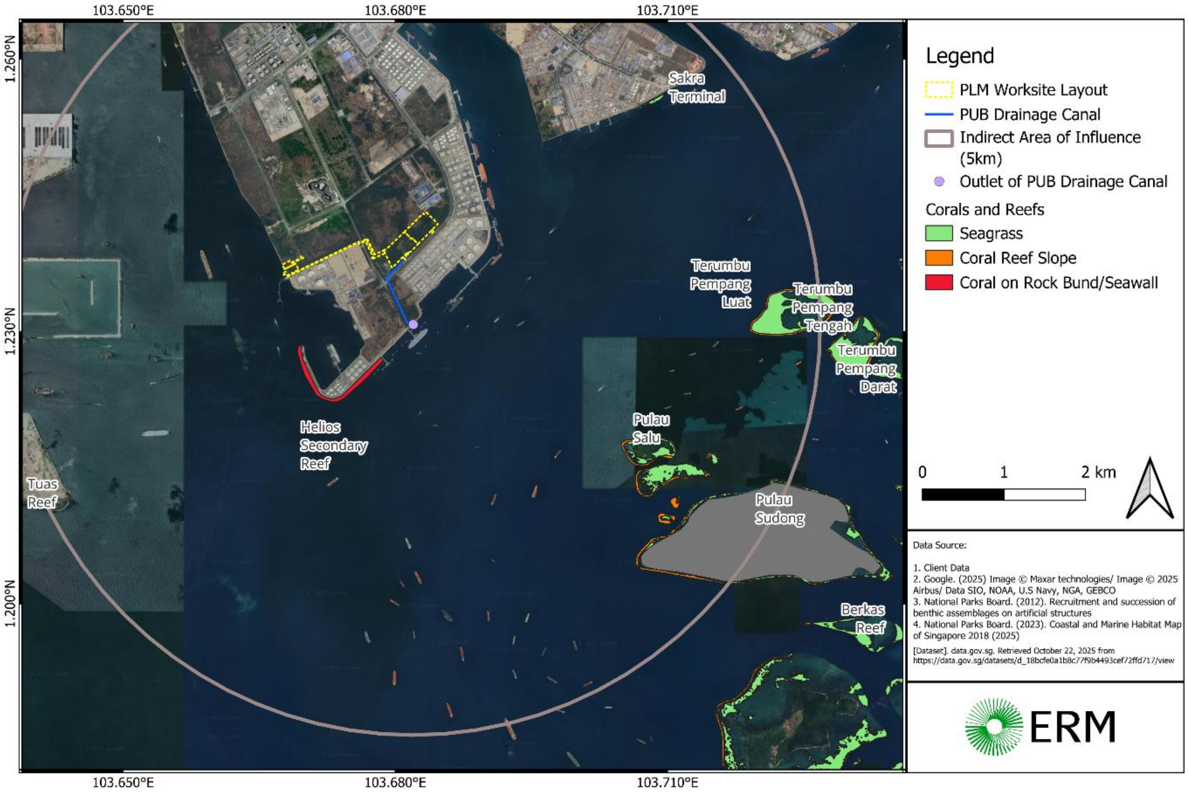
[11] Rock Bund/Seawall in legend: Shoreline protection structures (man-made revetments made of armor rock), to protect the coastline from erosion and flooding by absorbing wave energy.

Indirect AOI

The indirect AOI of 5 km is a larger, precautionary buffer zone established to assess potential secondary impacts that may extend beyond the area of direct thermal influence. This larger area was established to encompass known marine biodiversity sensitive receptors and ecologically linked areas that fall outside the immediate thermal and chlorine plume model predictions. This includes the Helios Secondary coral reef, located 700 m south-west from its closest point to the drainage canal outlet, other coral habitats further away within the Southern Islands[12] along with other marine habitats and species that may experience indirect effects of thermal and chlorine plumes.

While fish farms are located outside of the indirect AOI (more than 9 km from the outlet of the drainage canal) per Figure 7-13, impacts on fish farms from thermal and chlorine plumes have been evaluated as part of this study based on consultation with the Technical Agencies on the EIA's scope of work.

FIGURE 7-2: INDIRECT AOI (5 KM) AND NEARBY MARINE HABITATS[13]



Desktop and site-based studies were undertaken to inform an understanding of marine biodiversity around the site. The coverage and methodologies of the marine biodiversity baseline surveys were discussed and agreed with relevant Technical Agencies, including NParks, during the scoping phase of the Project. Marine biodiversity baseline surveys were conducted on-site for plankton and macrobenthos on 28 July 2025 and 5 August 2025 to

[12] The Project site on Jurong Island is located adjacent to the Straits of Singapore. The Southern Islands are located further south,3.7km away.
[13] Coral slope in legend refers to: natural rocks, sand, coral or similar material lying beneath the water surface

cover four (4) tidal conditions: spring flood, spring ebb, neap flood, and neap ebb tides. Where information was available, desktop studies were conducted for other taxonomic groups (e.g. marine mammals, reptiles, fish and corals) to support establishment of the baseline conditions. Details of the survey methodology are summarised in Table 7-3, with locations of macrobenthos and plankton sampling in Figure 7-3.

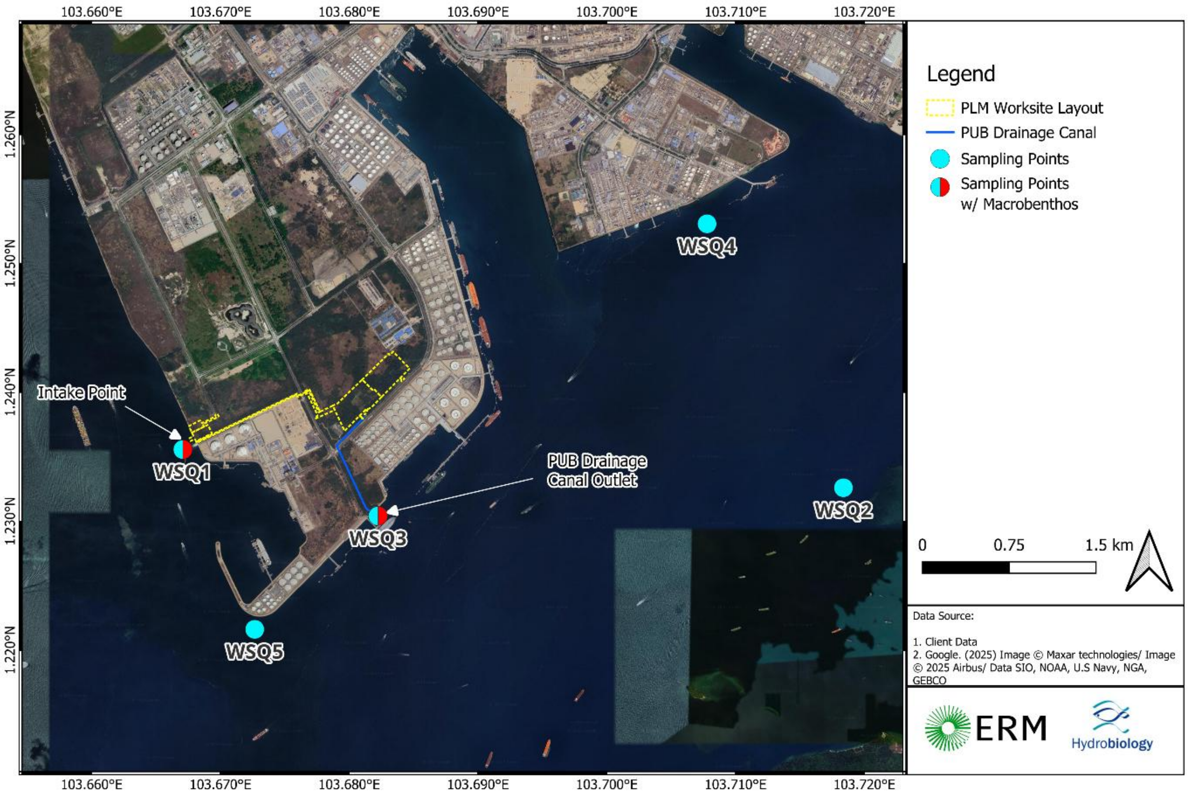
As outlined in Section 6.5.1, marine water quality surveys were conducted at WSQ1 to WSQ5 per Table 7-3 were also conducted during the baseline stage. The marine water quality sampling points were chosen to represent:

- WSQ1: Conditions at the cooling water intake;
- WSQ2: Conditions at marine biodiversity sensitive receptor Terumbu Pempang Laut;
- WSQ3: Conditions at the outlet of the PUB drainage canal for cooling water;
- WSQ4: Conditions at marine biodiversity sensitive receptor Sakra Terminal at Jurong Island; and
- WSQ5: Conditions at marine biodiversity sensitive receptor Helios Secondary Reef.

TABLE 7-3: SUMMARY OF MARINE BIODIVERSITY SURVEY METHODOLOGY

	Survey Component	**Methodology**
Marine Habitat	On-site Sampling	
	Planktons	• Sampled at 5 locations (WSQ1 to WSQ5) • Phytoplankton were collected using a 53 μm tow net while zooplankton were collected using a 250 μm tow net. • Triplicate (3 replicate) samples of planktons were taken for each location. • Identification of plankton was carried out based on morphological characteristics under a microscope, supported by related taxonomic keys and reference literature.
	Macrobenthos	• Sampled at 2 locations (WSQ1 and WSQ3) • At each location, a Van Veen grab sampler was used to take 3 replicate samples with a combined sample mass of at least 3kg • The samples were then sieved through a 250 μm mesh aperture for further analysis
	Desktop Studies	
	Coral Reefs and Seagrass	• Literature review based on research publications, published EIA reports, government and agency databases for potential sightings were collated to inform of biodiversity surrounding Jurong Island.
Marine Species	Marine Mammals	
	Reptiles	
	Fish	

FIGURE 7-3: LOCATIONS OF PLANKTON (BLUE DOTS) AND MACROBENTHOS (BLUE/RED DOTS) SAMPLING POINTS



7.5.2 MARINE HABITATS

The Project worksite is situated on vacant land on Jurong Island, which was created via the reclamation and merging of the Ayer Islands (Pulau Ayer Chawan, Pulau Merlimau, Pulau Merbau, Pulau Sakra, Pulau Pesek, Pulau Pesek Kechil, Pulau Seraya). The Jurong Island land reclamation project was completed in 2009.

The outlet of the drainage canal next to the Project site is situated next to a highly modified marine environment. From the discharge point at Meranti Crescent, the discharge will flow through an existing stormwater canal (PUB drainage canal) along Meranti Road for a distance of approximately 1 km before entering the Straits of Singapore next to the Singapore Refining Co. VLCC Terminal. This drainage canal (Figure 7-4) is a man-made concrete-lined drainage channel with vertical walls and no natural substrate or riparian vegetation inside the canal, designed for stormwater management on Jurong Island and typically lacks the water quality stability and salinity gradients that support diverse freshwater or estuarine assemblages. Additionally, based on site visits to the area, aquatic fauna and corals were not visually seen at the PUB drainage canal and hence the canal was not considered a sensitive receptor in the impact assessment.

This drainage canal outlet area is characterised by a heavily industrialized coastline in proximity to artificial reef structures (Helios Secondary Reef) and a dense network of natural patch reefs located 3.7 km south of the drainage canal outlet. Helios Secondary Reef, located 700 m from its closest point to the drainage canal, is termed as a secondary reef as the coral community has colonised the man-made seawall in this area over the years as opposed to a primary reef, which are natural reefs built by corals over a natural seabed foundation. Within the Straits of Singapore and Southern Islands further south, there are seagrass and other coral habitats (Figure 7-1) present within the 5 km direct AOI.

Plankton and macrobenthos are also indicators of habitat conditions (e.g. productivity, quality and complexity). For a detailed species list of plankton (phytoplankton and zooplankton) and macrobenthos found, please refer to Appendix C.

FIGURE 7-4: PUB DRAINAGE CANAL (ABOVE) AND OUTLET TO THE SEA (BELOW)

7.5.2.1 CORAL REEFS AND SEAGRASS

A coastal and marine habitat map of Singapore, created through satellite imagery and bathymetry data[14], is shown in Figure 7-2 and shows areas with corals and seagrass within the 5 km indirect AOI from the drainage canal outlet.

[14] National Parks Board. (2023). Coastal and Marine Habitat Map of Singapore 2018 (2024) [Dataset]. data.gov.sg. Retrieved November 4, 2025 from https://data.gov.sg/datasets/d_18bcfe0a1b8c77f9b4493cef72ffd717/view

Coral Reefs

Despite extensive coastal development, land reclamation and large-scale shipping activities resulting in suspended sediment, sedimentation, turbidity and eutrophication impacts[15,16], diverse coral communities still exist, and overall mean live coral cover remains relatively high in Singapore[17]. Singapore has 255 species of hard coral species present within an estimated 10 km^2 reef area, which is almost a third of global species data[18,19] and approximately 0.3 km^2 is located within the 5 km indirect AOI[20]. The majority of Singapore's Seleractinanian (reef building) corals are found within the Southern Islands. The Southern Islands, which are present within the 5km indirect AOI of the Project's outlet, include Pulau Salu (3.7 km), Terumbu Pempang Laut (4.7 km) and Pulau Sudong (4 km). These coral reef ecosystems provide an array of important marine ecosystems and marine biodiversity connectivity services, including coastal protection, water purification, carbon sequestration and shelter for juvenile fishes.

Helios Secondary Reef

Based on Figure 7-1, the nearest coral reef to the site's drainage canal outlet is the Helios Secondary Reef, located 700 m from its closest point to the drainage canal outlet on the southernmost edge of Jurong Island, where corals have developed on a modified environment (i.e. seawall, rock bund). Seleractinanian communities found on seawalls in Singapore are comparable to those found on rocky shores as they are subject to similar environmental changes, such as regular inundation from tides, waves and irregular salinities[21].

Based on a report from NParks, using data from a line intercept transect (LIT) (for recording benthic lifeforms typical of a coral reef community) and visual quadrat transect (for recording lower reef community) survey conducted in 2012[22], hard coral cover was at 29.3% (Figure 7-5). At the reef slope (3m; survey depth: 5 - 6.2 m), an overall 33.1%

---

[15] Browne NK, Tay JKL, Low J, Larson O, Todd PA (2015) Fluctuations in coral health of four common inshore reef corals in response to seasonal and anthropogenic changes in water quality. Mar Environ Res 105:39–52

[16] Heery EC, Hoeksema BW, Browne NK, Reimer JD, Ang PO, Huang D, Friess DA, Chou LM, Loke LHL, Saksena-Taylor P, Alsagoff N, Yeemin T, Sutthacheep M, Vo ST, Bos AR, Gumanao GS, Syed Hussein MA, Waheed Z, Lane DJW, Johan O, Kunzmann A, Jompa J, Suharsono TD, Bauman AG, Todd PA (2018) Urban coral reefs: degradation and resilience of hard coral assemblages in coastal cities of East and Southeast Asia. Mar Pollut Bull 135:654–681

[17] Wong JSY, Chan YKS, Ng CSL, Tun KPP, Darling ES, Huang D (2018) Comparing patterns of taxonomic, functional and phylogenetic diversity in reef coral communities. Coral Reefs 37:737–750

[18] Huang, D., Tun, K.P.P., Chou, L.M. & Todd, P.A. (2009). An inventory of zooxanthellate scleractinian corals in Singapore, including 33 new records. Raffles Bulletin of Zoology Supplement 22: 69–80

[19] Loke M.C., Kok B.T, Ywee C.T., Phang V. (2012). Coral reefs in Singapore: past, present and future. The Asian Conference on Sustainability, Energy and the Environment. Retrieved from https://coralreef.nus.edu.sg/publications/Chou2012IAF.pdf

[20] Estimated value based on calculations on qGIS from Coastal and Marine Habitat Map of Singapore 2018

[21] Thompson, R. C., T. P. Crowe & S. J. Hawkins (2002). Rocky intertidal communities: past environmental changes, present status and predictions for the next 25 years. Environmental Conservation, 29: 168–191.

[22] Given that no publicly available data is available for Helios Secondary Reef, data from a 2012 report by NParks has been used. More recent data on this reef is not available. Source: NParks (2012). Recruitment and Succession of Benthic Assemblages on Artificial Structures.

coral cover was recorded at Helios Secondary Reef. For hard coral diversity, a total of 30 genera of hard corals were found (per Table 7-4), which is 54% of the total coral genera (56) recorded from Singapore's reefs[23]. Despite being located in an industrial area, Helios Secondary Reef recorded a rich lower reef community at 3 m survey depth with 92 individuals per square metre (Figure 7-6). Some examples of genera found at 3m depth of the seawall were *Pachyseris, Euphyllia, Cyphastrea* and *Oulastrea*. Genera found at 0m of the seawall (located on the waterline) include *Acropora, Montipora, Plesiastrea* and *Sympyllia*. At both 0 m and 3 m depths, there was presence of *Turbinaria, Favia, Favites* and *Leptastrea*. There was also an abundance of soft corals within the high current velocity area of the seawall (Figure 7-7). Helios Secondary Reef has a similar coral cover of 33.1% at 3 m depth (NParks, 2012) compared to other coral reefs within the 5 km AOI at the Southern Islands in Table 7-5.

Coral baseline surveys have not been conducted for this project given that Helios Secondary Reef is located 700m away from the PUB drainage canal, outside of the 300m direct AOI zone. The list of coral genera, photos from the study site and all other relevant information from the NParks 2012 report has been included within this section of the EIA report. Hence, additional baseline surveys are not expected to alter the impact assessment in Section 7.9.1.

TABLE 7-4: LIST OF CORAL GENERA RECORDED AT TWO (2) SURVEY DEPTHS OF THE JURONG ISLAND SEAWALL

Genera	Shallow Reef Crest Zone, 0 m	Submerged Zone, 3 m
Acropora	1[(a)]	0[(b)]
Montipora	1	0
Pachyseris	0	1
Turbinaria	1	1
Euphyllia	0	1
Cyphastrea	0	1
Favia	1	1
Favites	1	1
Leptastrea	1	1
Oulastrea	0	1
Platygyra	1	1
Plesiastrea	1	0
Fungia	0	1
Herpolitha	0	1
Lithophyllon	0	1

[23] Huang, D., Tun, K.P.P., Chou, L.M. & Todd, P.A. (2009). An inventory of zooxanthellate scleractinian corals in Singapore, including 33 new records. Raffles Bulletin of Zoology Supplement 22: 69–80

Genera	Shallow Reef Crest Zone, 0 m	Submerged Zone, 3 m
Podabacia	1	1
Hydnophora	1	0
Merulina	1	1
Acanthastrea	1	0
Lobophyllia	0	1
Symphyllia	1	1
Galaxea	1	1
Echinophyllia	0	1
Mycedium	0	1
Oxypora	0	1
Pectinia	0	1
Pocillopora	1	0
Goniopora	1	1
Porites	1	1
Psammocora	1	1
Total Number of Genera Found at Each Zone	18	24
Total Number of Genera Found for both Zones	**30**	

Notes:
(a) "1" indicates presence of genera at the respective survey depth
(b) "0" indicates no presence of that genera at the respective survey depth

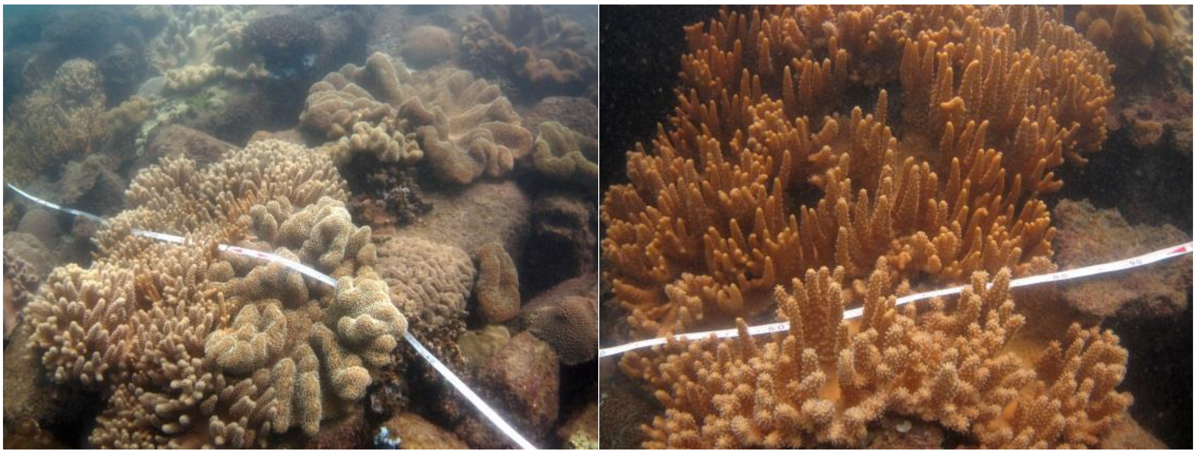
FIGURE 7-5: HARD CORAL COMMUNITIES AT HELIOS SECONDARY REEF

Source: NParks (2012)

FIGURE 7-6: LOWER REEF COMMUNITY AT HELIOS SECONDARY REEF

Source: NParks (2012)

FIGURE 7-7: SOFT CORALS IN HIGH CURRENT VELOCITY AREA (0M DEPTH TRANSECTS) AT HELIOS SECONDARY REEF



Source: NParks (2012)

TABLE 7-5: CORAL COVER IN REEFS WITHIN 5 KM INDIRECT AOI

Coral Reef Location	Distance from Project Outlet	% Coral Cover	
		0 m depth	**3 m depth**
Helios Secondary Reef	700m	Not Available	33.1
Pulau Salu	3.7km	49.7	37.3
Pulau Sudong	4km	50.2	27.8
Terumbu Pempang Laut	4.7km	57.0	22.3

Other coral reefs located within the indirect AOI from the drainage canal outlet in the Southern Islands include Pulau Salu, Terumbu Pempang Laut and Pulau Sudong. Coral reefs in the Southern Islands are either fringing reefs or patch reefs generally dominated by foliose and slow-growing stress-tolerant hard coral families (e.g. *Merulina, Pachyseris* and *Echinopora*) which provides lower structural complexity[24], can attach to rubble, and can optimise low light conditions in Singapore's highly turbid waters. Within the Southern Islands, the presence of soft corals is understood to be lower, which can be attributed to high sedimentation and suspended sediments, resulting in reduced light penetration. *Alyconiidae* is the most abundant family observed, with seven (7) genera found *(Lobophytum, Sarcophyton, Stereonephthya, Sinularia, Ciadiella, Nepthesa* and *Carijoa*)[25].

Coral Spawning

With the presence of coral reefs habitats within 5km of the outlet of the PUB drainage canal, it is noted that coral spawning events may occur within the Straits of Singapore and coral larvae may potentially flow with the currents along the outlet. Coral spawning of larvae occurs in the early life stage of corals, where successful settlement of larvae will allow for the population replenishment and thus persistence of coral communities in Singapore. These coral spawning events typically take place on a few nights after the full moon with the primary coral spawning events in Singapore (for most colonies) occurring between March to April and a secondary spawning event (for some colonies) occurring around October[26,27], both of which happen during the inter-monsoon months where wind speeds are low compared to Northeast and Southwest Monsoon seasons.

Seagrass

Singapore has a variety of seagrass species and habitats within a relatively small area in close proximity to many anthropogenic threats[28]. Seagrasses found in the Southern Islands (the closest island, Pulau Salu is located 3.7 km away from the drainage canal outlet) are typically associated with coral reefs, found between the reef break and shore, at depths of 10m or less. They are restricted to shallower waters in Singapore due to its high light requirements for photosynthesis[29]. Based on a study by McKenzie et al (2016)[30], a total of 12 species of seagrass have been recorded at 41 localities in Singapore, with the most commonly found species being *Healophila ovalis* (RDB3 LC, IUCN LC).

Based on the marine habitat map (Figure 7-2), the seagrass community is not present within 3.5 km of the Project's outlet at the drainage canal. Within the 5km AOI, seagrass

---

[24] Guest JR, Tun K, Low J, Verge´s A, Marzinelli EM, Campbell AH, Bauman AG, Feary DA, Chou LM, Steinberg PD (2016) 27 years of benthic and coral community dynamics on turbid, highly urbanised reefs off Singapore. Sci Rep 6:36260

[25] Goh, B., Tan, G.and Tan, L.T. (2011). Diversity, distribution and biological activity of soft corals (Octocorallia, Alcyonacea) in Singapore. Journal of Coastal Development. 12, (2),89-98. ISSN 1410-5217.

[26] Guest, J.R., Baird, A.H., Goh, B.P.L and Chou L.M. (2005). Sexual reproduction in equatorial reef corals. Invertebrate Reproduction and Development, 48(1–3), 207–218

[27] Bauman AG, Guest JR, Dunshea G, Low J, Todd PA, Steinberg PD. (2015). Coral settlement on a highly disturbed equatorial reef system. PLoS One. 20;10(5):e0127874. doi: 10.1371/journal.pone.0127874.

[28] Yaakub SM, McKenzie LJ, Erftemeijer PLA, Bouma T & Todd PA (2014) Courage under fire: Seagrass persistence adjacent to a highly urbanised city–state. Marine Pollution Bulletin, 83(2): 417–424

[29] Ralph PJ, Durako MJ, Enriquez S, Collier CJ & Doblin MA (2007) Impact of light limitation on seagrasses. Journal of Experimental Marine Biology and Ecology, 350(1–2): 176–193.

[30] McKenzie, Len & Yaakub, Siti & Tan, Ria & Seymour, Jamie & Yoshida, Rudi. (2016). Seagrass habitats of Singapore: Environmental drivers and key processes. The Raffles Bulletin of Zoology. 2016. 60-77.

habitats are located at Pulau Salu (3.7 km), Sakra Terminal at Jurong Island (3.7 km), Pulau Sudong (3.9 km) and Terumbu Pempang Laut (4.1 km). These locations have small seagrass patches that are not large enough to form substantial seagrass meadows. A list of seagrass species available for Pulau Salu, Pulau Sudong and Terumbu Pempang Laut can be found in Table 7-6 below. Information for seagrass at Sakra Terminal is not publicly available due to the area being controlled and restricted to the public.

TABLE 7-6: SEAGRASS SPECIES FOUND IN LOCATIONS WITHIN AOI

Location	Species Found and Conservation Status
Pulau Salu	• *Halophila ovalis* (RDB3 LC, IUCN LC)
Pulau Sudong	• *Enhalus acoroides* (RDB3 CR, IUCN LC) • *Halophila ovalis* (RDB3 LC, IUCN LC)
Terumbu Pempang Laut	• *Syringodium isoetifolium* (RDB3 EN, IUCN LC) • *Enhalus acoroides* (RDB3 CR, IUCN LC) • *Halophila ovalis* (RDB3 LC, IUCN LC) • *Thalassia hemprichii* (RDB3 EN, IUCN LC)

Source: McKenzie et al (2016)

7.5.2.2 PLANKTON

Phytoplankton

Phytoplankton are primary producers which depend on sunlight and nutrients for growth. Phytoplankton are sensitive to changes in water characteristics such as changes in light, nutrients and other pollutants. They have a fast response rate to change, making them good indicators to changes in water quality[31], nutrient enrichment and potential eutrophication. Samples were collected to determine phytoplankton abundance. Across the 5 sampling locations, a total of nine (9) genera of phytoplankton were identified within 2 phyla groups, Dinophyta and Ochrophyta, with dominant genera being:

1. *Skeletonema spp.*, accounting for approximately 60%-100% of total abundance across all replicates. *Skeletonema spp*. often flourishes in nutrient-rich waters and plays a key role in carbon fixation and oxygen production.
2. *Chaetoceros spp.*, accounting for approximately 5%-35% across replicates. *Chaetoceros spp.* is also a major food source for many zooplankton groups including copepods.

Similar results were present for WSQ3 at the drainage canal outlet, showing a dominance of *Skeletonema spp.* (73.9 – 98.6% of total abundance) and lower levels of *Chaetoceros spp.* (0.9 – 26.1% of total abundance). Total phytoplankton counts per 1 mL range from 5,023 to 6,647 organisms, with minimal species diversity besides a trace of *Rhizosolenia* sp. and rare *Ochrophyta* taxa. Results for WSQ3 show a low species richness but high

[31] Suthers I.M and Rissik D. (2009). Plankton. A guide to their ecology and monitoring for water quality. CSIRO Publishing. Retrieved from https://www.uv.es/hegigui/ebooksclub.org__Plankton__A_Guide_to_their_Ecology_and_Monitoring_for_Water_Quality.pdf

abundance of phytoplankton, which creates potential plankton bloom conditions symptomatic of impaired water quality from elevated nutrient loading.

These two genera are common across coastal ecosystems as they can tolerate a wide range of temperatures and salinity[32]. The dominance of *Skeletonema* indicates productive phytoplankton communities, high nutrient availability which can potentially cause plankton blooms. These fast-growing, chain-forming diatoms under adequate silicate and mixing are typical of bloom stages in tropical coastal systems. *Skeletonema*, particularly *Skeletonema costatum,* is usually the most abundant species[33] which shows a strong relationship (i.e. high biomass at areas) with nutrients such as Total Nitrogen (TN) and Dissolved Inorganic Nitrogen (DIN)[34]. High abundance of *Skeletonema* suggests a stable diatom-driven productivity, typical of nutrient rich and well-mixed coastal waters. *Chaetoceros*, due to its small size, is able to outcompete the slower-growing larger phytoplankton for nutrients and outcompete smaller phytoplankton as it is better adapted to withstand turbulent conditions and is less palatable to grazers[35,36]. The baselines show a dominance of *Skeletonema* as it will dominate in nitrogen limitation, however in silicate limitation, it will be changed to *Chaetoceros*-dominated waters[37].

These findings are corroborated by exceedances in Nitrate-nitrogen (NO_3-N) levels against MWQC for all sampling locations (refer to Marine Water Quality Section 6.5.2), which promotes phytoplankton growth and increases total algal biomass, often leading to algal blooms. The limited diversity and dominance by a few species may also indicate environmental stress or disturbance, where only these tolerant species thrive.

Zooplankton

Zooplankton cover a range of drifting planktonic animals which feed on phytoplankton and transfer energy to higher trophic levels such as fish and marine mammals. They are vital for nutrient recycling and help to control algal blooms. A total of five (5) zooplankton phyla belonging to Annelida, Arthropoda, Mollusca, Chordata and Rotifera with 13 species were identified across five sampling sites. Zooplankton analysis shows that the dominant zooplankton family found across all sampling sites were:

- *Paracalanidae* copepods, comprising 22%-67% of total abundance across all replicates.

---

[32] Rudiyanti, S. (2012). The Growth of Skeletonema costatum on Various Salinity Level's Media. *Saintek Perikanan : Indonesian Journal of Fisheries Science and Technology, 6*(2), 70-77. https://doi.org/10.14710/ijfst.6.2.70-77
[33] Zheng Y., Giodarno, M and Gao K. (2015). Photochemical responses of the diatom Skeletonema costatum grown under elevated CO2 concentrations to short-term changes in pH. *Aquat Biol*, 23: 109-118.
[34] Toming, K. and Jaanus, A. (2007). Selecting potential summer phytoplankton eutrophication indicator species for the northern Baltic Sea. Proc. Estonian Acad. Sci. Biol. Ecol. 56, 4, 297ñ311
[35] Raquel F. Flynn et al. (2023). Nanoplankton: The dominant vector for carbon export across the Atlantic Southern Ocean in spring.Sci. Adv.9,eadi3059.DOI:10.1126/sciadv.adi3059
[36] V. Smetacek, P. Assmy, J. Henjes. (2004). The role of grazing in structuring Southern Ocean pelagic ecosystems and biogeochemical cycles. *Antarct. Sci.* **16**, 541–558.
[37] Harrison P. J., Davis C. O. (1979). The use of outdoor phytoplankton continuous cultures to analyse factors influencing species selection. Journal of Experimental Marine Biology and Ecology, 41(1), 9–23.

The dominance of *Paracalanidae* copepods suggests a stable and productive coastal ecosystem, as these copepods are common in tropical and subtropical waters and serve as a key food source for higher trophic levels. The presence of diverse phyla indicates moderate biodiversity, which is typical for nearshore environments with good water circulation and nutrient availability.

At WSQ3, *Cirripeds* (barnacle larvae) are the most abundant group (subclass) in all replicates, contributing 30–45.5% of the total count. The family *Paracalanidae* also comprises a significant portion (22.5–29.5%), and the subclass *Copepod nauplii* (larval stages) are prominent in one replicate (32.5%). Dominance by *Cirripeds* and *Paracalanidae*, along with large fractions of *Copepod nauplii*, indicates a zooplankton community structured by high food (phytoplankton) availability and likely environmental stress from eutrophication, in line with the overwhelming *Skeletonema* bloom observed in the phytoplankton. The zooplankton profile based on baseline findings is typical of nutrient-enriched coastal waters where opportunistic and fast-reproducing taxa thrive and species decline. Such assemblages often result from, and sustain, primary producer blooms, reinforcing indications of eutrophication and ecological imbalance at WSQ3.

7.5.2.3 MACROBENTHOS

Macrobenthos are benthic (bottom-dwelling) macroinvertebrates that are visible to the naked eye (typically larger than 0.5-1 mm). They play critical roles in nutrient cycling, sediment stability, food web dynamics and are environmental indicators of ecological quality, pollution and sediment health in aquatic ecosystems.

A total of 398 macrobenthos individuals were recorded across two (2) sampling stations (WSQ1 and WSQ3), belonging to four (4) invertebrate classes: Malacostraca (crabs), Ophiuroidea (brittle stars), Bivalvia (bivalves), and Gastropoda (snails) grouped into 37 invertebrate families, with the full list detailed in Appendix C. Species level data is not available as individuals were only able to be identified to family level, hence conservation statuses are not assigned to the macrobenthos found.

Gastropoda dominated the community, comprising of a relative abundance of more than 82.6% of individuals at both stations (Table 7-7), with WSQ3 dominated by Columbellidae, Triphoridae, and Pyramidellidae families of snails and WSQ1 dominated by Turritellidae and Nassariidae families of snails. Gastropods play key roles in nutrient cycling and sediment turnover, with their dominance implying active ecological functioning. WSQ1 also had six (6) unique taxa sampled including brittle stars and certain bivalves, while WSQ3 had 11 unique gastropod taxa not found in WSQ1 (detailed results in Appendix C).

WSQ3 had a significantly higher macrobenthos abundance (99.6 individuals) and density (2,491.6 individuals/m^2) as compared to WSQ1 (30.4 individuals with 766.4 individuals/m^2).

FIGURE 7-8: REPRESENTATIVE PHOTOGRAPHS OF MACROBENTHOS TAXA FOUND[38]

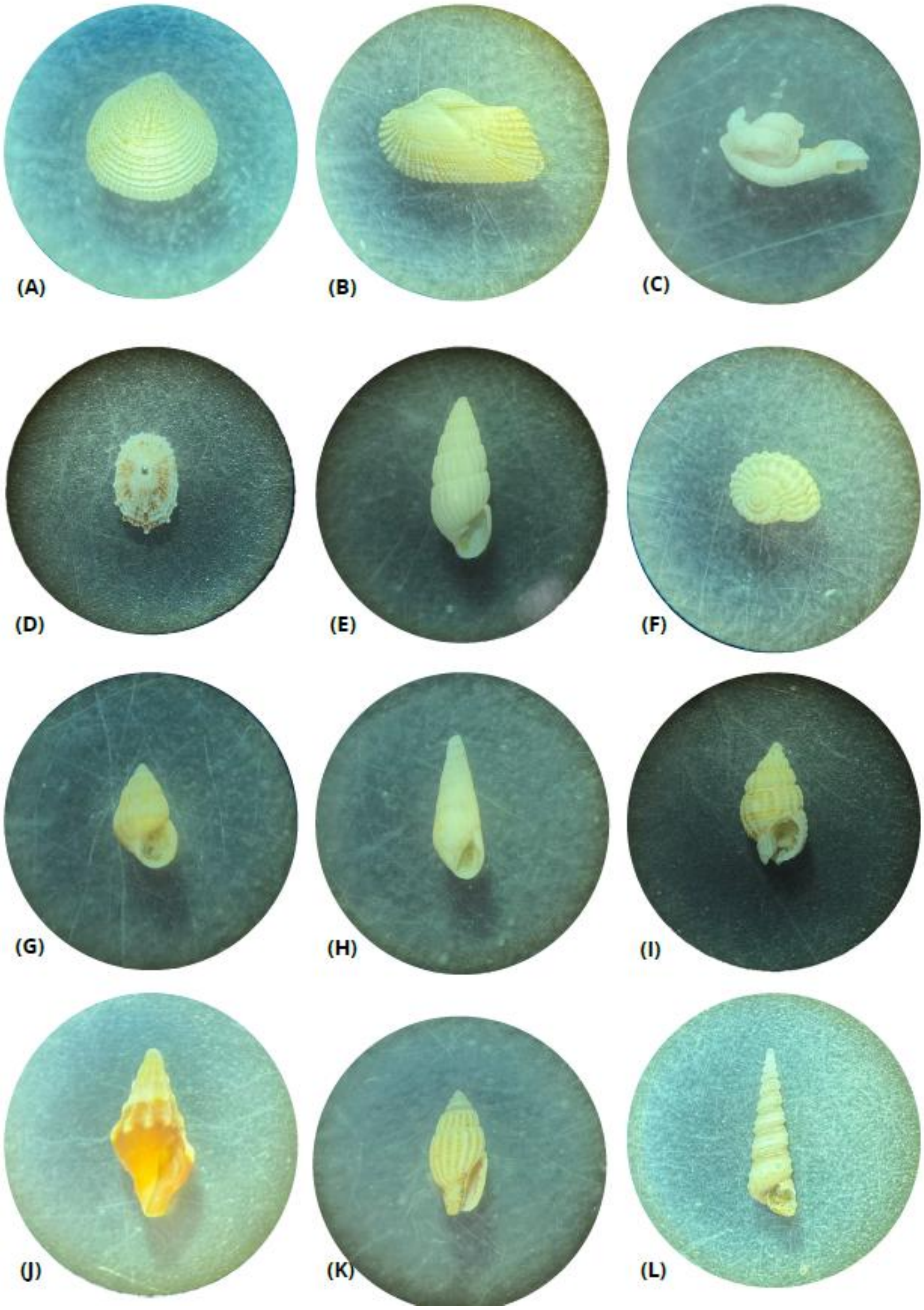


TABLE 7-7: MACROBENTHOS ABUNDANCE, RICHNESS AND DENSITY

Class	WQS1	WQS3
Malacostraca	0.3[(a)] (1.1%)[(b)]	0.0 (0.0%)
Ophiuroidea	1.0 (3.3%)	0.0 (0.0%)

38 (A)Lucinidae, (B)Arcidae, (C)Vermetidae, (D)Fissurellidae, (E)Pyramidellidae, (F)Skeneidae, (G)Rissoidae, (H)Eulimidae, (I)Nassariidae, (J)Turritellidae, (K) Columbellidae and (L) Turritellidae

Class	WQS1	WQS3
Bivalvia	4.0 (13.0%)	1.3 (1.3%)
Gastropoda	25.1 (82.6%)	98.3 (98.7%)
Total Macrobenthos Abundance	30.4	99.6
Total Taxonomic[(c)] Richness	20	25
Total Macrobenthos Density	766.4 individuals/m^2	2,941.6 individuals/m^2

Note:
(a) Values without parenthesis reflect Mean Abundance (MA)
(b) Values in parentheses reflect Relative Abundance (RA)
(c) Family level

WSQ3 had 25 taxonomic groups (family level) while WSQ1 had 20 taxonomic groups (family level). The Shannon Biodiversity Index (H')[39], which uses the formula below:

$$H = -\sum(p_i * \ln(p_i))$$

Where *Pi* is the is the proportion of individuals belonging to species *i* in the community and *ln* is the natural logarithm. A higher value of H indicates greater diversity. Based on Fernando et al (1998), the classification scheme for the Shannon Diversity Index is as below:

TABLE 7-8: CLASSIFICATION SCHEME FOR THE SHANNON BIODIVERSITY INDEX

Relative Values	Shannon Biodiversity Index (H')
Very High	3.50 and above
High	3.00 – 3.49
Moderate	2.50 – 2.99
Low	2.0 – 2.49
Very Low	1.99 and below

Source: Fernando E.S. (1998)[40]

TABLE 7-9: SHANNON DIVERSITY INDEX (H') VALUES FOR MACROBENTHOS RESULTS

Site	Sample Number	H'	Rating	H' (Mean)	Overall Rating
WSQ1	1	0.54	Very Low	1.43	Very Low
	2	1.27	Very Low		

[39] The Shannon Biodiversity Index is a measure of biodiversity in an ecological community that accounts for both the number of species (richness) and their relative abundance (evenness).
[40] Fernando ES 1998. Forest formations and flora of the Philippines: Handout in FBS 21. UPLB, Philippines

Site	Sample Number	H'	Rating	H' (Mean)	Overall Rating
	3	2.47	Low		
WSQ3	1	2.22	Low	2.20	Low
	2	2.28	Low		
	3	2.10	Low		

Based on the results of the Shannon Biodiversity Index, the mean diversity is Low at WSQ3 and Very Low at WSQ1 (Table 7-9). Between the two sampling locations, higher macrobenthos diversity and density at WSQ3 suggests a more complex and potentially healthier benthic habitat as compared to WSQ1. These findings corroborate with literature which states that there is poor macrobenthos community diversity within the Singapore Straits between Jurong Island and the Southern Islands, which may be attributable to reclamation around the area, sediment contamination and high current speeds in the Singapore Straits[41].

7.5.3 MARINE SPECIES

Publicly available data on marine species is not available for areas directly around the drainage canal outlet at Jurong Island, hence the following subsections state observed species present along the Singapore Straits (including some Southern Islands within the Project AOI) based off research publications. There were no opportunistic encounters with marine species (e.g. mammals, reptiles, fish) during the surveys conducted in July and August 2025.

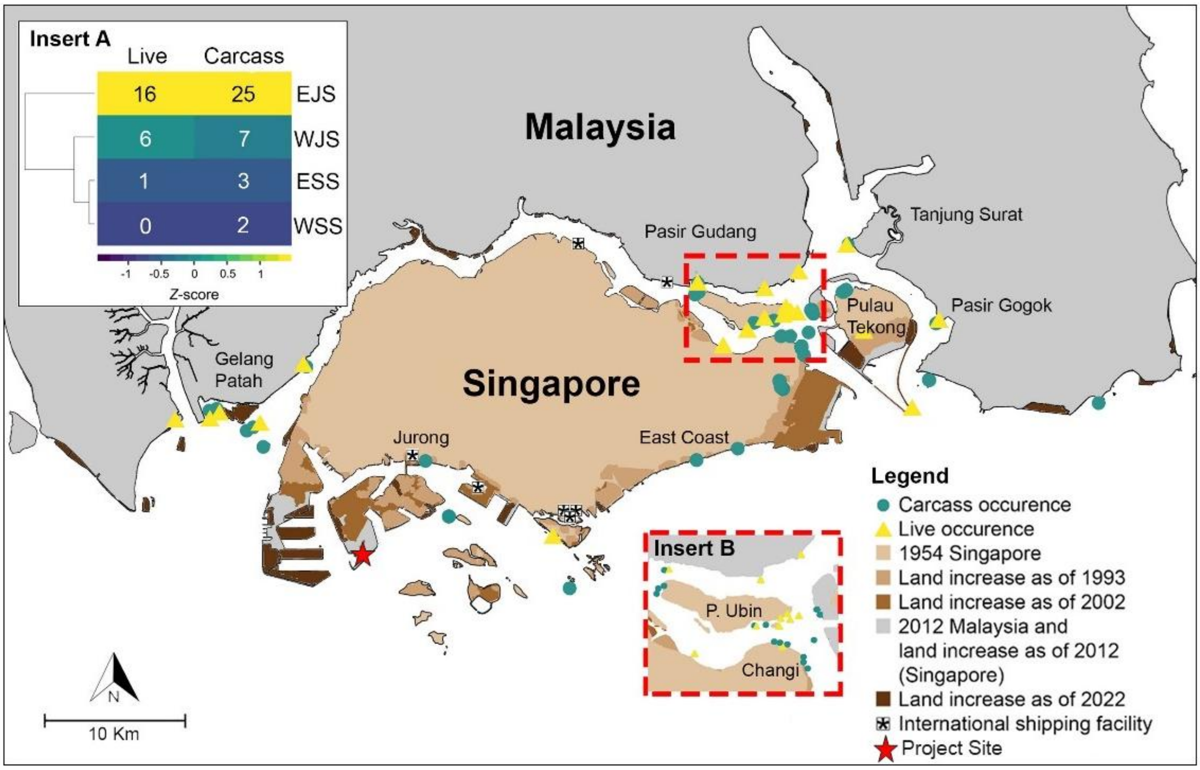
7.5.3.1 MAMMALS

Dugongs (*Dugong dugon*, RDB3 CR, IUCN VU) are a rare sight in Singapore. The eastern Johor Strait has a history of being a key area for dugongs, with 70% of sightings occurring in areas around Changi Beach, Pulau Tekong and Pulau Ubin[42]. Between 1954 and 2020 within the Singapore Straits, one (1) live dugong was spotted at Sentosa (approximately 15 km away from the drainage canal outlet), while three (3) carcasses were washed ashore at various other locations within the Southern Islands (approximately 7 km from the drainage canal outlet) and near Jurong Island (approximately 9 km away from the drainage canal outlet) per Figure 7-9[43,44]. For the latter, while carcasses washed ashore may not indicate that Dugong inhabit the direct area where they were found, strandings such as

[41] Lu, Lin. (2005). The Relationship between Soft-Bottom Macrobenthic Community and Environmental Variables in Singaporean Waters. Marine pollution bulletin. 51. 1034-40. 10.1016/j.marpolbul.2005.02.013.
[42] Ng Sirius Z. H., Ow Yan Xiang, Jaafar Zeehan (2022). Dugongs (Dugong dugon) along hyper-urbanized coastlines. Frontiers in Marine Science, 9. DOI=10.3389/fmars.2022.947700
[43] Ng Sirius Z. H., Ow Yan Xiang, Jaafar Zeehan (2022). Dugongs (Dugong dugon) along hyper-urbanized coastlines. Frontiers in Marine Science, 9. DOI=10.3389/fmars.2022.947700
[44] Budiarsa A. A., de Iongh H. H., Kustiawan W., van Bodegom P. M. (2021). Dugong foraging behavior on tropical intertidal seagrass meadows: the influence of climatic drivers and anthropogenic disturbance. *Hydrobiologia* 848, 4153–4166. doi: 10.1007/s10750-021-04583-0

these can indicate a local presence[45]. The prevalence of feeding trails (Figure 7-10) further suggests that there is a small resident population present within the Straits of Singapore[46]. One of the Dugong feeding trails is within the seagrasses at Terumbu Pempang Laut (4.1 km away from the drainage canal outlet) within the Project's indirect AOI. Their feeding trails are closely associated with seagrass habitat locations as shown in Figure 7-1.

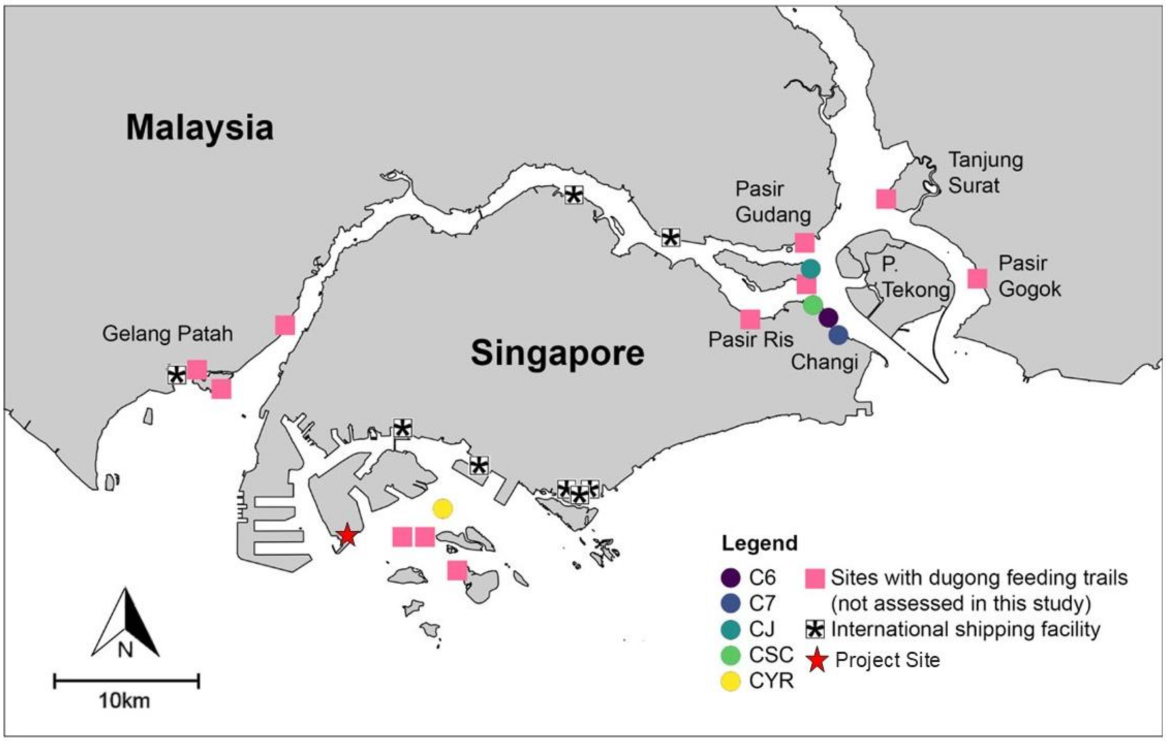
FIGURE 7-9: LOCATIONS OF LIVE AND CARCASS DUGONG SIGHTINGS AROUND SINGAPORE



Source: Ng et al. (2022)

[45] Ijsseldij, L., Camphuysen, K., Keijl, G., Troost, G, Aarts, G. (2021). Predicting Harbor Porpoise Strandings Based on Near-Shore Sightings Indicates Elevated Temporal Mortality Rates. *Front. Mar. Sci*, 8. https://doi.org/10.3389/fmars.2021.668038
[46] Marsh H, Penrose H, Eros C & Hugues J (2002) Dugong status report and action plans for countries and territories. UNEP, Nairobi Kenya, 162 pp.

FIGURE 7-10: DUGONG FEEDING TRAILS



Source: Ng et al. (2022)

Another mammal, the Indo-Pacific Humpback Dolphin (*Sousa chinensis*, RDB3 CR, IUCN VU), is the most common cetacean found in the Singapore waters[47]. These dolphins occur in shallow (<30 m deep), coastal waters of the tropics and are usually found in areas including open coasts, bays, lagoons and reefs[48]. The Tropical Marine Science Institute (TMSI) reported sightings of at least 168 dolphins between 2008 and 2011 near the Southern Islands (Ee, 2014)[49]. The Indo-Pacific Humpback Dolphin has also previously been spotted in two separate incidents[50] near Jurong Island at East Quay of Tanjong Kling Yard (8.24 km away from drainage canal outlet) in 2019 and 2020. While there have been no documented sightings within 5 km of the drainage canal outlet, these dolphins are typically found within the Southern Islands south of the site[51], and have the potential to travel near the Project outlet.

---

47 Jaafar, Z., Huang, D., Tanzil, J. T., Ow, Y. X. and Yap, N. (2018). The Singapore Blue Plan. Singapore: Singapore Institute of Biology. Retrieved from https://sibiol.org.sg/wp-content/uploads/2020/10/The_Singapore_Blue_Plan_2018.pdf

48 Jefferson TA, Smith BD. Re-assessment of the Conservation Status of the Indo-Pacific Humpback Dolphin (Sousa chinensis) Using the IUCN Red List Criteria. Adv Mar Biol. 2016;73:1-26. doi: 10.1016/bs.amb.2015.04.002. Epub 2015 Sep 26. PMID: 26790886.

49 Ee, D. (2014, November 15). Dolphins frolicking in Singapore's backyard. Retrieved from The Straits Times: https://www.straitstimes.com/singapore/environment/dolphins-frolicking-in-singapores-backyard

50 Benjamin P. Y-H. Lee & Michelle Ooi (2020). Indo-Pacific humpback dolphins near Jurong Island. Singapore Biodiversity Records 2020: 84-85 ISSN 2345-7597

51 The Straits Times (2018). Pod of Indo-Pacific humpbacked dolphins spotted off Pulau Semakau. Retrieved from https://www.straitstimes.com/singapore/pod-of-indo-pacific-humpbacked-dolphins-spotted-off-pulau-semakau

Other mammals such as the Irrawaddy Dolphin (*Orcaella brevirostris*, RDB3 CR, IUCN CR) and the Indo-Pacific Finless Porpoise (*Neophocaena phocaenoides*, RDB3 CR, IUCN VU) have last been sighted in Singapore in 2014 and 2011 respectively, with no other recent records of the species; suggesting that no resident individuals or populations occur within the territorial waters of Singapore (Davidson et al., 2024)[52]. For the Irrawaddy Dolphin, there are a total of four (4) unconfirmed and one (1) confirmed record of this species in Singapore (Davidson et al., 2024). For the confirmed record, the skeletal remains of a carcass washed up at East Coast beach (28 km away) in 2014, no occurrence within the indirect 5 km AOI has been confirmed. No further information is available on the Indo-Pacific Finless Porpoise sighting.

7.5.3.2 REPTILES

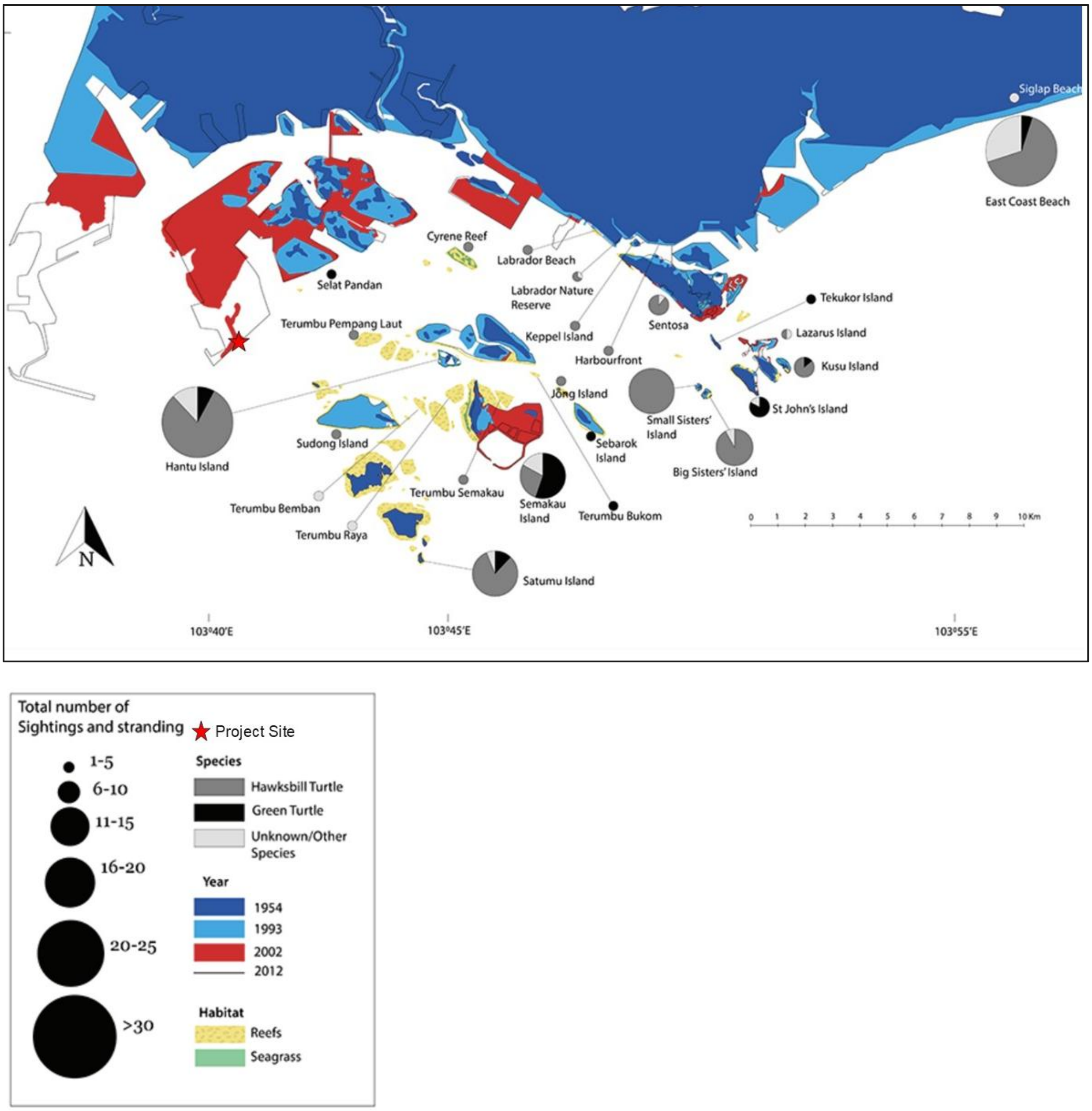
Two (2) species of sea turtles, Hawksbill (*Eretmochelys imbricata*, RDB3 CR, IUCN CR) and Green Turtle (*Chelonia mydas*, RDB3 CR, IUCN LC) have been sighted in Singapore (Jaafar et al., 2018). These marine turtles are usually found in shallow, inshore waters around coral reefs, feeding on crustaceans and sponges (NParks, n.d.)[53]. They have been sighted on the reefs along the Southern Islands and Singapore Straits (Figure 7-11). Two (2) live Hawksbill Turtle sightings have been recorded within the Project AOI at Terumbu Pempang Laut (4.1 km away from drainage canal outlet) between 1883 and 2020 (Cham et al., 2025). In addition, one dead carcass of a Green Turtle[54] was found at Selat Pandan (Pandan Straits), approximately 3.9 km away in 2015.

There are numerous records of females coming ashore to lay eggs on the sandy beaches along the southern coastlines of Singapore (Chiok, 2019)[55]. A sea turtle hatchery was launched in 2018 at Sister’s Island (17 km away from Project drainage canal outlet) to support the monitoring and conservation of the turtle population in Singapore.

---

[52] Davison GWH, Gan JWM, Huang D, Hwang WS, Lum SKY & Yeo DCJ (eds.) (2024) The Singapore Red Data Book: Red Lists of Singapore Biodiversity. 3rd ed. National Parks Board, Singapore.
53 NParks. (n.d.). Eretmochelys imbricata (Linnaeus, 1766). Retrieved from Flora & Fauna Web: https://www.nparks.gov.sg/florafaunaweb/fauna/2/6/262
[54] Tan Y. K. (2015). Green turtle carcass showing sign of boat strike at Selat Pndan. Singapore Biodiversity Records, 212-213. Retrieved from https://lkcnhm.nus.edu.sg/wp-content/uploads/sites/11/app/uploads/2017/04/sbr2015-212-213.pdf
55 Chiok Pei Wen (2019). Analysis and Comparison of Coastal Beaches for Nest Site Selection of Hawksbill Turtles (Eretmochelys Imbricata) in Singapore. ScholarBank@NUS Repository.

FIGURE 7-11: MARINE TURTLE SIGHTINGS IN SINGAPORE STRAITS BETWEEN 1883 AND 2020



Source: Cham et al. (2025)[56]

7.5.3.3 FISH

Some examples of fish species including sharks, rays, and other types of fish (under *Actinopterygii* class) have been observed in the Straits of Singapore, including sightings at Terumbu Pempang Laut (4.1 km from the drainage canal outlet) are listed in Table 7-10.

[56] Cham J., Tun K., and Jaafar, Z. (2025). Distribution of marine turtles in Singapore: humanwildlife coexistence in a highly urbanized seascape. Bull Mar Sci. 101(1):157–177. https://doi.org/10.5343/bms.2023.0117

TABLE 7-10: EXAMPLE OF FISH SPECIES FOUND IN THE STRAITS OF SINGAPORE

Type	Species Observed
Sharks (Ip et al., 2021)	Blacktip reef shark *(Carcharhinus melanopterus,* RDB3 EN, IUCN VU*),* Bull shark *(Carcharhinus leucas*, RDB3 CR, IUCN VU*),* Silky shark *(Carcharhinus falciformis*, RDB3 CR, IUCN VU*),* Brownbanded bamboo shark *(Chiloscyllium punctatum*, RDB3 EN, IUCN NT*),* White-spotted bamboo shark *(Chiloscyllium plagiostomum*, RDB3 EN, IUCN NT*)*
Rays (Ip et al., 2021)	Bluespotted ribbontail ray *(Taeniura lymma*, RDB3 VU, IUCN LC*), Whitespotted whipray (Maculabatis gerrardi*, IUCN EN*),* Oriental blue-spotted maskray *(Neotrygon orientale*, IUCN LC*),* Reticulate whipray *(Himantura uarnak*, RDB3 CR, IUCN EN*),* Broad cowtail ray *(Pastinachus ater*, RDB3 CR, IUCN VU*),* Scaly whipray *(Brevitrygon imbricata*, IUCN VU*),* Cowtail stingray *(Pastinachus sephen,* IUCN NT*),* Short-tail whipray *(Brevitrygon heterura*, RDB3 VU, IUCN VU*),* Ocellated eagle ray *(Aetobatus ocellatus*, RDB3 CR, IUCN EN*),* Longtail butterfly ray *(Gymnura poecilura*, RDB3 CR, IUCN VU*),* Javan cownose ray *(Rhinoptera javanica*, RDB3 CR, IUCN EN*)*
Other fish (*Actinopterygii*)[57,58]	Titan triggerfish *(Balistoides viridescens*, RDB3 CR, IUCN LC*),* Janss' pipefish *(Doryrhamphus janssi*, RDB3 VU, IUCN LC*),* Humpback grouper *(Cromileptes altivelis*, RDB3 CR*),* Banded blunthead goby *(Amblygobius phalaena*, RDB3 NT, IUCN LC*),* horned bannerfish *(Heniochus varius*, IUCN LC*),* Urchin clingfish *(Diademichthys lineatus*, RDB3 EN, IUCN LC*),* Brick Solderfish *(Myripristis amaena*, IUCN LC*),* Philippine butterflyfish *(Chaetodon adiergastos*, IUCN LC*),* Lemon damsel *(Pomacentrus moluccensis*, RDB3 EN, IUCN LC*),* Pajama cardinalfish *(Sphaeramia nematoptera,* IUCN LC*),* Pink anenomefish (*Amphiprion perideraion*, RDB3 CR, IUCN LC*)*

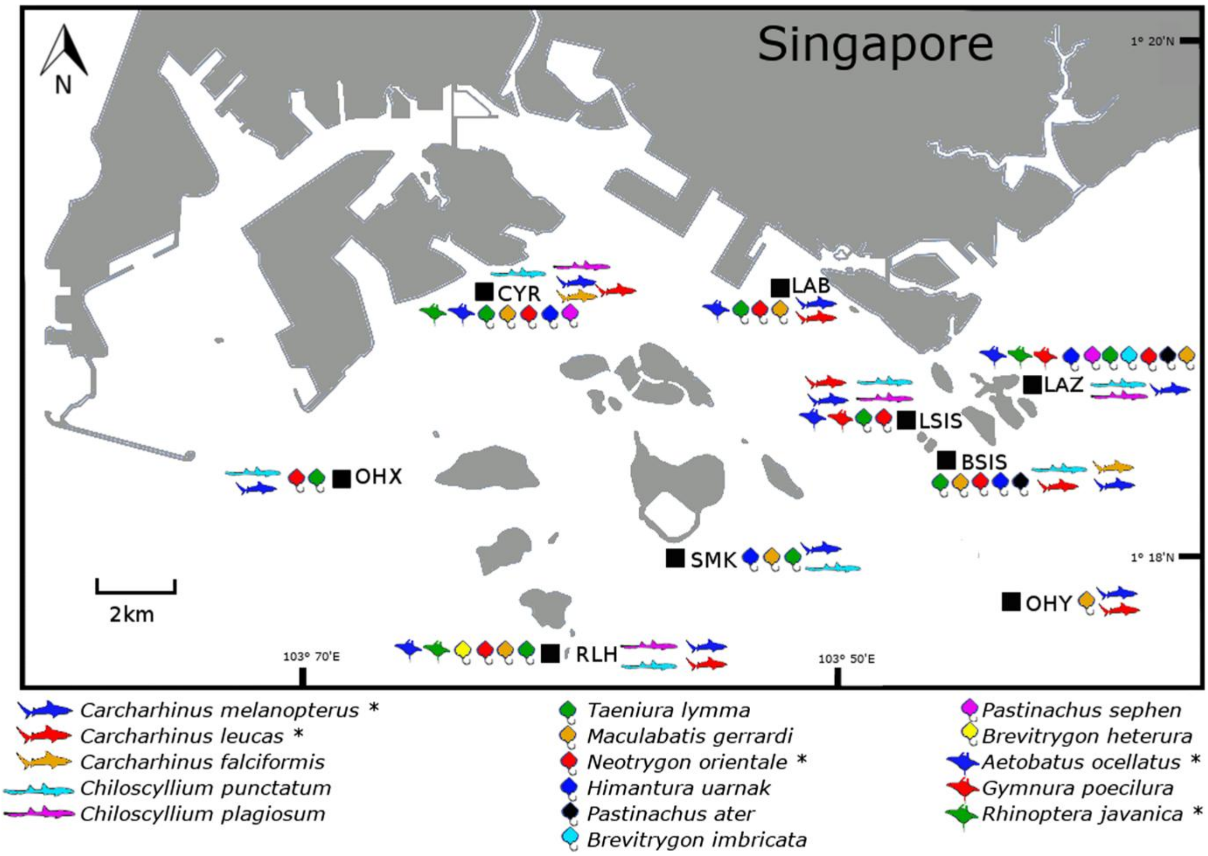
Note:
List above are examples based off observations from selected publications and are not exhaustive.

For sharks, the Blacktip Reef Shark (*Carcharhinus melanopterus*, RDB3 EN, IUCN VU), is one of the most commonly observed sharks in Singapore[59], however most publications feature trapped individuals[60,61,62]. A study by Ip et al. (2021)[63] on sharks and rays successfully detected the presence of the Blacktip Reef Shark in the waters off the Southern Islands (Pulau Semakau, Cyrene Reef and open area “OHX” per Figure 7-12 below).

---

[57] Low, Jeffrey & Jaafar, Zeehan & Tanzil, Jani. (2009). Some noteworthy fishes observed in the Singapore Straits. Nature in Singapore. 2. 77-82.
[58] Low, Jeffrey. (2013). More noteworthy fishes observed in the Singapore Straits. Nature in Singapore. 6. 31-37.
[59] Wang LK & Lim KKP (2011) Requiem sharks. In: Ng PKL, Corlett R & Tan HTW (eds.) Singapore Biodiversity: An Encyclopedia of the Natural Environment and Sustainable Development. National University of Singapore & Editions Didier Millet, Singapore, p. 430.
[60] Yeo R (2014) Blacktip reef sharks at Semakau Landfill. Singapore Biodiversity Records, 2014: 33–34.
[61] Chim CK, Lee Y-L, Tong S, Tay T & Ong R (2015) Blacktip reef sharks caught in trammel nets at Lazarus Island. Singapore Biodiversity Records, 2015: 158–159
[62] Ong T (2020) 3 shark pups found dead on St. John's Island. Mothership, 21 July 2020. Retrieved from https://mothership.sg/2020/07/ shark-pup-st-john-island
[63] Ip, Y.C.A., Chang, J.J.M., Lim, K.K.P. et al. (2021). Seeing through sedimented waters: environmental DNA reduces the phantom diversity of sharks and rays in turbid marine habitats. BMC Ecol Evo 21, 166. https://doi.org/10.1186/s12862-021-01895-6

FIGURE 7-12: SHARKS AND RAYS SIGHTINGS IN THE SINGAPORE STRAITS



Source: Ip et al (2021)

Fish Farm

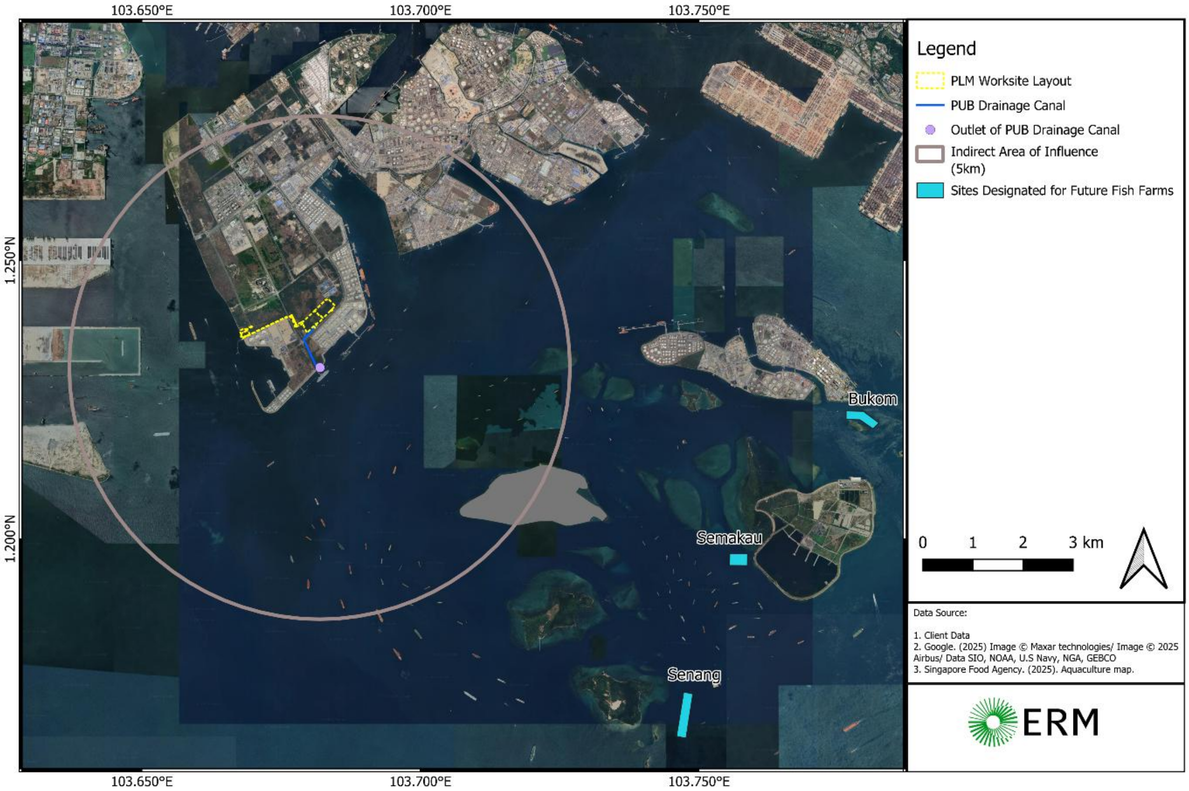
Fish farms were previously located to the west of the Pulau Semakau (9.1 km from the PUB drainage canal outlet) and east of Pulau Senang (9.7 km from the PUB drainage canal outlet) but ceased operations in June 2023[64]. SFA is reviewing plans to further develop these two fish farm sites, as well as another site located near Pulau Bukom (10.8 km from the PUB drainage canal outlet), for seafood production. As such, the above marine fish farm sites are included as sensitive receptors in this EIA. These are both illustrated in Figure 7-13 below.

Despite the Pulau Semakau fish farm not operating there are plans by the SFA to improve fish farming infrastructure within the southern waters[65]. For this reason, ERM has considered the locations of the Pulau Semakau and Pulau Senang fish farms (9km and 9.7km respectively from the PUB drainage canal outlet) and a future location near Pulau Bukom (10.8 km from the PUB drainage canal outlet) in this EIA.

[64] Qing and behum (2024, November 21) Barramundi Group stops farming sea bass in S'pore due to deadly virus outbreakhttps://www.straitstimes.com/singapore/barramundi-group-stops-farming-sea-bass-in-s-pore-due-to-deadly-virus-outbreak

[65] Tan (2024, May 19). SFA to improve fish farming infrastructure in southern waters after Barramundi Group exits https://www.straitstimes.com/singapore/sfa-to-improve-fish-farming-infrastructure-in-southern-waters-after-barramundi-group-exits

FIGURE 7-13: FISH FARM LOCATIONS WITHIN SOUTHERN WATERS



7.6 SENSITIVE RECEPTORS

The marine biodiversity receptors identified by the baseline have been evaluated for their relative level of sensitivity and importance (developed based on the sensitivity criteria in Table 7-1 and Table 7-2). These receptors will be considered throughout the impact assessment.

TABLE 7-11: MARINE BIODIVERSITY RECEPTORS AND LEVELS OF SENSITIVITY

Sensitive Receptor	Level of Sensitivity		
	High	**Medium**	**Low**
Habitats			
Corals		Helios Secondary Reef (located 700 m south-west from its closest point to the drainage canal outlet). As coral reef health is similar across the reefs, it can be assumed to be the same sensitivity as the Helios Secondary Reef As species level information is not available, based on a conservative assessment using the local conservation status of all species within the genera found at Helios Secondary Reef (Table 7-5), this coral habitat is significant in supporting a number of nationally VU and NT species under the genera found.	
Planktons			Plankton counts indicate signs of elevated nutrient loading and eutrophication in the waters, showing contamination within the seawater surrounding the outfall areas. From a project impact perspective, elevated plankton counts are expected to pose limited / low risks to the project and the strong currents along the outfall area will ensure flushing and mixing of the water quality conditions.
Macrobenthos			Macrobenthos are of low, and very low diversity levels, which is typical of aquatic systems that are eutrophic and hence is of low conservation interest.

Sensitive Receptor	Level of Sensitivity		
	High	Medium	Low
Seagrass	Presence of seagrass species (located more than 3.9 km away from site) which are nationally CR and EN. Seagrass habitats are key environments for dugongs and sea turtles, making them important ecological resources in Singapore.		
Species			
Marine Mammals	While no sightings have been observed near the Project drainage canal outlet area, marine mammals that are nationally CR have been sighted in the Straits of Singapore, with the closest sighting 4.1 km away. These mammals may use the Straits of Singapore channel to travel to various reefs or for foraging.		
Reptiles	While no sightings have been observed near the Project drainage canal outlet area, reptiles such as marine turtles that are nationally CR have been sighted in the Straits of Singapore, with the closest sighting 4.1 km away. These turtles may use the Straits of Singapore channel to travel to various reefs, seagrass or beaches to forage and nest.		
Fish	While fish data around the drainage canal outlet is not available, some fish species which are nationally CR that may		

Sensitive Receptor	Level of Sensitivity		
	High	Medium	Low
	use the Straits of Singapore channel to forage and travel.		
Fish Farm		Future marine fish farm developments are planned at previous marine fish farm sites to the west of Pulau Semakau and to the east of Pulau Senang, and a new site near Terumbu Bukom. The water quality near the fish farm sites (represented by WQS2) is generally in compliance with the corresponding MWQC except for the criterion for NO3-N. The discharge of heated effluent containing residual chlorine could result in adverse effects on the fish farming operation in case effluent plume encroaches these fish farms. Aquaculture facilities typically stock commercially viable and common fish species. Considering the socio-economic importance of these operations where aquaculture stock could be sensitive to change in water quality, a Medium sensitivity rating has been applied.	

7.7 IMPACT ASSESSMENT – OPERATION PHASE

7.8 EMBEDDED CONTROLS

Detailed embedded controls that will be put in place to control the potential degradation of marine water quality due to thermal and chlorine plume discharge are detailed in Section 6.7 of the Marine Water Quality section. These embedded controls will be considered in the assessment of impacts in the sub-sections below.

7.9 IMPACT ASSESSMENT – OPERATION PHASE

7.9.1 IMPACT OF CHANGES IN WATER QUALITY (THERMAL AND CHLORINE PLUMES) TO CORAL HABITAT

7.9.1.1 IMPACT SIGNIFICANCE

<u>Chlorine Plume Impact</u>

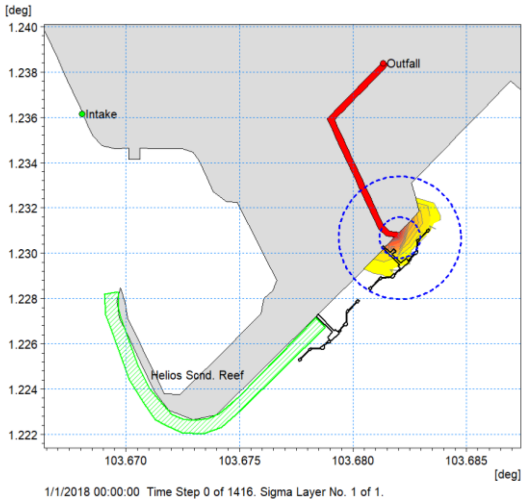
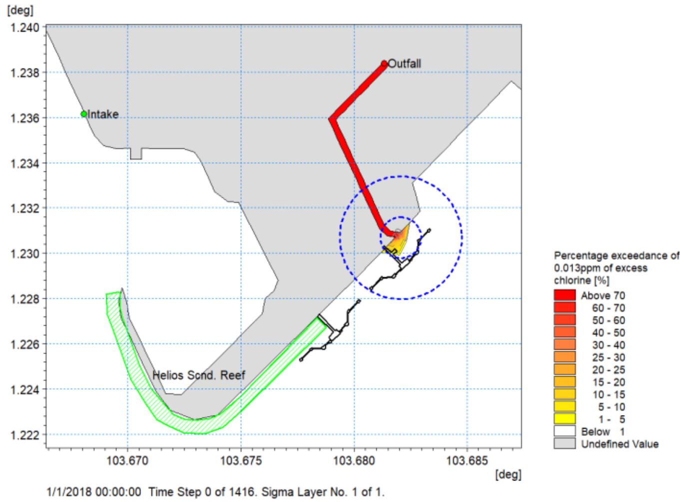
Discharged residual chlorine could affect marine life. The USEPA recommends that levels of chlorine should not exceed a one-hour average limit of 13 µg/L (or 0.013 mg/L) and a four-day average limit of 7.5 µg/L (or 0.0075 mg/L). This criterion has been adopted for evaluating the potential impact on marine life at the receiving water from the Project's residual chlorine discharge.

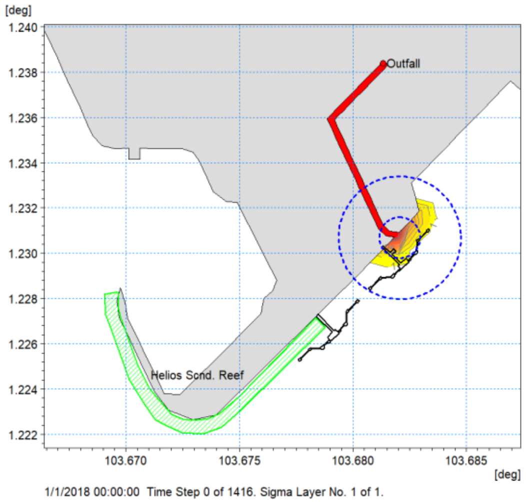
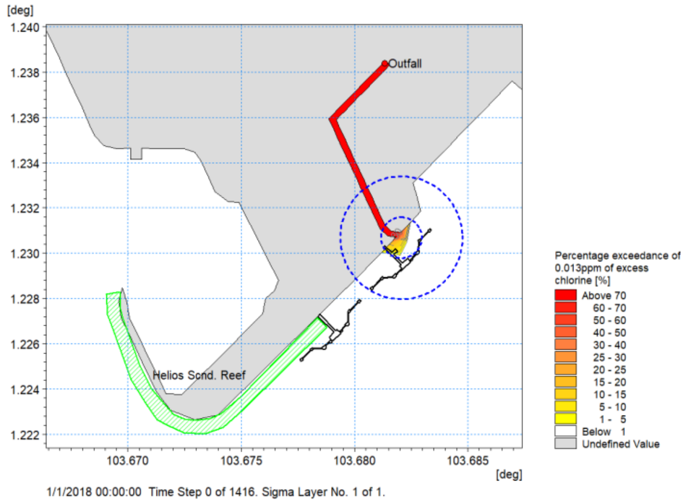
The results of the water quality model (Section 6.8.2) identified that the maximum chlorine elevation predicted at about 200 m from the outlet of the drainage canal is approximately 0.02 mg/L near the surface. For predicted maximum chlorine elevation near the bottom, the effluent plume was predicted to be localised within 300 m from drainage canal outlet. Overall, chlorine dispersion is largely confined within a 300 m radius from the drainage canal outlet.

Beyond 700 m from the drainage canal outlet, where the nearest coral receptor, Helios Secondary Reef is located, the impact magnitude is **Negligible**. Modeling results indicate that, over the 30-day simulation period, the percentage of time during which chlorine concentrations exceed the USEPA limit of 0.013 mg/L is less than 1% (Table 7-12). Similarly, reefs located among the Southern Islands including Pulau Salu (3.7 km), Terumbu Pempang Laut (4.7 km) and Pulau Sudong (4 km), would experience negligible impact from the chlorine plume as the chlorine dispersion is largely confined within a 300 m radius. The primary baseline survey did not include any data collection regarding coral health and percentage coral cover, nor is there any information available on coral spawning. Based on high-level desktop research, coral spawning in Singapore typically occurs during the inter-monsoon months (between March to April and around October) where wind speeds are expected to be lower compared to Northeast and Southwest Monsoon seasons. Based on modelling results, the spread of chlorine will be less during the inter-monsoon periods than presented in Table 7-12 and confined to the 300m radius from the drainage canal outlet. Therefore, there will be negligible impact to the ecological health of the corals and its associated marine biodiversity at Helios reef and beyond in Singapore.

Overall, a negligible impact magnitude has been assigned given that the predicted chlorine concentrations remain within the normal range of natural variability for corals. Given that the Helios Secondary Reef is assessed as having **Medium** sensitivity, the resulting impact significance of chlorine plume is classified as **Negligible**.

TABLE 7-12: PERCENTAGE EXCEEDANCE AGAINST USEPA CRITERIA UNDER OPERATIONAL SCENARIO

Monsoon	**Depth**	
	Surface	Bottom
NE		

Monsoon	Depth	
	Surface	Bottom
SW		

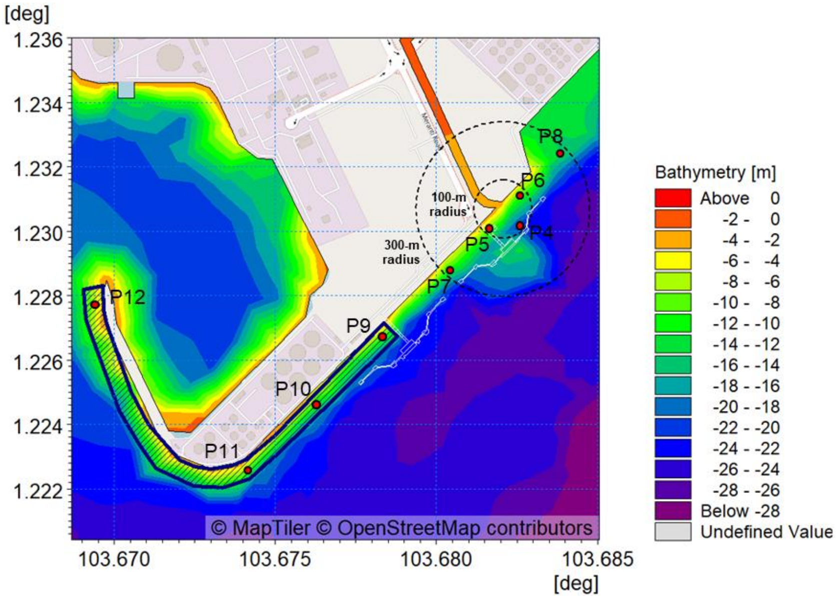
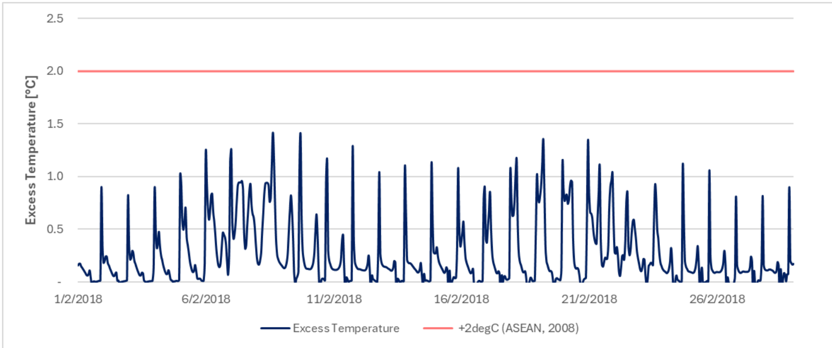
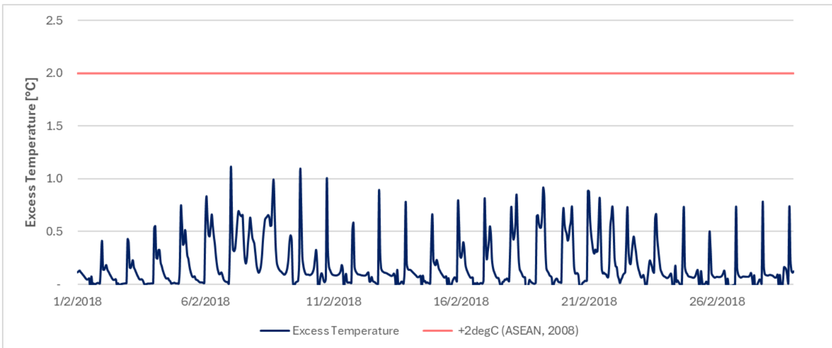
Thermal Plume Impact

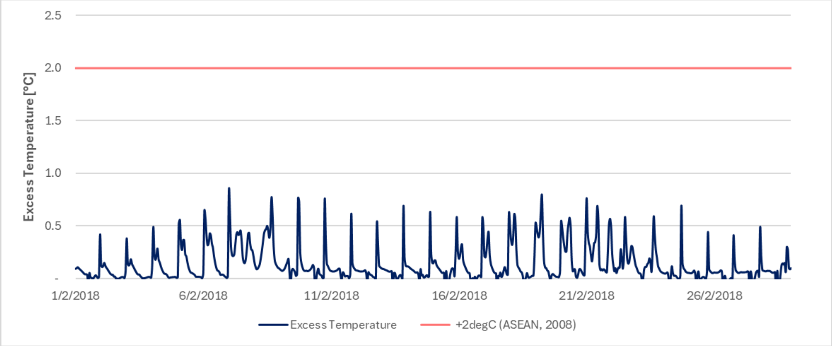
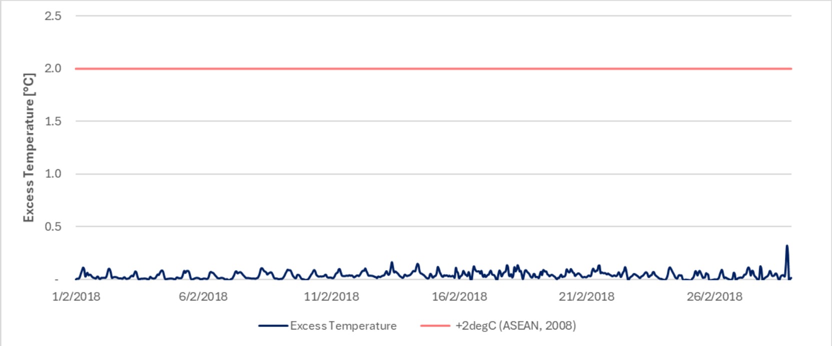
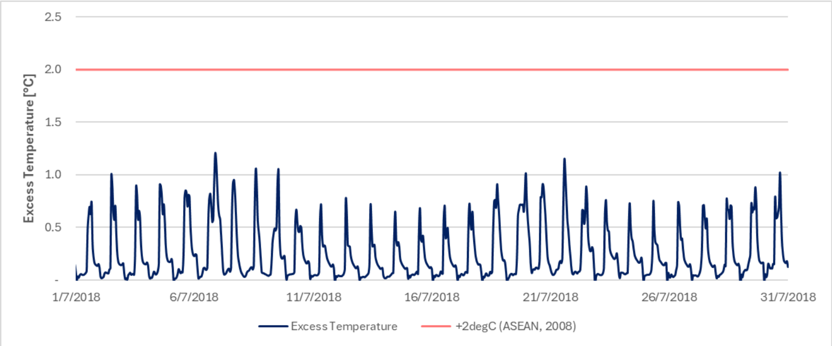
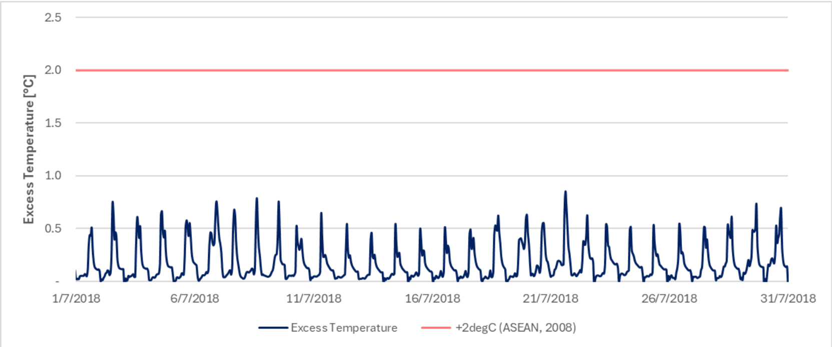
Coral reefs are highly sensitive to thermal stress and increase in seawater temperature which can lead to disease and mortality from coral bleaching. The MWQC stipulates that the allowable temperature elevation should not be more than 2˚C above the maximum ambient temperature. Furthermore, studies indicate thermally induced coral bleaching can occur when the maximum monthly average temperature increases by 1°C and can result in mortality if the temperature is 2°C or above for a month [66,67]. With regards to coral spawning, there are variable effects of temperature on the spawning itself, the coral larval survival and their development depending on species[68]. Temperature increases can result in the lack of spawning, or a higher number of abnormally developed larvae[69] and can reduce larval survivorship[70] particularly in larvae with symbiotic algae present[71].

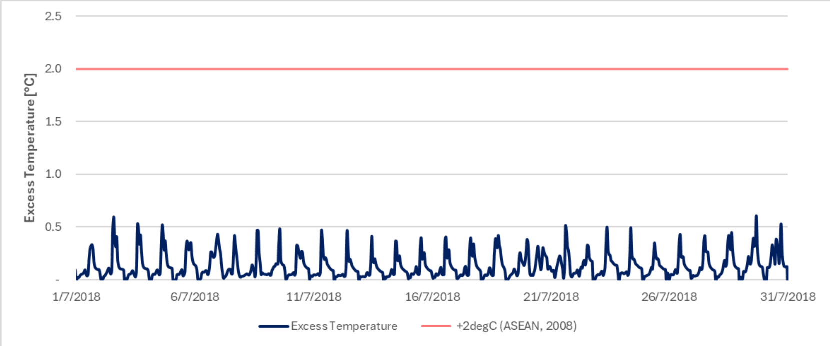
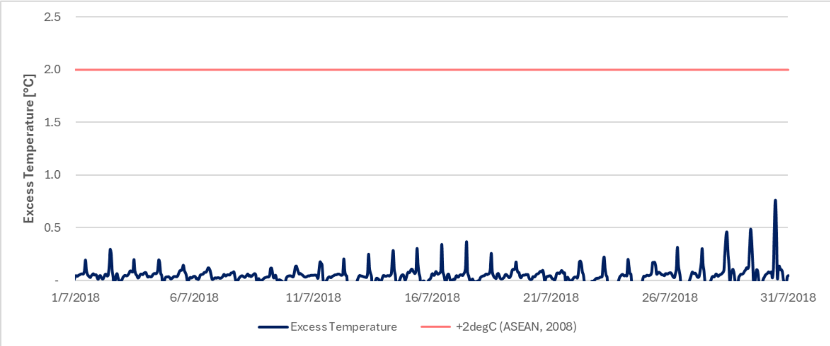
Results from the thermal discharge model in (Section 6.8.1) indicate at the Helios Secondary Reef, the change in maximum surface temperature was predicted to be close to 1.5˚C, whereas change in maximum bottom water temperature was predicted to be 0.4-0.5˚C. The predicted temperature elevation at the reef, time series outputs around the outlet were produced and compared against the corresponding MWQC Guideline in Table 7-13 below. Location P9 refers to the north-east section of the Helios Secondary Reef, located nearest to the drainage canal outlet. While locations P10, P11 and P12 refer to sections of the reef located further away from the drainage canal outlet.

[66] Manzello, D. (2023). Rising Ocean Temps Raise New Concerns for Coral Reefs. Retrieved from https://www.nesdis.noaa.gov/news/rising-ocean-temps-raise-newconcerns-coral-reefs
[67] Goreau TJF, Hayes RL (2021). Global warming triggers coral reef bleaching tipping point : This article belongs to Ambio's 50th Anniversary Collection. Theme: Climate change impacts. Ambio. \Jun;50(6):1137-1140. doi:. 10.1007/s13280-021-01512-2. PMID: 33650066; PMCID: PMC8068737.
[68] O'Connor et al (2007). Temperature control of larval dispersal and the implications for marine ecology, evolution, and conservation. Proc. Natl Acad. Sci. USA 104, 1266-1271
[69] Negri AP, Marshall PA, Heyward AJ (2007) Differing effects of thermal stress on coral fertilization and early embryogenesis in four Indo Pacific species. Coral Reefs 26: 759−763
[70] Baird AH, Gilmour JP, Kamiki TM, Nonaka M, Pratchett MS, Yamamoto HH, Yamasaki H (2006) Temperature tolerance of symbiotic and non-symbiotic coral larvae. Proc 10th Int Coral Reef Symp, Okinawa, p 38−42
[71] Nesa B, Baird AH, Harii S, Yakovleva I, Hidaka M (2012) Algal symbionts increase DNA damage in coral planulae exposed to sunlight. Zool Stud 51: 12−17

TABLE 7-13: TIME SERIES OUTPUT FOR TEMPERATURE NEAR SURFACE AT HELIOS SECONDARY REEF

Season	Location	Plot
Cross Section Location	N/A	
NE	P9	
	P10	

Season	Location	Plot
	P11	
	P12	
SW	P9	
	P10	

Season	Location	Plot
	P11	
	P12	

At the Helios Secondary Reef, the predicted maximum temperature elevation for the surface varies according to the distance from the drainage canal outlet. The North-east corner of the reef, location P9, was predicted to be most impacted, with maximum temperature elevation of about 1.4°C. At this location, the temperature increase exceeds 1.0°C for approximately 4% of the 30-day NE monsoon simulation period and 1% during the SW monsoon. The longest continuous exceedance under NE monsoon conditions is about three (3) hours, while all other occurrences last less than one (1) hour. The result is below the criteria set in the literature[66] which indicates a turning point for coral sustainability at a 1.0°C temperature elevation, continuously for one (1) month.

The predicted maximum temperature decreases further away from the drainage canal outlet, reaching about 1.1°C at P10, below 0.9°C at P11 and below 0.4°C at P12. At point P10, exceedances above 1.0°C occur only during the NE monsoon, accounting for 0.4% of the 30-day monsoon simulation period. In general, the predicted elevation at the Helios Secondary Reef would be higher in NE monsoon compared to the SW monsoon.

Meanwhile, other reef habitats (Pulau Salu, Terumbu Pempang Laut and Pulau Sudong), located at least 3.7 km from the outlet of the drainage canal are expected to experience negligible impact from the thermal plume, as temperature elevation is predicted to dissipate before reaching these areas.

The primary baseline survey did not include any data collection regarding coral health and percentage coral cover, nor is there any information available on coral spawning. Based on high-level desktop research, coral spawning in Singapore typically occurs during the inter-monsoon months (between March to April and around October) where wind speeds are expected to be lower compared to Northeast and Southwest Monsoon seasons. Based on modelling results, the spread of chlorine will be less during the inter-monsoon periods than presented in Table 7-12 and confined to the 300m radius from the drainage canal outlet. Therefore, there will be negligible impact to the ecological health of the corals and its associated marine biodiversity at Helios reef and beyond in Singapore.

Given the results of the thermal modelling a **Small** impact magnitude was assigned for thermal impact to the Helios Secondary Reef. Although the thermal discharge model predicts that the maximum temperature elevations at the Helios Secondary Reef may exceed 1°C, these exceedances will not be sustained throughout the month. Between periods of exceedance, temperatures are expected to return to ambient levels. Therefore, the impact will be limited to a small area of habitat, such that there is no loss of viability/function of the habitat. With the Helios Secondary Reef being of **Medium** receptor sensitivity, the resulting impact is considered to be **Minor**.

Overall, the impact of chlorine plume to Helios Secondary Reef will be **Negligible**, while the impact of the thermal plume to the same reef will be **Minor**. While no mitigation measures are required for this impact, proposed management measures detailed in the EMMP (Section 8) will be implemented as part of best practice for environmental management.

7.9.1.2 SUMMARY

TABLE 7-14: IMPACT SIGNIFICANCE – IMPACT OF CHANGES IN WATER QUALITY (THERMAL AND CHLORINE PLUMES) TO CORAL HABITAT

Impact		Impact of changes in water quality to coral habitat				
Impact Nature		**Negative**		Positive		Neutral
IMPACT CHARACTERISTICS	**Type**	**Direct**		Indirect		Induced
		Thermal-induced stress such as increased risk of disease, coral bleaching and mortality due to thermal plume impact.				
	Extent	Site	**Local**	Regional	National	International
		Impact will be within 300 m of the outlet of the drainage canal for thermal and chlorine plume, compliant with MWQC and USEPA thresholds respectively.				
	Scale	**Negligible**	Small	Medium		Large
		Chlorine impact will not reach where coral reefs are located (700 m from the drainage canal outlet). For thermal impact, the predicted temperature elevation of 2°C will only extend 100 m from the drainage canal outlet for approximately 20% of time in a month, the predicted elevation would be less than 1.8°C (compliant with MWQC thresholds) beyond 300 m from the drainage canal outlet. Temperature increases of up to 1.4°C would apply at the eastern-most end of the Helios reef (located 700 m from its closest point to the drainage canal outlet) for approximately 4% of the time in a month.				
	Duration	**Temporary**	Short-term	Medium-term	Long-term	Permanent

		The discharge will be continuous throughout the operation phase (long term), but the discharge will not significantly alter the ambient water temperature beyond the immediate vicinity of the drainage canal outlet (including at the identified marine ecological resources) during the period. Temperature elevation exceeding 1°C would only extend 4% of time across a month on average at the eastern end of the reef closest to the outlet. The predicted maximum temperature decreases further away from the drainage canal outlet and exceedances above 1.0°C occur only during the NE monsoon, accounting for 0.4% of the 30-day monsoon simulation period. Long-term impacts of coral bleaching and mortality are not expected as the predicted thermal conditions remain below the critical tipping point of a sustained 1 °C temperature increase over a continuous one-month period. Likewise for chlorine, the discharge will not significantly increase the residual chlorine levels at any of the identified marine sensitive receptor locations. Model predictions indicate compliance with the USEPA criterion for residual chlorine, as exceedances of the 0.013 mg/L limit are anticipated to occur less than 1% of the time. Therefore, the predicted change over which the receptors may be impacted by the thermal and chlorine plume is considered temporary with no lasting impact.			
	Frequency	The discharge will be continuous throughout the operation phase and compliance is expected beyond 300 m from the outlet, including at all identified marine sensitive receptor locations. Therefore, the predicted change over which the receptors may be impacted is unlikely.			
IMPACT MAGNITUDE		**Negligible**	**Small**	Medium	Large
		For the chlorine plume, there will be no impact on corals as they are not within the 300 m area of the plume. For thermal plume it will affect part of the habitat (eastern end) for short durations but does not threaten the long-term viability/function of the habitat.			
RECEPTOR SENSITIVITY		Negligible	Low	**Medium**	High
		Helios Secondary Reef coral habitat is of significant importance in supporting species that are nationally Vulnerable and Near Threatened. Therefore, it is considered a habitat of Medium sensitivity.			
Impact Significance		**Negligible**	**Minor**	Moderate	Major

The significance of impacts is expected to be **Negligible** to **Minor**. No mitigation measure for this potential source of impact is deemed necessary.

While no mitigation measures are required for this impact, proposed management measures detailed in EMMP (Section 8) will be implemented as part of best practice for environmental management

7.9.2 IMPACT OF CHANGES IN WATER QUALITY (THERMAL AND CHLORINE PLUMES) TO THE PLANKTONIC COMMUNITY

7.9.2.1 IMPACT SIGNIFICANCE

Chlorine Plume Impact

While chlorination has shown to inhibit photosynthesis and respiration of phytoplankton[72], effects of low chlorine doses (<0.1 mg/L) on phytoplankton communities have been found in published studies to have limited impacts on total biomass[73].

At the drainage canal outlet, there will be a 200 m radius where zooplankton (especially copepods and larvae) found at WSQ3 may have the potential to experience sublethal impairment in short-term exposures from 0.05 – 0.20 mg/L within hours and sublethal feeding/respiration impairment beginning near 0.01 – 0.05 mg/L[74]. Effects would taper rapidly with dilution away from the outlet, hence impact to planktons was only assessed at the WSQ3 area.

While some impact may be observed on zooplanktons, given rapid advection, high turnover, flushing and mixing, and quick decay rate in seawater, the local zooplankton community typically recovers quickly once exposures drop below effect thresholds. There will also be limited impacts on phytoplankton at WSQ3, hence the overall impact would be localised and the impact magnitude to zooplankton and phytoplankton will be **Small**, as it affects only a small area of the community, such that there is no loss of viability / function of the community.

With both chlorine plume impact magnitude being **Small**, and the sensitivity of the planktonic community being **Low**, the overall impact significance will be **Negligible**.

Thermal Plume Impact

Based on the results of the water quality model (Appendix D), areas exceeding the +2.0°C threshold (AMWQC) is confined within approximately 300 m of the drainage canal outlet location, hence impact to planktons was only assessed at the WSQ3 area. Temperatures within 300 m of the outlet of the drainage canal would range from +2.0°C to +3.0°C. This would cause a localised acceleration of plankton metabolism and growth at WSQ3, leading

---

[72] Brook A J, Baker A L (1972). Chlorination at power plant: impact on phytoplankton productivity[J]. Science, 178(4042): 1414-1415.
[73] Marta Vannoni, Alastair Grant, Dave Sheahan, Véronique Créach. (2024). Evaluating the impact of residual low chlorine concentration on phytoplankton communities by flow cytometry, Chemosphere, Volume 367, 143634, ISSN 0045-6535, https://doi.org/10.1016/j.chemosphere.2024.143634.
[74] Heinle, D.R., Beaven, M.S (1997). Effects of chlorine on the copepod *Acartia tonsa*. *Chesapeake Science* **18**, 140. https://doi.org/10.2307/1350385

to high turnover and altered size/taxanomic structure near the drainage canal outlet[75] during periods of weak currents.

Studies note that +3.0°C warming can trigger phytoplankton blooms, often depressing peak chlorophyll amplitude and altering succession through combined direct effects and warming-mediated trophic interactions[76]. For zooplanktons, warming would favour smaller, faster-reproducing zooplankton and can reduce body size and alter functional composition. This might weaken top-down control on phytoplankton depending on the magnitude and duration of warming[77].

While there will be some increases in plankton metabolic rates and community shifts near the outlet at WSQ3, with rapid attenuation and recovery outside the immediate mixing zone and the small spatial extent of 300m where the +2.0°C to +3.0°C is generally confined to, impacts which will be localised and low outside the mixing zone due to the rapid and effective mixing of discharge with seawater[78]. Hence the impact magnitude is deemed to be **Small,** as it affects only a small area of habitat, such that there is no loss of viability / function of the habitat.

With the thermal plume impact magnitude being **Small**, and the sensitivity of the planktonic community being **Low**, the overall impact significance will be **Negligible**. While no mitigation measures are required for this impact, proposed management measures detailed in EMMP (Section 8) will be implemented as part of best practice for environmental management.

7.9.2.2 SUMMARY

FIGURE 7-14: IMPACT SIGNIFICANCE – IMPACT OF CHANGES IN WATER QUALITY (THERMAL AND CHLORINE PLUMES) TO THE PLANKTONIC COMMUNITY

Impact		Impact of changes in water quality to the planktonic community				
Impact Nature		**Negative**		Positive		Neutral
IMPACT	**Type**	**Direct**		Indirect		Induced
		Mortality, changes in physiology and community shifts of planktons due to thermal and chlorine plume impact.				
	Extent	Site	**Local**	Regional	National	International

[75] Capuzzo, J.M (1980). Impact of power-plant discharges on marine zooplankton: A review of thermal, mechanical and biocidal effects. *Helgolander Meeresunters* **33**, 422–432. https://doi.org/10.1007/BF02414767
[76] Trombetta T, Mostajir B, Courboulès J, Protopapa M, Mas S, Aberle N, Vidussi F (2024). Warming and trophic structure tightly control phytoplankton bloom amplitude, composition and succession. PLoS One.19(10):e0308505. doi: 10.1371/journal.pone.0308505. PMID: 39365779; PMCID: PMC11451980.
[77] Thu-Hương Huỳnh, Zsófia Horváth, Károly Pálffy, Vivien Kardos, Beáta Szabó, Péter Dobosy, Csaba F. Vad (2024). Heatwave-induced functional shifts in zooplankton communities result in weaker top-down control on phytoplankton. 14 (8), https://doi.org/10.1002/ece3.70096
[78] Poornima, E.H. & Rajadurai, M. & Toleti, Subba Rao & Bhaskarapillai, Anupkumar & Rajamohan, Raja & Narasimhan, S.V. & Rao, V.N.R. & Venugopalan, Vayalam. (2005). Impact of thermal discharge from a tropical coastal power plant on phytoplankton. Journal of Thermal Biology. 30. 307-316. 10.1016/j.jtherbio.2005.01.004.

		Impact will be within 300 m of the drainage canal outlet for thermal and chlorine plume, compliant with MWQC and USEPA thresholds respectively.				
	Scale	**Negligible**	Small	Medium	Large	
		Impact is limited to planktons within 300 m of outlet of the drainage canal.				
	Duration	**Temporary**	Short-term	Medium-term	Long-term	Permanent
		The discharge will be continuous throughout the operation phase (long term), but the discharge will not significantly alter the ambient water temperature beyond the immediate vicinity of the outlet (including at identified marine ecological resources) during the period. Temperature elevation exceeding 2°C would only extend beyond 100 m from the drainage canal outlet for approximately 20% of time. Exceedances of temperatures above 2°C are confined within approximately 300 m of the outlet of the drainage canal. Likewise for chlorine, discharge will not significantly increase the residual chlorine levels at all identified marine sensitive receptor locations. Compliance of acute and chronic criteria for residual chlorine is expected beyond 300 m from the outlet, including at all identified marine sensitive receptor locations. Therefore, there is not considered to be any predicted change at the receptors by the thermal and chlorine plume.				
	Frequency	The discharge will be continuous throughout the operation phase and compliance is expected beyond 300 m from the outlet, including at all identified marine sensitive receptor locations. Therefore, the predicted change over which the receptors may be impacted is unlikely.				
IMPACT MAGNITUDE		Negligible	**Small**	Medium	Large	
		Affects part of the habitat (within 300 m) but does not threaten the long-term viability/function of the habitat.				
RECEPTOR SENSITIVITY		Negligible	**Low**	Medium	High	
		Existing plankton community indicates signs of elevated nutrient loading and eutrophication in the waters, showing contamination within the seawater. The strong currents along the outfall area will ensure flushing and mixing of the water quality conditions, therefore, it is considered a community with low interest for biodiversity.				
Impact Significance		**Negligible**	Minor	Moderate	Major	

The significance of impacts is expected to be **Negligible**. No mitigation measure for this potential source of impact is deemed necessary.

While no mitigation measures are required for this impact, proposed management measures detailed in EMMP (Section 8) will be implemented as part of best practice for environmental management

7.9.3 IMPACT OF CHANGES IN WATER QUALITY (THERMAL AND CHLORINE PLUMES) TO THE MACROBENTHOS COMMUNITY

7.9.3.1 IMPACT SIGNIFICANCE

Chlorine Plume Impact

The predicted maximum chlorine elevation is predicted to be below 0.02 mg/L within 300 m of the drainage canal outlet at the bottom of the water column. This limited spread is expected as the chlorine has a fast decay rate of 1.185/hour, resulting in a rapid decrease of chlorine concentration over time (30.6% of original chlorine concentration remains after an hour). While the maximum chlorine concentration exceeds the USEPA one-hour average limit of 0.013 mg/L for estuarine and marine life and 4-day average of 0.0075 mg/L within 300 m of the drainage canal outlet, beyond 300 m of the outlet, the maximum chlorine concentrations are predicted to be well within the USEPA one-hour and 4-day average limits.

Elevated levels of chlorine at the bottom of the water column will impact benthic communities such as macrobenthos and may result in mortality for some larval and juvenile stages of species which may lead to. Given the area is localised it is not expected that this will lead to a loss of sensitive species and a dominance of chlorine tolerant species may arise over a large area[79]. While the macrobenthos community naturally has the potential to recover from these chlorination events, given that shock dosing is only done three (3) times a day, there will still be some impact to the macrobenthos community. Hence the impact magnitude to macrobenthos is expected to be **Small** and localised, affecting only a small part of the habitat within 300 m of the outlet of the drainage canal. Beyond 300 m of the outlet, impacts to macrobenthos are negligible as chlorine concentrations are expected to be within USEPA limits.

Coupled with a **Low** receptor sensitivity due to the low macrobenthos diversity at WSQ3, the impact to macrobenthos from chlorine plume will be **Negligible.**

Thermal Plume Impact

Macrobenthos have a limited tolerance for high temperatures, with a maximum temperature range of approximately 35 – 45.8°C[80,81]. For tropical seas, even a temperature increase of less than 5°C is capable of pushing certain organisms beyond their thermal tolerance limits[82,83]. Elevated temperature increases metabolic demand and

---

[79] Chang Y.Y (1989). An on-site assessment of chlorination impacts on benthic macroinvertebrates. University of Massachusetts. Retrieved from https://scholarworks.umass.edu/server/api/core/bitstreams/930dd69b-c4eb-4a2b-9ba1-c2ff619c47df/content

[80] Saraswat R., Nigam R., Pachkhande S. (2011). Difference in optimum temperature for growth and reproduction in benthic foraminifer Rosalina globularis: Implications for paleoclimatic studies. *J. Exp. Mar. Biol. Ecol.* 405, 105–110. doi: 10.1016/j.jembe.2011.05.026

[81] Hamilton H. J., Gosselin L. A. (2020). Ontogenetic shifts and interspecies variation in tolerance to desiccation and heat at the early benthic phase of six intertidal invertebrates. *Mar. Ecol. Prog. Ser.* 634, 15–28. doi: 10.3354/meps13189

[82] Farshchi M., Nasrolahi A., Shokri M. R. (2020). Variability in benthic invertebrate community structure near warm water effluents of a power plant in the southern Caspian Sea. *Regional Stud. Mar. Sci.* 40, 101507. doi: 10.1016/j.rsma.2020.101507

[83] Kimmerer W., Weaver M. J. (2013). Vulnerability of estuaries to climate change. (Oxford, UK: CRC Press), 277–289. doi: 10.1016/B978-0-12-384703-4.00438-X

reduces oxygen availability, which, depending on species, may result in mortality, diminished growth rates, reproductive failure and heightened vulnerability to diseases[84,85].

The predicted thermal plume at the bottom of the water column is expected to increase by approximately 2.0°C to 3.0°C above baseline temperatures (28°C to 30°C) within 100m of the drainage canal. Beyond 300m, thermal elevation is expected to dissipate below a 2.0°C elevation. As such, a localised shift in macrobenthos community structure is expected. There will be a lower total abundance/diversity near the drainage canal outlet, favouring opportunistic taxa rather than widespread mortality. Near-field communities can shift towards tolerant, fast-recruiting polycheates particularly around the drainage canal outlet with higher temperatures[86]. Given that thermal stress can result in changes to the macrobenthos community structure, a conservative impact magnitude is **Medium**, where it may affect part of the macrobenthos habitat, but will not threaten the long-term viability / function of the habitat. As the existing macrobenthos community is of low diversity at WSQ3, hence of a **Low** receptor sensitivity, the impact significance of thermal plume will be **Minor**.

While no mitigation measures are required for this impact, proposed management measures detailed in EMMP (Section 8) will be implemented as part of best practice for environmental management.

7.9.3.2 SUMMARY

TABLE 7-15: IMPACT SIGNIFICANCE – IMPACT OF CHANGES IN WATER QUALITY (THERMAL AND CHLORINE PLUMES) TO THE MACROBENTHOS COMMUNITY

<table>
<tr><td colspan="2">Impact</td><td colspan="5">Impact of changes in water quality to the macrobenthos community</td></tr>
<tr><td colspan="2">Impact Nature</td><td colspan="2">Negative</td><td colspan="2">Positive</td><td>Neutral</td></tr>
<tr><td rowspan="6">IMPACT CHARACTERISTICS</td><td rowspan="2">Type</td><td colspan="2">Direct</td><td colspan="2">Indirect</td><td>Induced</td></tr>
<tr><td colspan="5">Mortality, changes in physiology and community shifts of macrobenthos due to thermal and chlorine plume impact.</td></tr>
<tr><td rowspan="2">Extent</td><td>Site</td><td>Local</td><td>Regional</td><td>National</td><td>International</td></tr>
<tr><td colspan="5">Impact is expected to be localised to within 300 m of the outlet of the drainage canal for thermal and chlorine plume</td></tr>
<tr><td rowspan="2">Scale</td><td>Negligible</td><td>Small</td><td colspan="2">Medium</td><td>Large</td></tr>
<tr><td colspan="5">Impact is limited to macrobenthos residing within 100 m and 300 m of the outlet of the drainage canal for chlorine plume and thermal plume respectively.</td></tr>
</table>

[84] Hyvärinen H. S., Sjönberg T., Marjomäki T. J., Taskinen J. (2022). Effect of low dissolved oxygen on the viability of juvenile Margaritifera margaritifera: Hypoxia tolerance *ex situ*. *Aquat. Conserv.: Mar. Freshw. Ecosyst.* 32, 1393–1400. doi: 10.1002/aqc.3859

[85] Briggs M. A., Albertson L. K., Lujan D. R., Tronstad L. M., Glassic H. C., Guy C. S., et al. (2021). Carcass deposition to suppress invasive lake trout causes differential mortality of two common benthic invertebrates in Yellowstone Lake. *Fundam. Appl. Limnol.* 194, 285–295. doi: 10.1127/fal/2020/1352

[86] Kwon, Soon Hyun, Lee, Jae Hac and Yu, Ok Hwan. (2017). Environmental Effects on the Benthic Polychaete Communities Around the Power Plant Areas in the East Sea of Korea. The Sea: Jorunal of the Korean Society of Oceanography, 22(1), 18–30. https://doi.org/10.7850/JKSO.2017.22.1.018

	Duration	**Temporary**	Short-term	Medium-term	Long-term	Permanent
		The discharge will be continuous throughout the operation phase (long term), but the discharge will not significantly alter the ambient water temperature beyond the immediate vicinity of the drainage canal outlet (including at identified marine ecological resources) during the period. Temperature elevation exceeding 2°C would only extend beyond 100 m from the drainage canal outlet for about 20% of time. Exceedances of temperatures above 2°C are confined within approximately 300 m of the outlet of the drainage canal. Likewise for chlorine, discharge will not significantly increase the residual chlorine levels at all identified marine sensitive receptor locations. Compliance of acute and chronic criteria for residual chlorine is expected beyond 300 m from the outlet, including at all identified marine sensitive receptor locations. Therefore, the predicted change over which the receptors may be impacted the thermal and chlorine plume is considered temporary.				
	Frequency	The discharge will be continuous throughout the operation phase and compliance is expected beyond 300 m from the outlet, including at all identified marine sensitive receptor locations. Therefore, the predicted change over which the receptors may be impacted is rare.				
IMPACT MAGNITUDE		Negligible	**Small**	**Medium**	Large	
		Chlorine plume impact: Affects part of the habitat (within 300 m) such that there is no loss of viability/function of the habitat. Impact magnitude will be Small. Thermal plume impact: Affects part of the habitat (within 300 m) with the potential to cause changes to the macrobenthos structure. However, this does not threaten the long-term viability / function of the habitat. A conservative impact magnitude of Medium has been given for this.				
RECEPTOR SENSITIVITY		Negligible	**Low**	Medium	High	
		Macrobenthos are of low and very low diversity levels, which is typical of aquatic systems that are eutrophic and hence is of low conservation interest. Therefore, it is considered a community with low interest for biodiversity.				
Impact Significance		**Negligible**	**Minor**	Moderate	Major	

The significance of impacts is expected to be **Negligible** to **Minor**. No mitigation measures for this potential source of impact is deemed necessary.

While no mitigation measures are required for this impact, proposed management measures detailed in EMMP (Section 8) will be implemented as part of best practice for environmental management.

7.9.4 IMPACT OF CHANGES IN WATER QUALITY (THERMAL AND CHLORINE PLUMES) TO SEAGRASS HABITAT

7.9.4.1 IMPACT SIGNIFICANCE

Chlorine Plume Impact

While there are limited studies on seagrass specific toxicology of chlorine or Total Residual Oxidants (TRO)[87], impacts to seagrass from chlorine plume would occur via oxidative stress to leaves and photosynthesis during short near-field exposures.

The predicted chlorine plume impacts will be confined to 300 m from the drainage canal outlet, given rapid advection, high turnover, flushing and mixing, and quick decay rate. Given that the nearest seagrass receptor is 3.7 km away from the outlet of the drainage canal at Pulau Salu, and considering rapid oxidant decay, dilution and seawater hydrodynamics, it is unlikely that chlorine will impact the seagrass habitat, as the effect would still be within the normal range of natural variation. Hence the impact magnitude is **Negligible**. With the seagrass habitats being of **High** sensitivity, the overall impact significance will be **Negligible**.

Thermal Plume Impact

Within 300 m of the outlet of the drainage canal, channel temperatures are predicted to increase by 0.1°C to 3.0°C over the baseline temperatures (approximately 28°C to 30°C). Given that the nearest seagrass receptor is 3.7 km away, after considering seawater hydrodynamics, it is unlikely that any temperature impacts will reach seagrass habitats, as the effect would still be within the normal range of natural variation. Hence the impact magnitude is **Negligible**. With the seagrass habitats being of **High** sensitivity, the overall impact significance will be **Negligible**.

While no mitigation measures are required for this impact, proposed management measures detailed in EMMP (Section 8) will be implemented as part of best practice for environmental management.

7.9.4.2 SUMMARY

TABLE 7-16: IMPACT SIGNIFICANCE – IMPACT OF CHANGES IN WATER QUALITY (THERMAL AND CHLORINE PLUMES) TO SEAGRASS HABITAT

<table>
<tr><td colspan="2">Impact</td><td colspan="5">Impact of changes in water quality to seagrass habitat</td></tr>
<tr><td colspan="2">Impact Nature</td><td colspan="2">Negative</td><td colspan="2">Positive</td><td>Neutral</td></tr>
<tr><td rowspan="4">IMPACT</td><td rowspan="2">Type</td><td colspan="2">Direct</td><td colspan="2">Indirect</td><td>Induced</td></tr>
<tr><td colspan="5">Oxidative stress and potential mortality due to chlorine and thermal plume impact respectively.</td></tr>
<tr><td rowspan="2">Extent</td><td>Site</td><td>Local</td><td>Regional</td><td>National</td><td>International</td></tr>
<tr><td colspan="5">Impact will be within 300 m of the outlet of the drainage canal for thermal and chlorine plume, compliant with MWQC and USEPA thresholds respectively.</td></tr>
</table>

[87] Includes direct products of chlorine e.g. chlorine that reacts with bromide ions in the sea to form hypobromous acid and hypobromite ions.

<table>
<tr><td rowspan="6"></td><td rowspan="2">Scale</td><td>Negligible</td><td>Small</td><td colspan="2">Medium</td><td>Large</td></tr>
<tr><td colspan="5">Chlorine and thermal plume impact will not reach where seagrasses are located (3.7km)</td></tr>
<tr><td rowspan="2">Duration</td><td>Temporary</td><td>Short-term</td><td>Medium-term</td><td>Long-term</td><td>Permanent</td></tr>
<tr><td colspan="5">The discharge will be continuous throughout the operation phase (long term), but the discharge will not significantly alter the ambient water temperature beyond the immediate vicinity of the outlet (including at identified marine ecological resources) during the period. Temperature elevation exceeding 2°C would only extend beyond 100 m from the drainage canal outlet for approximately 20% of time. Exceedances of temperatures above 2°C are confined within approximately 300 m of the outlet of the drainage canal.
Likewise for chlorine, discharge will not significantly increase the residual chlorine levels at all identified marine sensitive receptor locations. Compliance of acute and chronic criteria for residual chlorine is expected beyond 300 m from the outlet, including at all identified marine sensitive receptor locations. Therefore, the predicted change over which the receptors may be impacted the thermal and chlorine plume is considered temporary.</td></tr>
<tr><td>Frequency</td><td colspan="5">The discharge will be continuous throughout the operation phase and compliance is expected beyond 300 m from the outlet (where seagrass habitats are located 3.7 km away), including at all identified marine sensitive receptor locations. Therefore, the predicted change over which the receptors may be impacted is rare.</td></tr>
<tr><td></td><td colspan="5"></td></tr>
<tr><td colspan="2" rowspan="2">IMPACT MAGNITUDE</td><td>Negligible</td><td>Small</td><td colspan="2">Medium</td><td>Large</td></tr>
<tr><td colspan="5">No impact to seagrass located more than 3.7 km away from the outlet of the drainage canal hence no effects to seagrass beyond its range of natural variation.</td></tr>
<tr><td colspan="2" rowspan="2">RECEPTOR SENSITIVITY</td><td>Negligible</td><td>Low</td><td colspan="2">Medium</td><td>High</td></tr>
<tr><td colspan="5">Presence of seagrass species, which are nationally CR and EN, within 5 km AOI. Seagrass habitats are key environments for dugongs and sea turtles, making them important ecological resources in Singapore.</td></tr>
<tr><td colspan="2">Impact Significance</td><td>Negligible</td><td>Minor</td><td colspan="2">Moderate</td><td>Major</td></tr>
</table>

The significance of impacts is expected to be **Negligible**. No mitigation measure for this potential source of impact is deemed necessary.

7.9.5 IMPACT OF CHANGES IN WATER QUALITY (THERMAL AND CHLORINE PLUMES) TO MARINE SPECIES

7.9.5.1 IMPACT SIGNIFICANCE

Chlorine Plume Impact

The predicted chlorine plume is limited to within 300 m from the outlet of the drainage canal. Beyond this distance, chlorine concentrations are expected to decrease and be compliant to both the acute and chronic chlorine thresholds (USEPA). This is due to the chlorine concentrations decreasing rapidly due to high reactivity, a quick decay rate, and strong tidal mixing. Within 300 m of the outlet, there are ships and jetties, with Very Large Crude Carriers (VLCCs) berthed at the jetty adjacent to the outlet for extended periods which are disturbances to marine species and hence would likely be avoided. Within 300 m of the outlet there are also limited food sources or shelter options (e.g. coral reef) as it is a highly modified area. Should any marine species enter within this 300 m of the outlet, it is considered that fish are particularly vulnerable to chlorine toxicity as it causes severe damage to gill tissues, leading to respiratory failure[88]. However, fish have been shown to display strong avoidance behaviour upon sensing residual chlorine in the range of 0.04 to 0.41 mg/L (depending on species)[89]. This is part of their survival mechanism to move away from potentially lethal aquatic environments. The chlorine concentration 300 m from the outlet of the drainage canal will fall within the range of 0.02 mg/L which is lower than the threshold for aquatic life at 0.013 mg/L. Hence the impact magnitude to fish will be **Negligible**, as they are expected to naturally move away from areas of high chlorine concentration.

At the fish farm sites (more than 9 km SE of drainage canal outlet), notable changes in chlorine levels due to the Project are not anticipated as predicted chlorine plume is limited to within 300 m from the outlet of the drainage canal. As such, the impact magnitude to the fish farms will also be **Negligible** where impacts are within the normal range of natural variation.

Marine reptiles and mammals will face similar impacts. Marine turtles typically accumulate organochlorine contaminants through their diet (e.g. jellyfish which bioaccumulate chlorine pollutants), affecting immune function[90] and potentially causing anemia[91]. For marine mammals, they also bioaccumulate organochlorines such as polychlorinated biphenyls (PCBs), which are potent endocrine disruptors that interfere with reproductive hormones and processes, immunosuppression and disease susceptibility[92,93]. Given that there are

---

[88] Li X., Shou Y.P., Li H. (2023). Marine ecological impact analysis of residual chlorine emission from LNG transfer station. E3S Web of Conferences 393, 02009

[89] Fisher, Daniel & Burton, Dennis & Yonkos, Lance & Turley, Steven & Ziegler, Gregory. (1999). The relative acute toxicity of continuous and intermittent exposures of chlorine and bromine to aquatic organisms in the presence and absence of ammonia. Water Research. 33. 760-768. 10.1016/S0043-1354(98)00278-4.

[90] Keller, J. M., McClellan-Green, P. D., Kucklick, J. R., Keil, D. E., & Peden-Adams, M. M. (2006). Effects of organochlorine contaminants on loggerhead sea turtle immunity: comparison of a correlative field study and in vitro exposure experiments. *Environmental health perspectives*, *114*(1), 70–76. https://doi.org/10.1289/ehp.8143

[91] C Mckenzie, B.J Godley, R.W Furness, D.E Wells (1999). Concentrations and patterns of organochlorine contaminants in marine turtles from Mediterranean and Atlantic waters. Marine Environmental Research, 47 (2), pp 117-135, ISSN 0141-1136, https://doi.org/10.1016/S0141-1136(98)00109-3.

[92] R. F. Addison. (1989). Organochlorines and Marine Mammal Reproduction. *Canadian Journal of Fisheries and Aquatic Sciences*. **46**(2): 360-368. https://doi.org/10.1139/f89-047

[93] Tilen Genov, Paul D. Jepson, Jonathan L. Barbe, Ana Hace, Stefania Gaspari, Tina Centrih, Jan Lesjak, Polona Kotnjek (2018). Linking organochlorine contaminants with demographic parameters in free-ranging common bottlenose dolphins from the northern Adriatic Sea. Science of the Total Environment, 657, 200-212.

more suitable habitats located beyond 1 km of the outlet such as Helios Secondary Reef and further south at natural reefs such as Terumbu Pempang Laut, Pulau Sudong, Pulau Salu and other southern island reefs, it is unlikely for marine turtles and mammals to be present within 300 m of the site to forage or seek shelter. Marine turtles and mammals are also not typically seen around the waters of Jurong Island. Considering the above, the impact magnitude for marine reptiles and mammals will be **Negligible** as any effects would be within the normal range of natural variation.

Given that the receptor sensitivity of all three (3) marine species is **High** and **Medium** for the fish farm, in addition to the impact magnitude being **Negligible**, the resulting significance of impact will be **Negligible**.

Thermal Plume Impact

Temperatures are predicted to increase by 2.0°C to 3.0°C above baseline temperatures (approximately 28°C to 30°C) within 300 m of the drainage canal outlet throughout the operational period of the CCGT plant.

Elevated temperatures increase metabolic oxygen demand which reduces dissolved oxygen availability, resulting in respiratory stress, as fish must increase ventilation to extract sufficient oxygen from oxygen-depleted water[94,95]. Similar to chlorine impacts, fish exhibit species-specific behavioral responses such as active avoidance of thermal plumes when temperatures exceed their preferred ranges[96]. Hence the impact magnitude to fish will be **Negligible** where impacts are within the normal range of natural variation, as they are expected to naturally move away from the small area of higher temperature.

At the fish farm sites (more than 9 km SE of drainage canal outlet), the predicted change in maximum surface temperature would be much lower and at the level of 0.1˚C or below. Therefore, notable changes in water temperature at the fish farm is not anticipated. As such, the impact magnitude to fish farms will also be **Negligible** where impacts are within the normal range of natural variation.

Marine reptiles and mammals may be indirectly impacted through potential loss of prey due to thermal impacts, they would not be directly impacted as they also exhibit the same avoidance behavior toward warmer waters beyond their thresholds. Marine turtles being ectotherms, rely on behavioral thermoregulation. In tropical warmer waters such as Singapore’s, they have less capacity to shed heat than in cooler waters and may shift to cooler habitats if plume temperatures exceed preferred ranges[97]. Marine mammals such as dolphins regulate heat by modulating blood flow and using their fins and flippers to dissipate heat. As they lack evaporative cooling in water, they generally avoid abnormally

[94] Simon Kumar Das, Moumita De, Mazlan Abd. Ghaffar, Noorashikin Md Noor, Sabuj Kanti Mazumder, Yosni Bakar (2021). Effects of temperature on the oxygen consumption rate and gill fine structure of hybrid grouper, Epinephelus fuscoguttatus and E. Lanceolatus. Journal of King Saud University - Science, 33 (2), ISSN 1018-3647, https://doi.org/10.1016/j.jksus.2021.101358.
[95] Svobodová Z., Llyod. R., Máchová, J. and Vykusová B. (1992). Water quality and fish health EIFAC Technical Paper. No. 54. Rome, FAO. Pp 59.
[96] Romberg G.P., Spigarelli S.A., Prepejchal, W. and Thommes M.M. (1974). Migratory behaviour of fish tagged at nuclear power plant discharge into lake Michigan. 17th Conference on Great Lakes Research, Hamilton, Ontario.
[97] Goudarzi F, Doxa A, Hemami MR, Mazaris AD (2024). Thermal vulnerability of sea turtle foraging grounds around the globe. Commun Biol. Mar 21;7(1):347. doi: 10.1038/s42003-024-06013-y. PMID: 38514821; PMCID: PMC10958041.

warm patches[98]. As described above, more suitable habitats with food and shelter located beyond 1 km of the outlet. Thus, it is unlikely for these marine reptiles and mammals to be present with 300 m of the outlet. Coupled with their natural avoidance behaviour towards warmer waters, the impact magnitude for marine reptiles and mammals will be **Negligible**, where impacts are within the normal range of natural variation.

Given that the receptor sensitivity of all marine species is **High** and **Medium** for fish farms, coupled with the impact magnitude of **Negligible**, the resulting significance of impact will be **Negligible**.

While no mitigation measures are required for this impact, proposed management measures detailed in EMMP (Section 8) will be implemented as part of best practice for environmental management.

7.9.5.2 SUMMARY

TABLE 7-17: IMPACT SIGNIFICANCE – IMPACT OF CHANGES IN WATER QUALITY (THERMAL AND CHLORINE PLUMES) TO MARINE SPECIES

<table>
<tr><td colspan="2">Impact</td><td colspan="5">Impact of changes in water quality to marine species</td></tr>
<tr><td colspan="2">Impact Nature</td><td colspan="2">Negative</td><td>Positive</td><td colspan="2">Neutral</td></tr>
<tr><td rowspan="8">IMPACT CHARACTERISTICS</td><td rowspan="2">Type</td><td colspan="2">Direct</td><td>Indirect</td><td colspan="2">Induced</td></tr>
<tr><td colspan="5">Chlorine plume impact:
Direct impact on fish through respiratory failure and indirect impact on marine reptiles and mammals through bioaccumulation.
Thermal plume impact:
Direct impact on fish through respiratory stress and indirect impacts on marine reptiles and mammals through potential loss of prey.</td></tr>
<tr><td rowspan="2">Extent</td><td>Site</td><td>Local</td><td>Regional</td><td>National</td><td>International</td></tr>
<tr><td colspan="5">Impact will be within 300 m of the outlet of the drainage canal outlet for thermal and chlorine plume, compliant with MWQC and USEPA thresholds respectively.</td></tr>
<tr><td rowspan="2">Scale</td><td>Negligible</td><td>Small</td><td>Medium</td><td colspan="2">Large</td></tr>
<tr><td colspan="5">Chlorine and thermal plume impact is mainly limited to marine species swimming within 300 m of the outlet.</td></tr>
<tr><td>Duration</td><td>Temporary</td><td>Short-term</td><td>Medium-term</td><td>Long-term</td><td>Permanent</td></tr>
</table>

[98] Favilla AB, Horning M, Costa DP. (2021). Advances in thermal physiology of diving marine mammals: The dual role of peripheral perfusion. Temperature (Austin), 9(1):46-66. doi: 10.1080/23328940.2021.1988817. PMID: 35655662; PMCID: PMC9154795.

		The discharge will be continuous throughout the operation phase (long term), but the discharge will not significantly alter the ambient water temperature beyond the immediate vicinity of the outlet (including at identified marine ecological resources) during the period. Temperature elevation exceeding 3°C would only extend beyond 100 m from the drainage canal outlet for less than 10% of time. Exceedances of temperatures above 2°C are confined within approximately 300 m of the outlet of the drainage canal. Likewise for chlorine, discharge will not significantly increase the residual chlorine levels at all identified marine sensitive receptor locations. Compliance of acute and chronic criteria for residual chlorine is expected beyond 300 m from the outlet, including at all identified marine sensitive receptor locations. Therefore, the predicted change over which the receptors may be impacted the thermal and chlorine plume is considered temporary.			
	Frequency	The discharge will be continuous throughout the operation phase and compliance is expected beyond 300 m from the outlet, including at all identified marine sensitive receptor locations. Therefore, the predicted change over which the receptors may be impacted is rare.			
IMPACT MAGNITUDE		**Negligible**	Small	Medium	Large
		Given the avoidance behaviour of marine species to these plumes and that they are high mobile, any effects will be within the fauna's range of natural variation.			
RECEPTOR SENSITIVITY		Negligible	Low	**Medium**	**High**
		Presence of marine species which are nationally CR and EN (High sensitivity) within 5 km AOI that use the Straits of Singapore and/or nearby reefs to forage, travel and seek shelter and presence of fish farms of socio-economic importance which could be impacted by changes in water quality (Medium sensitivity).			
Impact Significance		**Negligible**	Minor	Moderate	Major

The significance of impacts is expected to be **Negligible**. No mitigation measures for this potential source of impact is deemed necessary.

7.10 SUMMARY OF MARINE BIODIVERSITY ASSESSMENT FINDINGS

The two (2) main sources of impact to marine biodiversity from the operation phase discharge include changes in water temperature and elevated chlorine levels at the receiving water upon discharge at the outlet of the drainage canal. These impacts have been assessed based on the results of computational modelling with a number of embedded controls (Section 6.7) incorporated into the design and reflected in the modelling / assessment to minimise potential impacts.

All marine biodiversity sensitive receptors are located at least 700 m away from the outlet of the drainage canal. The closest receptor is the Helios Secondary Reef, which is located on the Jurong Island seawall, is 700 m away from its closest point to the outlet of the PUB drainage canal. This reef has a coral cover of 33.1% at 3 m depth, where, based on the most recent data from a 2012 NParks report, many nationally Vulnerable and Near Threatened coral species are found (based on general information). The closest Seagrass habitats can be found more than 3.7 km away from the PUB drainage canal outlet.

Surveys for planktons at the PUB discharge canal outlet indicated phytoplankton abundance of *Skeletonema spp* and *Chaetoceros spp*, showing nutrient availability, limited diversity and potential for algal blooms. For zooplankton, dominant *Paracalanidae* copepods suggests a stable and productive coastal ecosystem. Surveys for macrobenthos indicate a dominance of Gastropoda (≥82.6% of individuals) in the community with a Low and Very Low diversity according to the Shannon Biodiversity Index. Marine species such as fish, reptiles and mammals have been mainly found within the Singapore Straits and the Southern Islands (>3.7km away from the outlet). Fish farm sites are also located more than 9 km away from the drainage canal outlet.

Modelling has confirmed that the chlorine plume from the Project will have no impact on the Helios Secondary Reef corals as chlorine concentrations decrease rapidly due to rapid advection, high turnover, flushing and mixing, and quick decay rate. For the thermal plume, areas exceeding the maximum temperature increase of 2.0°C threshold (AMWQC)[99] are confined within approximately 300 m of the drainage outlet location and will not encroach into the Helios Secondary Reef. While the maximum temperature increase at the surface may result in an increase of 1.0°C at the eastern end of the reef, exceedances will not be sustained and will typically only last for a maximum of three (3) hours during the NE monsoon. The temperature increase at the eastern tip of the reef for short durations is not expected to impact the reef. Hence, the impact significance of both chlorine and thermal plume to coral habitats (including coral spawning) is **Negligible** and **Minor** respectively.

The impact of chlorine and thermal plume to planktons within the direct AOI of the drainage canal outlet will be **Negligible**, as impacts are generally localised, due to high turnover, flushing and mixing from seawater and will not impact the long-term viability/function of the community.

Within 100m of the outlet, chlorine plume at the bottom layer of the water column will be <0.02 mg/L, which is 1.5 times higher than the acute toxicity limit of 0.013 mg/L. This has a localised impact to macrobenthos on the seabed, affecting a part of the habitat within 100 m of the outlet hence impact significance will be **Negligible**, due to the **Low** receptor sensitivity. Within 300 m of the outlet, thermal plume impacts may result in a shift towards tolerant, fast- recruiting

[99] Temperatures within 300m of the outlet of the discharge would range from +2.0°C to +3.0°C.

polycheates, causing a localised change in the macrobenthos community structure in the affected area. This will affect only a small area of habitat (within 300 m of the outlet) such that there is no loss of viability or function of the habitat. This coupled with the **Low** receptor sensitivity would result in an impact significance of **Minor**.

The impacts of chlorine and thermal plume to seagrass habitats and marine species will be **Negligible,** as seagrass habitats will face no impact as they are located away from the thermal and chlorine plumes and marine species are highly mobile, typically avoiding areas with higher chlorine levels or temperatures beyond their tolerance limits. For fish farms, **Negligible** impact will be observed for chlorine and thermal plumes due to the distance they are located at (more than 9 km from the drainage canal outlet).

While no mitigation measures are required for the assessed impacts, proposed management measures detailed in EMMP (Section 8) will be implemented as part of best practice for environmental management.

8. ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN (EMMP) FRAMEWORK

The Environmental Management and Monitoring Plan (EMMP) framework sets out actions for the pre-construction, construction and operation phases (including decommissioning) of the Project. The EMMP establishes actions that need to be undertaken in order to avoid, alleviate, mitigate and remediate the potential impacts that were systematically identified during development of the Project's EIA.

The EMMP was developed following the assessment of impacts, which was undertaken in accordance with the approach adopted for the EIA. The Project activities were reviewed to identify potential impacts across a range of environmental aspects such as surface water quality, biodiversity, air quality, airborne noise and vibration, soil and groundwater and vector controls. The EMMP takes into consideration management measures such as industry good practice and mitigation. Regulatory controls have been assumed to apply to specific environmental aspects per Appendix A (Embedded Controls).

The EMMP also assigns responsibilities for implementing and monitoring the actions required prior to, and during, the pre-construction, construction and operation work phases. This EMMP framework consolidates the mitigation and monitoring strategies required for the Project, developed based on the outcomes of this EIA.

The EMMP covers environmental aspects that have been scoped in and out of the EIA (as explained in Section 4.2) including air quality, noise, water quality, vector control, wastewater and waste management, marine water quality, marine and terrestrial biodiversity. The scale and approach of the EMMP have been tailored to the specific characteristics of the proposed works, and relevant management measures and monitoring measures are proposed in accordance with the requirements of the relevant Technical Agencies.

8.1 EMMP OBJECTIVES

The objectives of the EMMP include:

- Providing a database of environmental parameters against which short-term and long-term environmental impacts can be determined;
- Providing an early indication should any of the environmental control measures or practices fail to meet the acceptable standards;
- Clarifying and identifying potential sources of pollution, impact and nuisance arising from the works by the responsible parties;
- Confirming compliance with regulatory requirements and EIA recommendations, such as management and monitoring measures;
- Confirming compliance of environmental designs during the design phase of the Project with the specifications stated in the EIA;
- Monitoring performance of the mitigation measures and assessment of their effectiveness;
- Identifying remedial action if unexpected issues or unacceptable impacts arise; and
- Verifying the environmental impacts predicted in the EIA.

8.2 EMMP ROLES AND RESPONSIBILITIES

A number of parties will be involved in the management and mitigation of potential environmental impacts associated with the pre-construction, construction and operation phases of the Project. Details of the roles and responsibilities for implementing the EMMP throughout the Project are described below. The organisational structure and lines of communication are presented in Figure 8-1 while details of the roles within the EMMP team are presented in Table 8-1.

FIGURE 8-1: PROJECT ORGANISATION CHART FOR EMMP IMPLEMENTATION

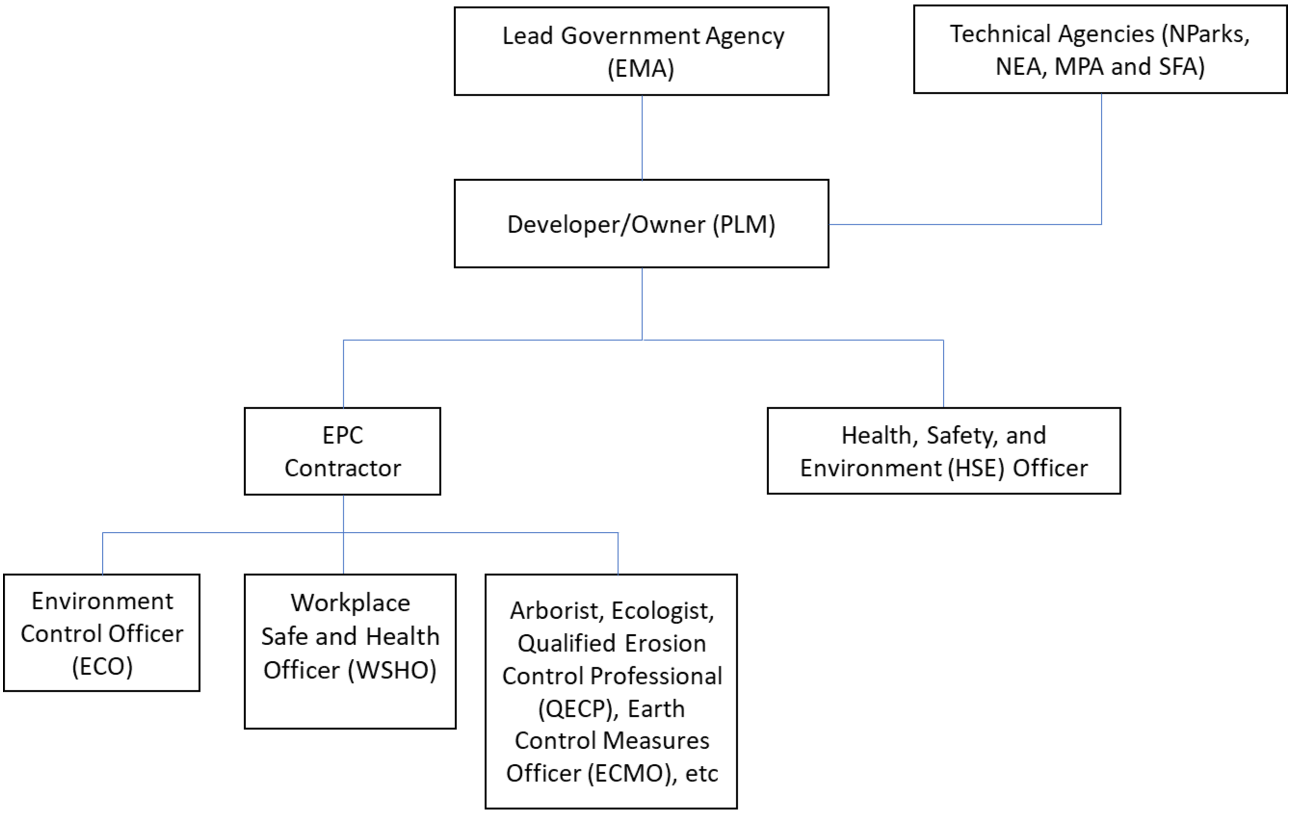


TABLE 8-1: DETAILS OF ROLES AND RESPONSIBILITIES OF EMMP TEAM

Roles	Responsibilities
Lead Government Agency (EMA)	• Oversee the overall development of the Project and is the main liaison with other Technical Agencies.
Technical Agencies (NParks, NEA, MPA and SFA)	• Review and approve the Construction and Operational EMMPs prior to commencement of the works and other relevant submissions throughout the course of the Project.
Developer/Owner (PLM)	• Owns, operates and maintains the CCGT system and has overall accountability for environmental compliance during the Project phases. • To develop a Construction EMMP (cEMMP) in conjunction with the EPC contractor and an Operational EMMP (oEMMP) prior to the commencement of construction and operation works respectively, to be approved by the relevant Technical Agencies. • Establish and maintain a system for complaints, corrective actions, and communication channels within the Project

Roles	Responsibilities
	organisation to ensure stakeholders' concerns are monitored and addressed in a timely manner.
Engineering, Procurement and Construction (EPC) Contractor	• Implement the cEMMP and ensure construction works are undertaken in accordance with design limits, management measures and mitigation (where appropriate) • Provide assistance to ECO, QECP, arborists, etc. with the necessary support required to carry out the required monitoring programmes, site inspections and implement all other EMMP related actions. • Implement corrective actions instructed by PLM and adhere to procedures for carrying out complaint investigations.
Environmental Control Officer (ECO)	• Implements the environmental monitoring programme within their responsibilities as outlined in the Code of Practice for Environmental Control Officers[100]. • NEA-registered with relevant experience in developing and implementing cEMMP for similar or large-scale projects. • Ensure compliance with management and monitoring measures of various environmental parameters e.g. vector control, waste management, noise management, sanitary facilities management, air pollution and dust abatement, water pollution and earth control. • Monitor environmental compliance with conditions set in this EMMP and relevant regulatory conditions. • Assist with the resolution of near misses/incidents, non-compliance incidents and complaint management. • Support the liaison with Technical Agencies and stakeholders on environmental related matters where necessary.
Arborist	• Arborist to hold a certification from the International Society of Arboriculture (ISA). • Carry out tree mapping and assessment. • Suggest tree protection measures and plans where required. • Implement tree maintenance and care where required. • Provide advice on tree transplanting where required. • Review site clearance and tree felling plans, and set up tree protection zones (TPZ) if required.
Ecologist	• Carry out pre-felling fauna inspections. • Facilitate the implementation of the fauna response plan. • Implement fauna management during site clearance and plan for passive wildlife shepherding via directional clearance.
Qualified Erosion Control Professional (QECP)	• Plan, design, supervise and review the earth control measures (ECM) to ensure effective implementation of the ECM system at the worksite. • Submits the ECM Plan requiring PUB's approval prior to the start of earth works. • Reviews the effectiveness of the ECM regularly during various stages of construction.
Earth Control Measures Officer (ECMO)	• Implement all ECM requirements in compliance with the ECM Plan approved by PUB.

[100] NEA (2022). Code of Practice for Environmental Control Officers for Specified Construction Sites. Retrieved from https://www.nea.gov.sg/docs/default-source/our-services/pest-control/environmental-control-officer/code-of-practice-for-eco-(scs)---5th-edition-finalad363da3b1064f94bdcf2f62f9429adf.pdf

Roles	Responsibilities
Workplace Safe and Health Officer (WSHO)	• Advise employer on compliance with Workplace Safety and Health (WSH) Act (2006), regulations, codes of practice, and ensure implementation of safe work procedures and risk assessments. • Develop and help implement WSH policies to ensure compliance with local regulations, manage site-specific risks, and promote a strong safety culture. • Conduct site inspections, accident investigations, deliver safety training and oversee environmental compliance measures.
Health, Safety and Environment (HSE) Officer	• Develop, implement and maintain internal HSE policies, procedures, and management systems, beyond what is strictly mandated by WSH regulations. • Conduct risk assessments, inspections and audits including for waste, emissions, spill prevention and compliance with environmental permits. • Lead or coordinate incident investigations.

8.2.1 REPORTING

8.2.2 CONSTRUCTION EMMP (CEMMP)

The contents and structure of the Construction EMMP (cEMMP) will follow legislation and the proposed measures contained within this EMMP and shall be agreed upon with the relevant Technical Agencies prior to construction commencement.

The Construction EMMP shall set out the overall construction management and monitoring requirements to be agreed upon with the relevant Technical Agencies, and to be carried out during the construction phase, and shall include, as a minimum the:

- Final Project design information;
- Current relevant legislation and best practice;
- Environmental Impact Register;
- Handling and storage of hazardous chemicals;
- Standard checklists and communication flows, e.g. for site inspections, wildlife management etc;
- Environmental management plans stating control measures and mitigation measures (see Table 8-2); and
- Environmental monitoring programmes (see Table 8-3).

8.2.3 OPERATIONAL EMMP (OEMMP)

The contents and structure of the Operational EMMP (oEMMP) will follow legislation and the proposed measures contained within this EMMP and shall be agreed with relevant Technical Agencies prior to operations commencing and will draw on the Construction EMMP as appropriate. The oEMMP shall set out the overall operational management and monitoring requirements and implemented during the operational phase.

8.2.4 COMPLAINTS AND CORRECTIVE ACTIONS

PLM and/or EPC Contractor will be responsible for handling all environmental complaints that may be received from the public. Complaint investigation procedures will be developed and implemented. The main elements of complaint investigation procedures encompass:

- Prompt acknowledgement and response to stakeholder complaints, keeping them informed of the progress and outcomes;
- Accurate recording of complaints, investigations and outcomes;
- Resolution by PLM or EPC Contractor and/or ECO within an agreed specified timeframe;
- An escalation mechanism in the event that grievance cannot be resolved by the EPC Contractor and/or ECO within the nominated timeframe; and
- The relevant Technical Agencies that will be kept informed of complaints, where required.

If complaints are made directly to the relevant agencies, i.e. EMA, NEA, NParks etc., PLM or the EPC Contractor and/or ECO should submit sufficient investigative and corrective action reports to the relevant agencies, to demonstrate that the complaint is being addressed.

8.3 SUMMARY OF EMMP

8.3.1 CONSTRUCTION EMMP

The appointed Contractor shall prepare a detailed Construction Environmental Management and Monitoring Plan (cEMMP) based on the EMMP framework in this EIA and obtain approval from NParks and the other relevant Technical Agencies prior to commencing construction. The approved cEMMP shall be strictly implemented throughout the construction phase to ensure environmentally responsible project execution.

Table 8-2 and Table 8-3 provide the proposed types of control measures/mitigation and monitoring that will be implemented respectively; however, this list is not exhaustive, and additional measures may be adopted where warranted.

TABLE 8-2: SUMMARY OF CONTROL MEASURES AND MITIGATION DURING CONSTRUCTION PHASE

Environmental Aspect	Impact	Management Measures	Verification	Duration/ Time	Location	Site Responsibility
Air	Increase of air pollutants & dust level to the environment and human receptors (i.e., workers) from construction works	• Watering to reduce dust emissions from exposed areas during the dry season. • Ensure regular maintenance of construction vehicles, equipment, machinery to reduce black smoke emissions. • Washing facilities to be provided at the designated exit points to wash away dirt from tires prior to leaving site. • Implementation of vehicular speed limits. • Transportation of construction materials to and from the Project site will be covered. • Carry out regular site inspections to monitor compliance of management measures. • All construction debris will be properly stored and removed for disposal quickly and will not be left to accumulate at the site. • Generators should be sited at locations that minimise the smell and noise nuisance affecting nearby residential premises (i.e. worker dormitory).	Visual inspection and compliance check	Throughout construction phase	Project Site	Contractor / ECO
Airborne Noise	Increase of noise level to the environment and human receptors (i.e., workers) from construction works	• Undertake ad-hoc spot checks of construction equipment to ensure that equipment is operating within its noise specification. • For construction personnel: Utilization of PPE (i.e., earmuff or ear plug) where the noise levels in the vicinity of the construction area exceed 85 dB(A). • All machines of intermittent use should be shut down or throttled down to a minimum during the intervening periods between works. • Extra care should be undertaken when loading or unloading vehicles or moving materials to reduce noise impact. • Low noise generating equipment and machines shall be used where possible. • Where possible generators should be sited at locations to minimise the impact to nearby residential premises (i.e. worker dormitory). • The Contractor must ensure compliance by their subcontractors of noise limits at the construction site.	Visual inspection and compliance check	Throughout construction phase	Project Site	Contractor / ECO
Surface water	Removal of vegetation leading to increase sedimentation due to soil erosion Deterioration of water quality due to runoff and siltation during project activities	• Implement, maintain and inspect Earth Control Measures (ECM) system for treatment of silty water/surface runoff prior to discharge. • Silt fencing is to be installed along the bottom of the hoarding, to prevent sediments from the construction site from washing into nearby watercourses. • Conduct weekly visual inspections of silt fencing. • All stockpiles and worksite entrances shall be located as far as practically possible from watercourses. • Excavated material (on land or on vehicles) shall be covered properly to prevent runoff. Excavated soil will typically be directed for immediate backfill in nearby areas or placed in designated zones within the main plant for near-term reuse. • Stockpiles near piles will be covered within 5 minutes of rain events using blue canvas sheets (0.22-0.4mm thick, waterproof PE or PVC), which provide effective water resistance for quick deployment over stockpiles. • Wheel wash areas should be set up at the exit points of the site.	Visual inspection and compliance check	Throughout construction phase	Project Site	Contractor / ECO

Environmental Aspect	Impact	Management Measures	Verification	Duration/ Time	Location	Site Responsibility
	Deterioration of surface water from accidental spillage or hazardous material	• Concrete mixer trucks are washed only at the batching plant, waste concrete is reused as paving in the temporary laydown area, small mixed quantities are contained and fully used. • All concrete wash water is routed to the ECM pond for treatment prior to discharge into PUB's drainage system. • Oil and chemicals in drums, carboys, containers, etc. shall be stored in a designated storage area within a building or covered shed with concrete floors and facilities to contain any leak or spillage. • Waste oil and chemicals generated from site activities shall only be sent to a licensed toxic industrial waste collector for proper disposal. • A full containment bund wall should be provided for bulk storage oil/fuel tanks, including skid tanks. A collection sump should be provided to collect any spillage. All leaks and spillages in the storage area or construction site shall be collected and sent to a licensed toxic waste collector for proper disposal. • Engine oils and grease, fuel oils, and other chemicals should be properly stored at a designated area. • A spill kit should be kept within the site in case of accidental spills. • Spent oil and grease shall be stored in steel drums, sealed and disposed accordingly. • Hazardous materials should be stored in designated areas. • The storage floor is recommended to be lined, to minimize the impact of chemical infiltration into the soil/groundwater. • All chemicals should be properly labelled and managed during construction activities. Spill kit should be available and accessible on site to contain any spillage. Workers should be appropriately trained, to handle situations in the event a spill occurs. • Storage of hazardous materials on site should be kept to a minimum, to minimise spillage impact. • A chemical inventory and emergency spill response plan should be developed.	Visual inspection and compliance check	Throughout construction phase	Project Site	Contractor / ECO
	Discharge of trade effluent during commissioning	• Approval must be obtained from PUB prior to discharge. • No discharge of untreated wastewater directly into the drain.	On-site visual verification	Throughout plant commissioning phase	Project Site	Contractor / ECO
	Leakage of sanitary wastewater into surface water body	• Place portable toilets on level, impermeable pads away from any drain or watercourse. • Ensure regular checks are conducted on portable toilets to ensure they are functioning well, without any signs of leakage.	Visual inspection and compliance check	Throughout construction phase	Project Site	Contractor / ECO
Waste	Hazardous waste	• Engagement of NEA licensed waste collector for hazardous waste. • Maintain a record of waste disposal.	Compliance check	Weekly during construction phase	Project Site	Contractor / ECO
	Construction waste	• Engagement of NEA licensed general waste collector. • Maintain a record of waste disposal. • Dumping of any waste materials into water bodies will be strictly prohibited.	Compliance check	Weekly during construction phase	Project Site	Contractor / ECO

Environmental Aspect	Impact	Management Measures	Verification	Duration/ Time	Location	Site Responsibility
Vector control	Increase in the incidence of vectors and related diseases	• Regular checks, minimally once a week, shall be conducted for mosquito breeding at the construction site. • It is not mandatory to conduct fogging at construction sites. Fogging treatment should only be done when there is a mosquito nuisance problem or disease outbreak.	Visual inspection and compliance check	Weekly during construction phase	Project Site	Contractor / ECO
Terrestrial Biodiversity	Mortality of flora species (conservation interest) due to land clearance	• Any species of conservation significance affected by the works will be transplanted out of the site prior to site clearance.	Visual inspection	During pre-construction phase	Project Site	Contractor / Arborist
	Injury or mortality of fauna due to construction works	• Carry out wildlife shepherding via directional clearing of the remaining vegetation. This entails clearing trees and vegetation progressively in one direction, e.g. from the south to the north of the Project Site, for both the main site and intake areas so that wildlife can escape into other forest/grassland areas. • Pre-felling fauna inspection should be conducted before felling all trees or removing any vegetation. This should be planned and overseen by an appropriately qualified Ecologist/Arborist. • Use only fully biodegradable erosion control blankets (ECB). • Erection and maintenance of worksite hoarding prior to vegetation clearance and repair of hoarding damage on a timely basis to avoid wildlife from entering the site. There should be no gaps between the hoarding and secured 300 mm into the ground.	Construction EMMP, visual inspection and compliance check	Throughout pre-construction and construction phase	Project Site	Contractor / ECO/ Ecologist/ Arborist

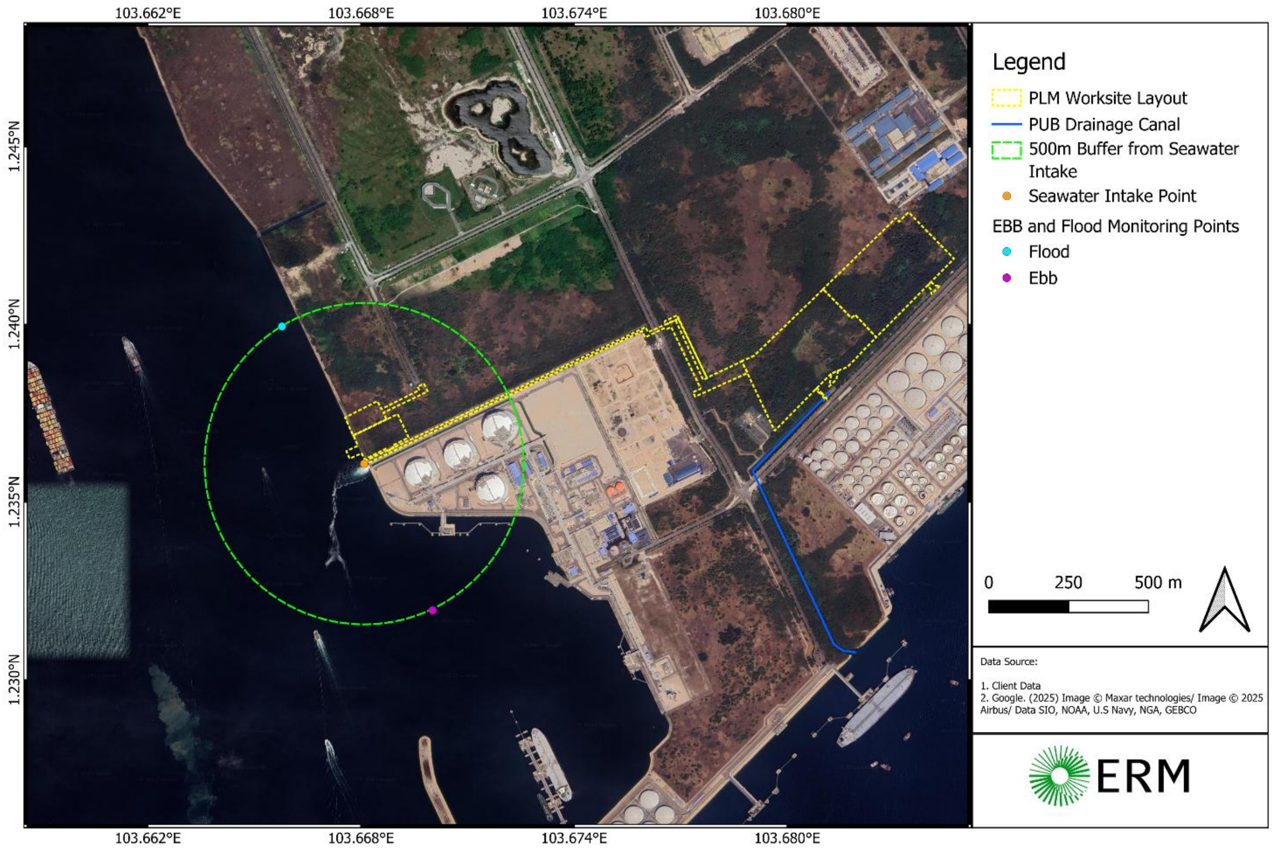
	Disturbance and/or displacement of fauna due to construction works	• Ensure proper housekeeping and train workers to avoid littering, especially food waste and food packaging around the construction worksite.
		• Sufficient fully covered waste bins will be provided within the construction site to prevent littering.
		• Ensure workers are reminded not to enter adjacent forests and grasslands, feed wildlife, cut any trees or plants.
		• For night-time construction works:
		  • Minimise light spill to remaining forests surrounding the site by ensuring that lighting is pointed away from the adjacent forests and light used for night works shall be installed lower than the hoarding height;
		  • Using lights with a high ultra-violet (UV) component shall be avoided. Preference for Light Emitting Diode (LED) and Low-Pressure Sodium lights.
		  • Use of warm lighting where possible during construction work (i.e., soft white and warm white light bulbs, preferably at <3,000 K).
			Construction EMMP, visual inspection and compliance check	Throughout construction phase	Project Site	Contractor / ECO

Marine Biodiversity	Increased sediments in the water due to construction works for intake structures	• Silt curtains to be used during the installation and removal of the cofferdam to minimise potential water quality impact from elevated turbidity / sedimentation. • All other mitigation measures for protection of surface water quality (mentioned above in this table under 'Surface water') also apply for marine water quality.	Visual inspection and compliance check	Throughout construction of intake structures.	Project Site	Contractor / ECO
Marine Water Quality	Deterioration of water quality due to construction works for intake					

TABLE 8-3: SUMMARY OF MONITORING DURING CONSTRUCTION PHASE

Environmental Aspect	Impact	Monitoring Programme/ Parameters	Monitoring Method	Frequency / Duration / Time	Location	Report	Site Responsibility
Noise	Increase of noise level to the environment and human receptors (i.e., workers)	Noise monitoring to measure the noise level at the boundary of the plant.	Measurement using Class 1 Sound Level Meters with valid calibration certificate.	One (1) post-commissioning survey.	At four (4) locations, one (1) at each side of the Project site.	Test report.	Contractor
Surface water	Deterioration of surface water due to runoff and siltation during site clearance	Total suspended solid (TSS) monitoring at all discharge points to monitor the quality of discharge.	Measurement using Total suspended solid (TSS) meter.	Continuous throughout the construction phase, an ECM audit check is to be carried out within six (6) months of earthworks or within the period of one third of the Project construction period. Readings should be recorded at interval not longer than 10 minutes.	At all final ECM discharge points (locations to be agreed with relevant agencies during the EMMP stage).	Automated measurement record.	Contractor / ECO
Marine Biodiversity Marine Water Quality	Discharge of effluent	Wastewater should be sampled and tested at accredited laboratory on three separate occasions. These three separate occasions should be chosen during periods of representative operational conditions at or close to designed capacity. Each consecutive operation should be at least one week apart to provide sufficient temporal representation.	Laboratory analysis of trade effluent, dependent on corresponding parameters to be tested.	At three representative occasions during pre-commissioning.	At discharge outlet (locations to be agreed with relevant agencies during the EMMP stage).	Laboratory analysis report	Contractor / ECO
	Increased sediments in the water due to construction works for intake structures	Turbidity measurement should be conducted at about 500 m upstream and downstream to the ebbing and flooding tides.	Onsite measurement using turbidity meter	One (1) time baseline sampling will be conducted prior to commencement of this construction activity. Monitoring should cover the entire marine construction works period, commencing before the completion of cofferdam. Monitoring should be carried out outside the cofferdam. The monitoring should be conducted once per week for both ebb and flood tides.	At about 500 m upstream and downstream to the ebbing and flooding tides (refer to Figure 8-2).	Onsite measurement record	Contractor / ECO

FIGURE 8-2: MARINE WATER QUALITY (TURBIDITY) MONITORING LOCATIONS



8.3.2 OPERATION EMMP

Table 8-4 and Table 8-5 provide a full list of the control measures/mitigation and the types of monitoring respectively to be implemented during the operational phase of the project, however, this is not necessarily an exhaustive list.

TABLE 8-4: SUMMARY OF CONTROL MEASURES AND MITIGATION DURING OPERATION PHASE

Environmental Aspect	Impact	Management Measures	Verification	Duration / Time	Location	Site Responsibility
Airborne Noise	Increased noise emissions during Project operation	Localised noise barriers will be installed as required during the construction phase near major noise sources to meet boundary noise level requirements.	On-site visual verification	Prior commissioning	At the boundary near major noise sources	Operation & Maintenance team
		Utilisation of PPE (i.e., earmuff or ear plug) by workers where the noise levels exceed 85 dB(A).		Throughout the plant lifecycle	Primarily at location with major noise source within the Plant	Operation & Maintenance team
Surface water	Discharge of stormwater collected within site	For stormwater, daily inspection of bunds will be conducted to monitor stormwater accumulation.	On-site visual verification	Throughout the plant lifecycle	Within site	Operation & Maintenance team
Waste	Toxic waste or toxic industrial waste generated from Power Plant	• Inspect scheduled waste storage areas. • Regular update of the inventory of scheduled wastes. • The O&M team will inform the Logistics & Procurement (L&P) department of any waste chemicals for disposal and provide the relevant Safety Data Sheets (SDS). L&P will engage an NEA-authorised waste disposal vendor and submit the required declaration to NEA. The authorised vendor will then collect and dispose of the waste chemicals safely and in compliance with regulations. • Maintain an inventory of all waste disposal.	Visual inspection and compliance check, Record of inventory and waste record	Throughout the plant lifecycle	Within project site	Operation & Maintenance team
Vector control	Increase in the incidence of vectors and related diseases	• Regular checks, at least once a week, shall be conducted within the Plant for mosquito breeding. • It is not mandatory to conduct fogging within the Plant. Fogging treatment will only be conducted when there is a mosquito nuisance problem or disease outbreak in the vicinity of the Plant.	Visual inspection (presence / absence of vectors)	Throughout the plant lifecycle	Within project site	Operation & Maintenance team
Terrestrial Biodiversity	Disturbance and/or displacement of fauna due to operational lighting.	For night-time operation works: • Minimise light spill to remaining forests surrounding the site by ensuring that lighting is pointed away from the adjacent forests; • Use lights with a high ultra-violet (UV) component shall be avoided. Preference for Light Emitting Diode (LED) and Low-Pressure Sodium lights; and • Use of warm lighting where possible (i.e., soft white and warm white light bulbs, preferably at < 3,000 K).	On-site visual verification	Throughout the plant lifecycle	Within project site	Operation & Maintenance team
Marine Biodiversity	Impact of changes in water quality to marine sensitive receptors (e.g. coral reefs, macrobenthos, fish, etc.)	Measures for controlling the discharge of trade effluent from Power Plant: • Wastewater effluent generated during demineralised water plant regeneration will be treated onsite for pH correction and shall be discharged to the PUB drain. The discharge will be monitored for parameters such as pH and temperature; • Waste effluent water generated from the GT Compressor wash shall be collected and treated offline by a third party; and	Daily visual inspection and compliance checks	Throughout the plant lifecycle	Within project site	Operation & Maintenance team
Marine Water Quality	Degradation of marine water quality due to process cooling water discharge					

Environmental Aspect	Impact	Management Measures	Verification	Duration / Time	Location	Site Responsibility
		• Boiler blowdown will be treated and recycled for using within the Plant.				

TABLE 8-5: SUMMARY OF MONITORING DURING OPERATION PHASE

Environmental Aspect	Impact	Monitoring Programme/ Parameters	Monitoring Method	Frequency / Duration / Time	Location	Report	Site Responsibility
Air	Emissions during Normal and Emergency Operations	To monitor the HRSG stack emissions and include stack analysis for SOx, NO_X, CO_2, O_2, CO and opacity.	Continuous Emissions Monitoring System (CEMS)	Continuous	HRSG stacks	Air emission monitoring record / log	Operation & Maintenance team
Noise	Noise monitoring at boundary	$L_{Aeq,\ 5min}$ in dBA for 24-hour continuous.	Measurement using Class 1 Sound Level Meters with valid calibration certificate.	Upon commissioning	Measurement at boundary	Noise monitoring report	Operation & Maintenance team
Surface water	Discharge of stormwater collected within site	Prior to discharge to stormwater drain, stormwater is tested against key parameters including pH, chemical oxygen demand (COD), and visual checks for oil and grease.	Built-in monitoring system	Prior to discharge	Stormwater holding or sampling point before discharge to public drain	Surface water monitoring record / log	Operation & Maintenance team
	Discharge of trade effluent and oily wastes from Power Plant	Prior to discharge, the effluent should undergo routine internal laboratory analysis (pH, temperature and conductivity test). In cases where sampling results indicate non-compliance with regulatory limits, the effluent should be diverted back to the wastewater holding pond for further treatment.	Built-in monitoring system	Prior to discharge	Wastewater holding point before discharge to public drain at the discharge point	Wastewater monitoring record / log	Operation & Maintenance team
Marine Biodiversity Marine Water Quality	Cooling water discharge from Power Plant	Measures for controlling the potential degradation of marine water quality due to thermal and chlorine plume discharge: • Real-time continuous online monitoring of water temperature and chlorine concentration at the outfall location shall be conducted throughout the Project's lifecycle to assess compliance to Singapore's trade effluent guidelines; • Adjust CCGT output in instances where monitored temperature may exceed NEA's limit of 45˚C; and • Daily visual observation for algal bloom/ eutrophication/ fish-kill will be conducted at the Project discharge point. Sampling of algal will also be carried out when there is presence of algal bloom, eutrophication or fish-kill at the outfall. In addition, the temperature of the discharge water will be lowered during algal bloom, eutrophication or fish-kill event.	Built-in monitoring system	Continuous	At / before discharge point	Marine water quality emission monitoring record / log	Operation & Maintenance team

9. CONCLUSION

The Environmental Impact Assessment (EIA) for the Project has been conducted by ERM on behalf of PLM to evaluate potential environmental impacts associated with the Project's construction and operational phases. This assessment was carried out in accordance with the scope agreed upon with the relevant Government Agencies (e.g. URA, MND) and Technical Agencies (e.g. NParks, NEA, SFA and MPA) during the scoping phase, following consultation and feedback. The agreed scope included the following key areas of study:

- Marine Biodiversity (Operation Phase); and
- Marine Water Quality (Operation Phase).

The study identified potential impacts primarily related to thermal and chlorine plume discharge during operation. Pre-mitigation assessments indicated that most impacts ranged from Negligible to Minor.

Table 9-1 presents a summary of the identified potential operational impacts. No mitigation measures are required as the significance of impacts for all impacts are Negligible or Minor per EIA impact assessment methodology mentioned in Section 4.6.

TABLE 9-1: IMPACT ASSESSMENT SUMMARY FOR OPERATION PHASE

Sensitive Receptor	Potential Impact	Significance of Impact
Marine water quality	Chlorine plume discharge from the outfall	Negligible
	Thermal plume discharge from the outfall	Minor
Marine habitat (Corals)	Chlorine plume discharge from the outfall	Negligible
	Thermal plume discharge from the outfall	Minor
Planktonic community	Thermal and chlorine plume discharge from the outfall	Negligible
Macrobenthos community	Chlorine plume discharge from the outfall	Negligible
Macrobenthos community	Thermal plume discharge from the outfall	Minor
Marine habitat (Seagrass)	Thermal and chlorine plume discharge from the outfall	Negligible
Marine species	Thermal and chlorine plume discharge from the outfall	Negligible

A comprehensive Environmental Monitoring and Management Plan (EMMP) has been developed for both the construction and operational phases to monitor, and manage the environmental impacts identified in this assessment. The EMMP outlines specific measures to minimise impacts to the extent practicable and ensure that management and monitoring actions are implemented effectively throughout the entire Project lifecycle where applicable.

PLM and its appointed contractors have extensive experience in managing the development, construction, and operation of projects within Singapore and are fully familiar with all local standards, regulations, and requirements. This experience, combined with the implementation of the EMMP, provides assurance that environmental risks will be managed responsibly and transparently.

In summary, the EIA confirms that all identified environmental impacts have been comprehensively assessed and addressed through appropriate management and monitoring measures. No significant impacts are anticipated, and the Project will proceed with robust environmental safeguards and management measures in place.

10. REFERENCES

Alex Thiam Koon, Yee & Chong, Kwek Yan & Neo, Louise & Tan, Hugh. (2016). Updating the classification system for the secondary forests of Singapore. 2016. 11-21.

Ang et al (2010). The status and distribution of Finalysonia obovate wall (Apocynaceae). Nature in Singapore. 3: 7-11. Retrieved from https://lkcnhm.nus.edu.sg/wpcontent/uploads/sites/11/app/uploads/2017/06/2010nis7-11.pdf on 8 Oct 2025

ASEAN. (2008). ASEAN Marine Water Quality Criteria.

Baird AH, Gilmour JP, Kamiki TM, Nonaka M, Pratchett MS, Yamamoto HH, Yamasaki H (2006) Temperature tolerance of symbiotic and non-symbiotic coral larvae. Proc 10th Int Coral Reef Symp, Okinawa, p 38−42

Bauman AG, Guest JR, Dunshea G, Low J, Todd PA, Steinberg PD. (2015). Coral settlement on a highly disturbed equatorial reef system. PLoS One. 20;10(5):e0127874. doi: 10.1371/journal.pone.0127874.

Benjamin P. Y-H. Lee & Michelle Ooi (2020). Indo-Pacific humpback dolphins near Jurong Island. Singapore Biodiversity Records 2020: 84-85 ISSN 2345-7597

Bhatt, D., Sethi, V., Kumar, A., & Singh, A. (2014). Some notes on the breeding behaviour Of the Oriental Magpie Robin (Copsychus Saularis) from Uttarakhand, India. Journal of Sustainability Science and Management, 9, 112–119. https://jssm.umt.edu.my/wp-content/uploads/sites/51/2015/02/10w.pdf

Birds of Singapore (2016). Oriental magpie-robin. Retrieved from https://singaporebirds.com/species/oriental-magpie-robin/

Briggs M. A., Albertson L. K., Lujan D. R., Tronstad L. M., Glassic H. C., Guy C. S., et al. (2021). Carcass deposition to suppress invasive lake trout causes differential mortality of two common benthic invertebrates in Yellowstone Lake. Fundam. Appl. Limnol. 194, 285–295. doi: 10.1127/fal/2020/1352

Brook A J, Baker A L (1972). Chlorination at power plant: impact on phytoplankton productivity[J]. Science, 178(4042): 1414-1415.

Brown, Lex. (2001). Overview of research on the effects of noise on wildlife. Retrieved from https://www.researchgate.net/publication/29452622_Overview_of_Research_on_the_Effects_of_Noise_on_Wildlife

Browne NK, Tay JKL, Low J, Larson O, Todd PA. (2015). Fluctuations in coral health of four common inshore reef corals in response to seasonal and anthropogenic changes in water quality. Mar Environ Res 105:39–52

Budiarsa A. A., de Iongh H. H., Kustiawan W., van Bodegom P. M. (2021). Dugong foraging behavior on tropical intertidal seagrass meadows: the influence of climatic drivers and anthropogenic disturbance. Hydrobiologia 848, 4153–4166. doi: 10.1007/s10750-021-04583-0

C Mckenzie, B.J Godley, R.W Furness, D.E Wells (1999). Concentrations and patterns of organochlorine contaminants in marine turtles from Mediterranean and Atlantic waters.

Marine Environmental Research, 47 (2), pp 117-135, ISSN 0141-1136, https://doi.org/10.1016/S0141-1136(98)00109-3.

Capuzzo, J.M (1980). Impact of power-plant discharges on marine zooplankton: A review of thermal, mechanical and biocidal effects. Helgolander Meeresunters 33, 422–432. https://doi.org/10.1007/BF02414767

Cham J., Tun K., and Jaafar, Z. (2025). Distribution of marine turtles in Singapore: humanwildlife coexistence in a highly urbanized seascape. Bull Mar Sci. 101(1):157–177. https://doi.org/10.5343/bms.2023.0117

Chang Y.Y (1989). An on-site assessment of chlorination impacts on benthic macroinvertebrates. University of Massachusetts. Retrieved from https://scholarworks.umass.edu/server/api/core/bitstreams/930dd69b-c4eb-4a2b-9ba1-c2ff619c47df/content

Changeable hawk-eagle. (2016). Birds of Singapore. https://singaporebirds.com/species/changeable-hawk-eagle/

Chatterjea, K. (2014). Edge effects and exterior influences on Bukit Timah Forest, Singapore. European Journal of Geography, 5(1), 8-31.

Chim CK, Lee Y-L, Tong S, Tay T & Ong R (2015) Blacktip reef sharks caught in trammel nets at Lazarus Island. Singapore Biodiversity Records, 2015: 158–159

Chiok Pei Wen (2019). Analysis and comparison of coastal beaches for nest site selection of Hawksbill Turtles (Eretmochelys Imbricata) in Singapore. ScholarBank@NUS Repository.

Chong, K. Y., Tan, H. T. W., & Corlett, R. T. (2009). A checklist of the total vascular plant flora of Singapore: Native, naturalised and cultivated species. Raffles Museum of Biodiversity Research.

Davison GWH, Gan JWM, Huang D, Hwang WS, Lum SKY & Yeo DCJ (eds.) (2024) The Singapore Red Data Book: Red lists of Singapore biodiversity. 3rd ed. National Parks Board, Singapore.

Ee, D. (2014). Dolphins frolicking in Singapore's backyard. Retrieved from The Straits Times: https://www.straitstimes.com/singapore/environment/dolphins-frolicking-in-singapores-backyard

Farshchi M., Nasrolahi A., Shokri M. R. (2020). Variability in benthic invertebrate community structure near warm water effluents of a power plant in the southern Caspian Sea. Regional Stud. Mar. Sci. 40, 101507. doi: 10.1016/j.rsma.2020.101507

Favilla AB, Horning M, Costa DP. (2021). Advances in thermal physiology of diving marine mammals: The dual role of peripheral perfusion. Temperature (Austin), 9(1):46-66. doi: 10.1080/23328940.2021.1988817. PMID: 35655662; PMCID: PMC9154795.

Fernando ES (1998). Forest formations and flora of the Philippines: Handout in FBS 21. UPLB, Philippines

Fisher, Daniel & Burton, Dennis & Yonkos, Lance & Turley, Steven & Ziegler, Gregory. (1999). The relative acute toxicity of continuous and intermittent exposures of chlorine and bromine to aquatic organisms in the presence and absence of ammonia. Water Research. 33. 760-768. 10.1016/S0043-1354(98)00278-4.

Gaw LYF, Richards DR (2021) Development of spontaneous vegetation on reclaimed land in Singapore measured by NDVI. PLOS ONE 16(1): e0245220. https://doi.org/10.1371/journal.pone.0245220

Goh, B., Tan, G. & Tan, L.T. (2011). Diversity, distribution and biological activity of soft corals (Octocorallia, Alcyonacea) in Singapore. Journal of Coastal Development. 12, (2),89-98. ISSN 1410-5217.

Golden-bellied Gerygone. (2016). Birds of Singapore. https://singaporebirds.com/species/golden-bellied-gerygone/

Goreau TJF, Hayes RL (2021). Global warming triggers coral reef bleaching tipping point: This article belongs to Ambio's 50th Anniversary Collection. Theme: Climate change impacts. Ambio. \Jun;50(6):1137-1140. doi:. 10.1007/s13280-021-01512-2. PMID: 33650066; PMCID: PMC8068737.

Goudarzi F, Doxa A, Hemami MR, Mazaris AD (2024). Thermal vulnerability of sea turtle foraging grounds around the globe. Commun Biol. Mar 21;7(1):347. doi: 10.1038/s42003-024-06013-y. PMID: 38514821; PMCID: PMC10958041.

Guest, J.R., Baird, A.H., Goh, B.P.L and Chou L.M. (2005). Sexual reproduction in equatorial reef corals. Invertebrate Reproduction and Development, 48(1–3), 207–218

Guest J.R., Tun K., Low J., Verge´s A, Marzinelli E.M., Campbell A.H., Bauman A.G., Feary D.A., Chou L.M., Steinberg P.D. (2016). 27 years of benthic and coral community dynamics on turbid, highly urbanised reefs off Singapore. Sci Rep 6:36260

Hamilton H. J., Gosselin L. A. (2020). Ontogenetic shifts and interspecies variation in tolerance to desiccation and heat at the early benthic phase of six intertidal invertebrates. Mar. Ecol. Prog. Ser. 634, 15–28. doi: 10.3354/meps13189

Harrison P. J., Davis C. O. (1979). The use of outdoor phytoplankton continuous cultures to analyse factors influencing species selection. Journal of Experimental Marine Biology and Ecology, 41(1), 9–23.

Heery EC, Hoeksema BW, Browne NK, Reimer JD, Ang PO, Huang D, Friess DA, Chou LM, Loke LHL, Saksena-Taylor P, Alsagoff N, Yeemin T, Sutthacheep M, Vo ST, Bos AR, Gumanao GS, Syed Hussein MA, Waheed Z, Lane DJW, Johan O, Kunzmann A, Jompa J, Suharsono TD, Bauman AG, Todd PA (2018). Urban coral reefs: degradation and resilience of hard coral assemblages in coastal cities of East and Southeast Asia. Mar Pollut Bull 135:654–681

Huang, D., Tun, K.P.P., Chou, L.M. & Todd, P.A. (2009). An inventory of zooxanthellate scleractinian corals in Singapore, including 33 new records. Raffles Bulletin of Zoology Supplement 22: 69–80

Hyvärinen H. S., Sjönberg T., Marjomäki T. J., Taskinen J. (2022). Effect of low dissolved oxygen on the viability of juvenile Margaritifera margaritifera: Hypoxia tolerance ex situ. Aquat. Conserv.: Mar. Freshw. Ecosyst. 32, 1393–1400. doi: 10.1002/aqc.3859

Ijsseldij, L., Camphuysen, K., Keijl, G., Troost, G, Aarts, G. (2021). Predicting Harbor Porpoise strandings based on near-shore sightings indicates elevated temporal mortality rates. Front. Mar. Sci, 8. https://doi.org/10.3389/fmars.2021.668038

IFC (2007). Stakeholder engagement: a good practice handbook for companies doing business in emerging markets. Retrieved from https://www.ifc.org/wps/wcm/connect/a6ed6140-b5ce-4e37-9f22-d9af5ee122c7/StakeholderEngagement1_Handbook_May15_2007.pdf?MOD=AJPERES&CVID=jqeukAV

Ip, Y.C.A., Chang, J.J.M., Lim, K.K.P. et al. (2021). Seeing through sedimented waters: environmental DNA reduces the phantom diversity of sharks and rays in turbid marine habitats. BMC Ecol Evo 21, 166. https://doi.org/10.1186/s12862-021-01895-6

IUCN (n.d). The IUCN Red List of Threatened Species, https://www.iucnredlist.org/es

Jaafar, Z., Huang, D., Tanzil, J. T., Ow, Y. X. and Yap, N. (2018). The Singapore Blue Plan. Singapore: Singapore Institute of Biology. Retrieved from https://sibiol.org.sg/wp-content/uploads/2020/10/The_Singapore_Blue_Plan_2018.pdf

Jefferson TA, Smith BD. (2016). Re-assessment of the Conservation Status of the Indo-Pacific Humpback Dolphin (Sousa chinensis) Using the IUCN Red List Criteria. Adv Mar Biol. 2016;73:1-26. doi: 10.1016/bs.amb.2015.04.002. Epub 2015 Sep 26. PMID: 26790886.

Keller, J. M., McClellan-Green, P. D., Kucklick, J. R., Keil, D. E., & Peden-Adams, M. M. (2006). Effects of organochlorine contaminants on loggerhead sea turtle immunity: comparison of a correlative field study and in vitro exposure experiments. Environmental health perspectives, 114(1), 70–76. https://doi.org/10.1289/ehp.8143

Kimmerer W., Weaver M. J. (2013). Vulnerability of estuaries to climate change. (Oxford, UK: CRC Press), 277–289. doi: 10.1016/B978-0-12-384703-4.00438-X

Kwon, Soon Hyun, Lee, Jae Hac and Yu, Ok Hwan. (2017). Environmental Effects on the Benthic Polychaete Communities Around the Power Plant Areas in the East Sea of Korea. The Sea: Jorunal of the Korean Society of Oceanography, 22(1), 18–30. https://doi.org/10.7850/JKSO.2017.22.1.018

Larkin, P. (1996). Effects of Military Noise on Wildlife: A literature review. USACERL Technical Report 96/21. Champaign, Illinois.

Li X., Shou Y.P., Li H. (2023). Marine ecological impact analysis of residual chlorine emission from LNG transfer station. E3S Web of Conferences 393, 02009

Lindsay, S., et al. (2022). Flora of Singapore: Checklist and bibliography. Gardens' Bulletin Singapore, 74(Suppl. 1), 3-860.

Loke M.C., Kok B.T, Ywee C.T., Phang V. (2012). Coral reefs in Singapore: past, present and future. The Asian Conference on Sustainability, Energy and the Environment. Retrieved from https://coralreef.nus.edu.sg/publications/Chou2012IAF.pdf

Low, Jeffrey & Jaafar, Zeehan & Tanzil, Jani. (2009). Some noteworthy fishes observed in the Singapore Straits. Nature in Singapore. 2. 77-82.

Low, Jeffrey. (2013). More noteworthy fishes observed in the Singapore Straits. Nature in Singapore. 6. 31-37.

Lu, Lin. (2005). The relationship between Soft-Bottom macrobenthic community and environmental variables in Singaporean waters. Marine pollution bulletin. 51. 1034-40. 10.1016/j.marpolbul.2005.02.013.

Manzello, D. (2023). Rising ocean temps raise new concerns for coral reefs. Retrieved from https://www.nesdis.noaa.gov/news/rising-ocean-temps-raise-newconcerns-coral-reefs

Marsh H, Penrose H, Eros C & Hugues J (2002) Dugong status report and action plans for countries and territories. UNEP, Nairobi Kenya, 162 pp.

Marta Vannoni, Alastair Grant, Dave Sheahan, Véronique Créach. (2024). Evaluating the impact of residual low chlorine concentration on phytoplankton communities by flow cytometry, Chemosphere, Volume 367, 143634, ISSN 0045-6535, https://doi.org/10.1016/j.chemosphere.2024.143634.

McKenzie, Len & Yaakub, Siti & Tan, Ria & Seymour, Jamie & Yoshida, Rudi. (2016). Seagrass habitats of Singapore: Environmental drivers and key processes. The Raffles Bulletin of Zoology. 2016. 60-77.

Middleton DJ & Rodda M (2019). Flora of Singapore: Volume 13 — Gentianales: Apocynaceae. Retrieved from https://www.nparks.gov.sg/-/media/sbg/flora-of-singapore/volume-13-gentianales/13,-d-,5_apocynaceae_lr1.pdf (accessed September 08, 2025)

Ministry of the Environment and Water Resources. (2015). Sustainable Singapore Blueprint 2015.

Ministry of Trade and Industry (2022). National Hydrogen Strategy. Retrieved from: https://www.mti.gov.sg/energy-and-carbon/energy-supply/low-carbon-alternatives/hydrogen/

National Parks Board. (2023). Coastal and Marine Habitat Map of Singapore 2018 (2024) [Dataset]. data.gov.sg. Retrieved November 4, 2025 from https://data.gov.sg/datasets/d_18bcfe0a1b8c77f9b4493cef72ffd717/view

NEA (2022). Code of Practice for Environmental Control Officers for Specified Construction Sites. Retrieved from https://www.nea.gov.sg/docs/default-source/our-services/pest-control/environmental-control-officer/code-of-practice-for-eco-(scs)---5th-edition-finalad363da3b1064f94bdcf2f62f9429adf.pdf

Negri AP, Marshall PA, Heyward AJ (2007) Differing effects of thermal stress on coral fertilization and early embryogenesis in four Indo Pacific species. Coral Reefs 26: 759−763

Nesa B, Baird AH, Harii S, Yakovleva I, Hidaka M (2012) Algal symbionts increase DNA damage in coral planulae exposed to sunlight. Zool Stud 51: 12−17

Ng, C. (2018). Pod of Indo-Pacific humpbacked dolphins spotted off Pulau Semakau. Retrieved from https://www.straitstimes.com/singapore/pod-of-indo-pacific-humpbacked-dolphins-spotted-off-pulau-semakau

Ng Sirius Z. H., Ow Yan Xiang, Jaafar Zeehan (2022). Dugongs (Dugong dugon) along hyper-urbanized coastlines. Frontiers in Marine Science, 9. DOI=10.3389/fmars.2022.947700

NParks (2012). Recruitment and Succession of Benthic Assemblages on Artificial Structures.

NParks. (n.d.). Eretmochelys imbricata (Linnaeus, 1766). Retrieved from Flora & Fauna Web: https://www.nparks.gov.sg/florafaunaweb/fauna/2/6/262

Nunes, M.H., Vaz, M.C., Camargo, J.L.C. et al (2023). Edge effects on tree architecture exacerbate biomass loss of fragmented Amazonian forests. Nat Commun 14, 8129. https://doi.org/10.1038/s41467-023-44004-5

O'Connor et al (2007). Temperature control of larval dispersal and the implications for marine ecology, evolution, and conservation. Proc. Natl Acad. Sci. USA 104, 1266-1271

Ong T (2020). 3 shark pups found dead on St. John's Island. Mothership, 21 July 2020. Retrieved from https://mothership.sg/2020/07/ shark-pup-st-john-island

Poornima, E.H. & Rajadurai, M. & Toleti, Subba Rao & Bhaskarapillai, Anupkumar & Rajamohan, Raja & Narasimhan, S.V. & Rao, V.N.R. & Venugopalan, Vayalam. (2005). Impact of thermal discharge from a tropical coastal power plant on phytoplankton. Journal of Thermal Biology. 30. 307-316. 10.1016/j.jtherbio.2005.01.004.

Qing (2024). Two lots for new seafood farms in waters off Pulau Bukom open for tender. The Straits Times. Available at https://www.straitstimes.com/singapore/2-lots-for-new-seafood-farms-in-waters-off-pulau-bukom-open-for-tender (last retrieved at 17 Nov 2025)

Qing and behum (2024, November 21) Barramundi Group stops farming sea bass in S'pore due to deadly virus outbreakhttps://www.straitstimes.com/singapore/barramundi-group-stops-farming-sea-bass-in-s-pore-due-to-deadly-virus-outbreak

R. F. Addison. (1989). Organochlorines and Marine Mammal Reproduction. Canadian Journal of Fisheries and Aquatic Sciences. 46(2): 360-368. https://doi.org/10.1139/f89-047

Ralph PJ, Durako MJ, Enriquez S, Collier CJ & Doblin MA (2007) Impact of light limitation on seagrasses. Journal of Experimental Marine Biology and Ecology, 350(1–2): 176–193.

Raquel F. Flynn et al. (2023). Nanoplankton: The dominant vector for carbon export across the Atlantic Southern Ocean in spring.Sci. Adv.9,eadi3059.DOI:10.1126/sciadv.adi3059

Romberg G.P., Spigarelli S.A., Prepejchal, W. and Thommes M.M. (1974). Migratory behaviour of fish tagged at nuclear power plant discharge into lake Michigan. 17th Conference on Great Lakes Research, Hamilton, Ontario.

Rudiyanti, S. (2012). The Growth of Skeletonema costatum on Various Salinity Level's Media. Saintek Perikanan: Indonesian Journal of Fisheries Science and Technology, 6(2), 70-77. https://doi.org/10.14710/ijfst.6.2.70-77

Saraswat R., Nigam R., Pachkhande S. (2011). Difference in optimum temperature for growth and reproduction in benthic foraminifer Rosalina globularis: Implications for paleoclimatic studies. J. Exp. Mar. Biol. Ecol. 405, 105–110. doi: 10.1016/j.jembe.2011.05.026

SFA (2024). SFA's tender briefing. Retrieved from https://www.sfa.gov.sg/docs/default-source/food-farming/presentation-slide-land-based-farm-workshop/bukom-tender-briefing-slides.pdf (last retrieved at 17 Nov 2025)

Simon Kumar Das, Moumita De, Mazlan Abd. Ghaffar, Noorashikin Md Noor, Sabuj Kanti Mazumder, Yosni Bakar (2021). Effects of temperature on the oxygen consumption rate and gill fine structure of hybrid grouper, Epinephelus fuscoguttatus and E. Lanceolatus. Journal of King Saud University - Science, 33 (2), ISSN 1018-3647, https://doi.org/10.1016/j.jksus.2021.101358.

Singapore Government. (2021). Singapore Green Plan 2030. https://www.greenplan.gov.sg

Suthers I.M and Rissik D. (2009). Plankton. A guide to their ecology and monitoring for water quality. CSIRO Publishing. Retrieved from https://www.uv.es/hegigui/ebooksclub.org__Plankton__A_Guide_to_their_Ecology_and_Monitoring_for_Water_Quality.pdf

Svobodová Z., Llyod. R., Máchová, J. and Vykusová B. (1992). Water quality and fish health EIFAC Technical Paper. No. 54. Rome, FAO. Pp 59.

Tan (2024). SFA to improve fish farming infrastructure in southern waters after Barramundi Group exits https://www.straitstimes.com/singapore/sfa-to-improve-fish-farming-infrastructure-in-southern-waters-after-barramundi-group-exits

Tan HTW, Chou LM, Yeo DCJ & Ng PKL (2010) The Natural Heritage of Singapore. Third Edition. Pearson Prentice Hall, Singapore, 9 + 323 pp.

Tan Y. K. (2015). Green turtle carcass showing sign of boat strike at Selat Pndan. Singapore Biodiversity Records, 212-213. Retrieved from https://lkcnhm.nus.edu.sg/wp-content/uploads/sites/11/app/uploads/2017/04/sbr2015-212-213.pdf

Tan, K. (n.d.). The status and distribution of Changeable Hawk-eagle (*Nisaetus Cirrhatus*) in Singapore. https://singaporebirdgroup.wordpress.com/wp-content/uploads/2015/06/the-status-and-distribution-of-changeable-hawk-eagle-2.pdf

Thompson, R. C., T. P. Crowe & S. J. Hawkins (2002). Rocky intertidal communities: past environmental changes, present status and predictions for the next 25 years. Environmental Conservation, 29: 168–191.

Thu-Hương Huỳnh, Zsófia Horváth, Károly Pálffy, Vivien Kardos, Beáta Szabó, Péter Dobosy, Csaba F. Vad (2024). Heatwave-induced functional shifts in zooplankton communities result in weaker top-down control on phytoplankton. 14 (8), https://doi.org/10.1002/ece3.70096

Tilen Genov, Paul D. Jepson, Jonathan L. Barbe, Ana Hace, Stefania Gaspari, Tina Centrih, Jan Lesjak, Polona Kotnjek (2018). Linking organochlorine contaminants with demographic parameters in free-ranging common bottlenose dolphins from the northern Adriatic Sea. Science of the Total Environment, 657, 200-212.

Toming, K. and Jaanus, A. (2007). Selecting potential summer phytoplankton eutrophication indicator species for the northern Baltic Sea. Proc. Estonian Acad. Sci. Biol. Ecol. 56, 4, 297ñ311

Trombetta T, Mostajir B, Courboulès J, Protopapa M, Mas S, Aberle N, Vidussi F (2024). Warming and trophic structure tightly control phytoplankton bloom amplitude, composition and succession. PLoS One.19(10):e0308505. doi: 10.1371/journal.pone.0308505. PMID: 39365779; PMCID: PMC11451980.

United Nations. (1993). Convention on Biological Diversity.

United States Environmental Protection Agency. (1986). Quality Criteria for Water.

V. Smetacek, P. Assmy, J. Henjes. (2004). The role of grazing in structuring Southern Ocean pelagic ecosystems and biogeochemical cycles. Antarct. Sci. 16, 541–558.

Voigt, CC, C Azam, J. Dekker, J. Ferguson, M. Fritze, S. Gazaryan, F. Hölker, G. Jones, N. Leader, D. Lewanzik, H.J.G.A. Limpens, F. Mathews, J. Rydell, H. Schofield, K. Spoelstra, M. Zagmajster (2018): Guidelines for consideration of bats in lighting projects. EUROBATS Publication Series No. 8. UNEP/EUROBATS Secretariat, Bonn, Germany, 62 pp.

Wang LK & Lim KKP (2011) Requiem sharks. In: Ng PKL, Corlett R & Tan HTW (eds.) Singapore Biodiversity: An Encyclopedia of the Natural Environment and Sustainable Development. National University of Singapore & Editions Didier Millet, Singapore, p. 430.

Wee, Y. C. (2006). Forty years of birding and ornithological research in Singapore. Birding Asia, 5, 12-15.

Wong JSY, Chan YKS, Ng CSL, Tun KPP, Darling ES, Huang D (2018) Comparing patterns of taxonomic, functional and phylogenetic diversity in reef coral communities. Coral Reefs 37:737–750

Yaakub SM, McKenzie LJ, Erftemeijer PLA, Bouma T & Todd PA (2014) Courage under fire: Seagrass persistence adjacent to a highly urbanised city–state. Marine Pollution Bulletin, 83(2): 417–424

YAP, C. A. M., & SODHI, N. S. (2004). Southeast Asian invasive birds: ecology, impact and management. Ornithological Science , 3, 57–67.

Yeo R (2014) Blacktip reef sharks at Semakau Landfill. Singapore Biodiversity Records, 2014: 33–34.

Yeo, R. (2010). Quick look at some mangrove plants of ubin and pasir ris. The Tide Chaser. http://tidechaser.blogspot.com/2010/05/quick-look-at-some-mangrove-plants-of.html

Yeo, R. (2014). The Climber Gymnanthera oblonga at East Coast Park, Singapore Biodiversity Records 2014: 1. Retrieved from https://lkcnhm.nus.edu.sg/wp-content/uploads/sites/11/app/uploads/2017/04/sbr2014-001.pdf

Zheng Y., Giodarno, M and Gao K. (2015). Photochemical responses of the diatom Skeletonema costatum grown under elevated CO2 concentrations to short-term changes in pH. Aquat Biol, 23: 109-118.

APPENDIX A EMBEDDED CONTROLS

SUMMARY OF KEY EMBEDDED CONTROLS

Legislation/ Standard/ Guideline/ Planned Design & Construction Approach	Relevance to the Environmental Aspect for this EIA
Environmental Aspects Scoped in this EIA	
MARINE WATER QUALITY *(SECTION 6)*	
Environmental Protection and Management (Trade Effluent) regulations, 2008	• Runoff will be treated to be compliant with allowable discharge limits prior to discharge. • Water quality of the cooling water will adhere to NEA's trade effluent limits at the point of discharge. • Runoff discharged to a watercourse will be regularly monitored and recorded.
ASEAN Marine Water Quality Guidelines, 2008	• The levels of dissolved oxygen for ecological receptors in the sea need to be above 4mg/L to support aquatic life. • Temperature increase of surrounding seawater should not be more than 2°C above the maximum ambient temperature.
US Environmental Protection Agency Quality Criteria for Water, 1986	• Levels of chlorine should not exceed a one-hour average limit of 13 µg/L to protect aquatic life from short and long-term exposure to chlorine and chlorine-produced oxidants (CPOs).
TERRESTRAL & MARINE BIODIVERSITY (*SECTION 7 & 8*)	
Parks and Trees Act (2021) and subsidiary legislation	• The Act provides for the planting, maintenance and conservation of trees and plants within national parks, nature reserves, tree conservation areas, heritage road green buffers and other specified areas. • The Project should strictly control any: – Activities that will damage flora, the land or cause injury to fauna within the Nature Reserves; – Cutting or damaging trees with a girth of more than 1 m within a Tree Conservation Area; and – Cutting or damaging trees or plants within the heritage road green buffers. • The Project should also: – Provide temporary sanitary facilities and waste management areas to avoid fouling of surface water resources; and – Seek approval from NParks before carrying out restricted activities. • Trees with girths exceeding 1 m growing on vacant land will only be cut down with approval from NParks.
Wildlife Act, 1965 (Revised edition 2020)	• The Director-General may direct a person to implement any wildlife-related measures necessary to safeguard wildlife or health of ecosystem. • Workers to be trained to avoid undertaking prohibited activities such as: – The killing, taking or keeping of any wildlife; – Taking and destroying eggs of wild birds; and – Placing contraptions that are likely to cause injury to humans.
Public Utilities (Reservoir and Catchment Areas and Waterway) Regulations 2018	The Project should: • Undertake measures to manage impacts to surface water quality; and • Ensure its activities will not lead to the damage of flora or fauna.
National Biodiversity Strategy and Action Plan (NBSAP), 2009	• Fulfilment of commitments to United Nations Convention on Biological Diversity (UNCBD); and • Sets out goals to conserve and enhance Singapore's biodiversity.

Nature Conservation Master Plan (NCMP), 2015	• The NCMP aims to systematically consolidate, coordinate, strengthen and intensify the biodiversity conservation efforts outlined in the NBSAP; and • Sets out biodiversity conservation plans for the following five years to achieve the Singapore's vision of a City in a Garden.
Singapore Red Data Book (3rd edition[1]), 2024	• List of species in Singapore which need improvement on their conservation status.
National Parks Board Guidelines on Greenery Provision and Tree Conservation for Developments, 2018	• Set of guidelines to describe the statutory requirements on greenery provision, tree planting and conservation for development projects in Singapore, including protection of trees during construction.
Biodiversity Impact Assessment (BIA) Guidelines, 2024	• Provides reference for developers and industry professionals to understand the common requirements for the biodiversity component of an EIA.
United Nations Convention on Biological Diversity, 1993	• Promotes conservation of biodiversity.
International Union for Conservation of Nature (IUCN) Red List of Threatened Species	• Provides global extinction risk status of animals, fungus, and plant species.
Singapore Blue Plan, 2018	• Promotes conducting an EIA for impacts to marine biodiversity and ecosystem connectivity.
Workplace Safety and Health (Construction) Regulations, 2007	• Construction hoarding must be constructed to prevent posing a danger to the public and preventing trespasses.
Good practice and planned design to be implemented during construction	**For Developer/ Owner and Contractor staff:** • Environmental Manager to monitor, supervise and evaluate works that may impact on biodiversity (as identified in this EIA); and • Tool-box talks and training to be provided to all site personnel prior to commencement of construction to communicate the Project's commitments regarding biodiversity and how it shall be managed, including: – Ecologically sensitive areas; – Proper protocols and reporting procedures to be adopted when wildlife is encountered; – Personnel need to be cautious when operating machinery to avoid injury/ mortality to fauna; – Need to keep all workplaces safe for wildlife (e.g. when not being actively worked on), storage and use of hazardous materials, and food/ waste management; – All workers will be prohibited from feeding animals; and – Refresher training will be provided every 2 years during the construction phase for all new and old personnel. **For tree/ vegetation clearance:** • Regulating contractor movements and activities to areas only within the construction and operational footprint, and prohibiting access to other areas; • Obtain permit required to control and limit the clearing of vegetation to the minimum necessary, and staging vegetation clearing, where practicable, e.g. seek NParks approval for felling of trees with girth >1m; and

[1] Singapore Red Data Book status of species as of May 2024 version. This may be subject to change.

	• Seek approval from NParks before carrying out restricted activities as outlined in the Parks and Trees Regulations, Part 2, Division 1 and 2. **For night-time works on land:** • Use directional lighting at night to avoid lighting directed at, and minimise light spill to surrounding forests; and • Minimise night-time security lighting as far as practicable whilst enabling safe and secure site. **For on-land works:** • Use only fully biodegradable erosion control blankets (ECB); • Maintenance of worksite hoarding and repair of damage on a timely basis; and • Separate storage of top- and subsoils, and reinstatement in correct order.
Environmental Aspects Scoped Out of this EIA	
SURFACE WATER QUALITY	
Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021 *Environmental Protection and Management (Trade Effluent) Regulations, 2011* *Environmental Protection and Management (Hazardous Substances) Regulations, 2008*	• The Act provides for the control of air, water and noise pollution, for the safe management of hazardous waste and for the protection and management of the environment and resource conservation. It establishes NEA Allowable Limits for Trade Effluent Discharge to Watercourse or Controlled Watercourses; • Only trade effluent that is treated and compliant with the discharge standards for watercourses and controlled watercourses, and which do not contain prohibited materials such as pesticides, refuse and petroleum will be discharged from the Project worksites; • Store concrete and cementitious materials according to the Material Safety Data Sheet (MSDS); • Carry out washout of cement and concrete mixing plant or ready-mix lorries and equipment in concrete washout areas to protect against spills and leaks; • Treat all trade effluent to relevant standards before it is discharged, and approval should be obtained from the Director-General of the NEA; • Install sampling test points, inspection chambers, flow-meters, and recording and other apparatuses for trade effluent discharged into any watercourse or land; • Analyse trade effluent discharged into any watercourse or land in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation of the United States; • Workers will be adequately trained to handle toxic waste stored on site, and to implement emergency action plans to deal with spills and leaks of toxic waste; and • Ensure that workers have received adequate instruction and training to handle any accident or emergency involving any toxic industrial waste stored or transported within the construction site.
Environmental Public Health Act (EPHA), (Amendment), 2022	• Ensure proper storage, handling and disposal of industrial waste; • Prevent excessive production of toxic industrial waste; • Ensure provision of adequate sanitary facilities; and • Adequate temporary sanitary facilities will be provided for workers to ensure no public areas will be used for sanitary purposes.
Environmental Public Health (Toxic Industrial Waste) Regulations (Amendment), 2022	• Toxic waste, such as contaminated soil from construction works, must be disposed of by a licensed toxic waste collector; • Ensure that toxic waste is stored in accordance with the approved code of practice; • Ensure that the toxic industrial waste is not mixed with non-toxic waste, unless it is an approved process of treatment, use or disposal; and • Emergency response kits will be provided at all worksites.

Environmental Public Health (General Waste Collection) Regulations (Amendment), 2019	• Only licensed general waste collectors will collect, transport and dispose of general waste to a licensed disposal facility; and • Incinerable, non-incinerable and recyclable waste will be disposed appropriately.
Fire Safety Act (Amendment), 2022	• Petroleum or flammable materials will be stored in compliance with requirements under the relevant storage licence; • All practical steps will be taken to prevent the occurrence of an accident through fire, explosion, leakage or ignition of any petroleum or flammable material or vapours; • Firefighting equipment and other emergency response equipment will be provided at all worksites; • Workers will be trained in the use of available firefighting and emergency response equipment; and • A SCDF Plan will need to be submitted to and approved by SCDF during the final design stage.
Sewerage and Drainage Act (Chapter 294) (Amendment) (SDA), 2021	• Identify location of public sewerage and drainage infrastructure near any grading, boring, excavation or ground-breaking works through desktop review of drainage and sewerage plans prior to the commencement of the works. Subsequently, carry out trial trenches to confirm the location of any such public sewerage system; • Restrict the erection of any structure or object above, or across, any surface water drain; • Prohibit works that will affect any storm water drainage system, drain or drainage reserve, directly or indirectly, without obtaining a clearance certificate or approval of PUB for the works; • Monitor trade effluent discharged to the public sewer and submit a monitoring record that includes the following information to PUB; - the amount of water consumed or used for the purposes of any trade, manufacture, business or building construction carried out in the course of which the trade effluent is wholly, or partly, produced or of which the trade effluent is the waste or refuse; - the physical, organic and chemical nature of trade effluent; - the raw materials and chemicals used in the trade, manufacture, business or building construction and the direction of the flow of any liquid or the trade effluent from, or produced by, any machinery, plant or equipment used in the trade, manufacture, business or building construction; and - such other matters relating to the trade effluent and the discharge thereof as may be required by PUB. • Prohibit the discharge of trade effluent with characteristics that exceed the statutory limits to the sewerage system; • Ensure that all activities involving repair, servicing and engine overhaul works, are carried out on a concreted area which will be bunded or provided with scupper drains to channel all wastewater into the sewerage system; • Trade effluent discharged to the public sewer from the worksites will be monitored and recorded; • Earth stockpiles will be positioned outside of the drainage reserve, and all land adjacent to drains will be turfed during general landscaping and finishing works to minimise sediment loading of stormwater drains during rainfall events; and • Used water will be recycled whenever practicable.
Sewerage and Drainage (Surface Water Drainage) Regulations, 2007	• No person shall discharge, or cause or permit the discharge, into the storm water drainage system of Total Suspended Solids (TSS) in concentrations greater than 50 milligrams per litre of the discharge; • Earth control measures will be provided and maintained in accordance with the Code of Practice on Surface Water Drainage;

	• Runoff within, upstream of and adjacent to the work site will be effectively drained away without causing flooding within or in the vicinity of the work site; • All earth slopes adjacent to any drain will be closed turfed; and • Adequate measures shall be taken to prevent any earth, sand, top-soil, cement, concrete, debris or any other material from falling or being washed into the storm water drainage system from any stockpile thereof.
Sewerage and Drainage (Trade Effluent) (Amendment) Regulations, 2022	• Any person who discharges trade effluent into any sewerage system shall, in connection with such discharge, install such sampling test points, inspection chambers, measuring devices and recording and other apparatuses as required. • Any person who discharges trade effluent into any sewerage system shall install a pre-treatment plant if PUB so requires and shall: - use or operate the plant to treat trade effluent before discharging the trade effluent into the sewerage system; and - maintain the plant in an efficient condition at all times. • A person must not discharge, or cause to be discharged, into any public sewer any trade effluent: - which is not of a nature or type approved by PUB; - the temperature of which exceeds 45°Celsius at the point of its entry into the public sewer (NEA allowable limit for trade effluent discharge); - the pH value of which is less than 6 or more than 9 at the point of its entry into the public sewer; or - the caustic alkalinity of which is more than 2,000 milligrams of calcium carbonate per litre at the point of its entry into the public sewer. • A person must not discharge, or cause to be discharged, any trade effluent which contains any of the following substances: - any toxic industrial waste specified in the first column of the Schedule to the Environmental Public Health (Toxic Industrial Waste) Regulations (Cap. 95, Rg 11); - calcium carbide; - petroleum spirit or other inflammable substance; - any organic compound specified in the First Schedule; - any substance that either by itself, or in combination or by reaction with other waste or refuse, may give rise to any gas, fume, odour or substance which is, or is likely to be, a hazard to human life, a public nuisance, injurious or otherwise objectionable, or which prevents, or is likely to prevent, entry into the public sewer by workmen maintaining or repairing it; - yeast, spent or unspent molasses, crude tar, tar oil, crude oil, carbon disulfide, hydro-sulfide and poly-sulfide; - any radioactive material; - any waste or refuse liable to form a viscous or solid coating or deposit on any part of the public sewer or sewerage system; - any excessively discolouring substance; - any pesticide, fungicide, herbicide, insecticide, rodenticide or fumigant; - blood waste; or - infectious waste. • Prohibit the discharge of trade effluent with characteristics that exceed the statutory limits to the public sewerage system.
Singapore Standard SS 593: 2013 Code of Practice for Pollution Control (COPPC), 2013	• Submit an Earth Control Management Plan endorsed by a Qualified Erosion Control Professional (QECP) to the PUB, prior to commencement of work; and • Implement adequate preventive measures including the provision of proper and stable barricades or screens, where deemed necessary by a QECP.
PUB Code of Practice on Surface Water Drainage,	• Provide and maintain Earth Control Measures (ECMs) in accordance with the Code of Practice on Surface Water Drainage;

7th Edition December, 2018	• Submit an Earth Control Management Plan to the PUB, endorsed by a QECP prior to commencement of work; • Effectively drain away runoff within, upstream and adjacent to the work site without causing flooding within, or in the vicinity of, the site; • Material from any stockpile shall not be allowed to fall or be washed into the drain. Adequate preventive measures, including the provision of proper and stable barricades or screens where necessary, shall be provided; and • Bare surfaces (including earth stockpiles) shall be covered by concrete-lining, concrete-paving, milled waste, erosion control blankets, close turfing or other suitable materials. Access roads within the site and at exit/ entrance as well as the surfaces around the site facilities shall be covered or paved. Work areas shall be covered with canvas sheets, tarpaulin sheeting or other suitable materials during rain or before work stops every day.
PUB Code of Practice on Sewerage and Sanitary Works, 2nd Edition, 2019	• After obtaining a Temporary Occupation Permit for the development, the operator shall apply to PUB for "Written Approval to Discharge Trade Effluent"; • PUB may require the installation of autosampler and/ or additional monitoring of the trade effluent (e.g. Volatile Organic Compound (VOC) monitoring), when granting the Written Approval; • All effluents that are prohibited to be discharged into a public sewer shall only be disposed of by NEA licensed toxic industrial waste collector; and • Animal waste and sludge generated shall be stabilised, dewatered and disposed of as solid waste.
PUB Guidebook on Erosion and Sediment Control at Construction Sites – For Site Implementation, 2018	• A Clearance Certificate will be obtained from the PUB, before the commencement of works; • Submission of an ECM proposal at the start of construction works; • Revision and resubmission of the ECM plans as required; and • The ECM and Sediment Control measures listed to be effectively implemented.
NEA's Code of Practice for Environmental Control Officers for Construction Sites, 2021	• Provides recommended guidelines on practice measures to manage earth control measures, wastewater and sanitary facilities on construction sites.
Good practice to be implemented during construction and operation	<u>For handling of chemical/ hazardous waste</u>: • Workers will be adequately trained to handle chemical/ hazardous waste stored on site, and to implement emergency action plans to deal with spills and leaks of toxic waste; • Appropriately licensed waste collectors to be used; • Emergency response kits will be provided at all Project Sites; and • Prepare, and keep up to date, a Spill Prevention and Emergency Response Plan detailing how spillage, leakage or accidents involving hazardous materials will be dealt with and ensure that workers on site have received adequate training and instruction to enable them to implement the emergency action plan in the event of an emergency. <u>For firefighting</u>: • Petroleum or flammable materials will be stored in compliance with requirements under the relevant storage license; • All practical steps will be taken to prevent the occurrence of an accident through fire, explosion, leakage or ignition of any petroleum or flammable material or vapours; • Firefighting equipment and other emergency response equipment will be provided; • An Emergency Response Plan detailing how fires/ explosions will be managed will be prepared and agreed with SCDF, including response arrangements, and how spillage, leakage or accidents involving firefighting water and materials resulting from fire/ explosion management will be dealt with;

AMBIENT AIR QUALITY	
Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021	• This Act provides for the control of air, water and noise pollution, for the safe management of hazardous waste and for the protection and management of the environment and resource conservation.
Environmental Protection and Management (Vehicular Emissions) Regulations (Amendment), 2023	• All motor vehicles being driven in Singapore, when using diesel or petrol, must only use Euro V diesel or petrol that conforms with the standard of using Ultra Low Sulphur Diesel (ULSD) Fuel with a maximum sulphur concentration of 10 parts per million (ppm) (0.001%) or lower to minimise SO2 emissions.
Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations, 2012	• Vehicles and off-road diesel engines used on site must comply with emissions standards stipulated in the relevant regulations.
Environmental Public Health Act (EPHA), (Amendment), 2022	• Control measures shall be put in place to minimise dust nuisances arising from construction works.
NEA Singapore Ambient Air Quality Targets (AAQTs), 2020	• Recommends air quality targets, sulfur dioxide emission inventory, and industrial and vehicle emission standards for Singapore.
NEA Code of Practice for Environmental Control Officers for Construction Sites, 2021	• Provides recommended guidelines on practice measures to reduce dust arising from construction; • Open burning of construction and other waste is not allowed at the worksite; • Effective measures, such as water sprinklers/ spray, shielding, netting, covers/ hoarding for aggregate and sand storage, should be taken to minimise dust pollution caused by construction or demolition works. The netting or barriers on the scaffolding of the construction site shall be of suitable height for effective containment of dust and debris; • All construction debris should be properly stored and removed for disposal quickly. They should not be left to accumulate at the site; • All construction equipment and machinery must be well maintained and should not emit dark smoke; and • Generators should be sited at locations that minimise the smell and noise nuisance affecting nearby sensitive receptors.
Guidance on Monitoring in the Vicinity of Demolition and Construction Sites (IAQM), 2018	• Provides recommendations for the method of monitoring of concentrations of particulate matter and dust deposition in the vicinity of demolition and construction sites.
Guidance on the Assessment of Dust from Demolition and Construction (Institute of Air Quality Management, IAQM), 2014	• Provides guidance on the assessment of dust arising from the construction and air quality impact magnitude and air receptor sensitivity criteria. • Provides guidelines on good practice measures to reduce dust arising from construction.
Land Use & Development Control: Planning for Air Quality	• Guidance to ensure that air quality is adequately considered in the land-use planning and development control processes.

Guidelines, IAQM (2017)	
World Health Organisation Air Quality Guidelines (WHO AGS), 2021	• Recommends levels for air quality guidelines and interim targets for common air pollutants: PM, O3, NO2 and SO2.
Good practice to be implemented during construction	• All temporary stockpiles of spoil or backfill that have not been used for more than 3 days shall be covered with canvas sheeting or erosion control blankets; • Vehicular access to worksites will be paved using suitable materials such as concrete, mill waste or hardcore; • All cement mixer trucks must have a containment system, or a flap installed to prevent spillage of cement; • Provide and maintain a truck wash bay for washing vehicles leaving the worksite onto a roadway at each vehicular egress point to minimise resuspension of dust due to trackout of dirt on roadways before commencement of works on site. As part of the Earth Control Measures (ECM) Plan, obtain approval from PUB for the design of each truck wash bay; • Speed limits will be applied within the construction worksite; • All asphalt roads, pavements and public footpaths will be kept clear of dust, silt and debris; • All machinery will be switched off when not in use; • All construction machinery used will complywith the USEPA Tier 4 emission standards for NOx and PM10; • All equipment and machinery, including excavators and gen-sets regularly, shall be maintained regularly to minimise smoke and dust exhaust emissions; and • To use Ultra Low Sulphur Diesel Fuel with a maximum sulphur concentration of 10 parts per million for diesel run construction equipment.
AIRBORNE NOISE AND VIBRATION	
Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021	• This Act provides for the control of air, water and noise pollution, for the safe management of hazardous waste and for the protection and management of the environment and resource conservation.
Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2011	• Airborne noise during construction works shall comply with the limits in the legislation based on various classifications of surrounding noise sensitive receptors; and • No work will be carried out during the prohibited periods (i.e. 10 pm on Saturday or eve of a Public Holiday, to 7 am on the following Monday or day after the Public Holiday) for construction work at any worksite located less than 150 m away from residential and noise-sensitive premises. If work is required to be carried out during the prohibited periods, permission shall be requested from the authority (i.e. NEA).
Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations, 2008	• Airborne noise during Project operation shall comply with the limits in the legislation based on the type of affected premises along the boundaries of the factory premise.
Environmental Protection and Management (Vehicular Emissions) Regulations (Amendment), 2023	• Motor vehicles used onsite will be comply with the noise emissions stipulated in the legislation.

Environmental Public Health Act (EPHA), (Amendment), 2022	• Noise control measures shall be put in place to minimise noise nuisance arising from construction works to the noise sensitive receptors.
NEA's Code of Practice for Environmental Control Officers for Construction Sites, 2021	• Provides recommended guidelines on practice measures to manage noise on construction sites; and • Generators should be sited at locations that minimise the smell and noise nuisance affecting nearby sensitive receptors.
Singapore Standards SS602:2014 Code of Practice for Noise Control on Construction and Demolition Sites, 2014	• Recommends methods of monitoring, estimation of construction equipment noise levels, noise control techniques and selection of quieter construction equipment and methods.
Singapore Standards SS593: 2013 Code of Practice for Pollution Control (COPPC)	• Recommends noise pollution control requirements and good practices to safeguard the noise sensitive receptors.
British Standard 5228:2009+A1:2014 and Code of Practice for Noise and Vibration Control on Construction and Open Sites	• Recommends basic methods of vibration and noise control relating to construction and open sites where work activities/ operations generate significant vibration or noise levels.
British Standard 6472-1:2008 - Part 1: Vibration sources other than blasting	• Provides guidelines to evaluate human exposure to vibration in buildings.
International Organization for Standardization (ISO), (1996); International Standard 9613-2: Acoustics – Attenuation of Sound During Propagation Outdoors	• Provides method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level (as described in ISO 1996) under meteorological conditions.
Fundamental of Acoustics, Fourth edition (2000)	• Provides physical and mathematical concepts related to the generation, transmission and reception of acoustic waves.
SOIL AND GROUNDWATER	
Environmental Protection and Management Act (Chapter 94A) (Amendment), 2021	• This Act provides for the control of air, water and noise pollution, for the safe management of hazardous waste and for the protection and management of the environment and resource conservation; and • Provides measures related to pollution control regarding the discharge of toxic substances or hazardous substances deemed to cause pollution of the environment including groundwater. •
Environmental Protection and Management	• A record indicating the quantity of hazardous substances shall be kept;

(Hazardous Substances) Regulations (Amendment), 2021	• Practices such as proper labelling and placement of containers storing hazardous substances will be employed; • Runoff discharged to any land or watercourse will comply with statutory limits and will not contain substances stipulated within the regulations; • Workers will be adequately trained to handle toxic waste stored on site, and to implement emergency action plans to deal with spills and leaks of toxic waste; and • Workers will receive adequate instruction and training to handle any accident or emergency involving any toxic industrial waste stored or transported within the construction site.
Environmental Protection and Management (Trade Effluent) Regulations, 2008	• Only trade effluent that are treated and compliant with the discharge standards for watercourses and controlled watercourses, and which do not contain prohibited materials such as pesticides, refuse and petroleum will be discharged from the Project worksites; • All trade effluent will be treated before it is discharged into any watercourse or land, unless an exemption is specifically granted by the Director-General of the NEA; • Install sampling test points, inspection chambers, flow-meters, and recording and other apparatuses for trade effluent discharged into any watercourse or land; • Runoff discharged into any watercourse or land will be analysed in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation of the United States; • There will be no discharge of any trade effluent, oil, chemical, sewerage or other polluting matters into any drain or land, without a license from the Director-General of the NEA; • There will be no discharge of trade effluent that contains: - pesticides, fungicide, herbicide, insecticide, rodenticide or fumigant; - refuse, garbage, sawdust, timber, human or animal waste or solid matter; - petroleum or other inflammable solvent; and - any reactive substance that may give rise to hazardous fumes or odour.
Environmental Public Health Act (EPHA) (Amendment), 2022	• Ensure proper storage and disposal of Toxic Industrial Waste (TIW); • Prevent excessive production of TIW; and • Provide adequate sanitary facilities for workers.
Environmental Public Health (Toxic Industrial Waste) Regulations (Amendment), 2022	• A register will be kept of the type, quantity and manner of disposal of TIW generated on site, date and quantity sold to TIW Collectors, and quantity held in stock and update it on a weekly basis; • An emergency action plan will be prepare and keep up to date detailing how spillage, leakage or accidents which arise from the storage of TIW will be dealt with and ensure that workers on site have received adequate training and instruction to enable them to implement the emergency action plan in the event of an emergency; • TIW such as contaminated soil from construction works will be disposed of by a licensed toxic waste collector; • TIW will be stored in accordance with the approved code of practice; • TIW will not be mixed with non-toxic waste, unless it is an approved process of treatment, use or disposal; and • Emergency response kits will be provided at all worksites.
Environmental Public Health (General Waste Collection) Regulations	• Only licensed general waste collectors shall be contracted to collect, transport, and dispose of general waste generated from the Project Site.

(Amendment), 2019	
Fire Safety (Petroleum and Flammable Materials – Exemption) Order (Amendment), 2020	• In the event that storage of petroleum and/or flammable materials in quantities exceeding that specified in the First Schedule of the Fire Safety (Petroleum and Flammable Materials – Exemption) Order, 2008, is required at the Project worksite, Contractors shall obtain a Petroleum & Flammable Materials Storage License from the Singapore Civil Defence Force (SCDF).
Fire Safety (Petroleum and Flammable Materials) Regulations (Amendment), 2022	• Contractors holding a Petroleum and Flammable Materials Storage License shall implement the controls listed in the regulations for the storage of petroleum and/or flammable materials on site; • Keep and maintain a register of petroleum and flammable materials stored for a period of 2 years; • Take all practicable steps to prevent the occurrence of an accident through fire, explosion, leakage or ignition of any petroleum or flammable material or vapours; • Ensure that security measures are undertaken to prohibit access to the licensed storage premises by untrained personnel; • Provide adequate fire-fighting material and other emergency response equipment, e.g. spill kits at the storage site; • Ensure that chemical handlers are trained to handle available equipment and are aware of the actions to be taken in the event of any fire, explosion, leakage or other similar emergencies; • Provide and keep updated an Emergency Response Plan to deal with any spillage, leakage, accidental discharge or emergency which may result from the storage of petroleum or flammable material stored at the premises. • Ensure that appropriate emergency information panels or warning labels as prescribed in the code of labelling (SS 286) are installed at the approved storage area; and • In the event of any loss, theft, fire, explosion, leakage, accident or accidental discharge of any petroleum and flammable material at the worksite, take immediate action to control and contain the leakage or discharge, and inform the Commissioner of the SCDF.
Sewerage and Drainage Act (Surface Water Drainage) Regulations, 2007	• Prohibit the discharge of silt or debris directly or indirectly into stormwater drainage systems; • Not cause any obstruction to the flow of any stormwater drainage system; and • Prohibit works that will affect any storm water drainage system, drain or drainage reserve, directly or indirectly, without obtaining in respect of those works, a clearance certificate or approval of the PUB.
Singapore Standard SS593: 2013 Code of practice for pollution control (COPPC)	• Ensure that only containers constructed and inspected in accordance with internationally acceptable standards are used for the storage of hazardous substances and affixed with approved labels; • Ensure that storage areas are equipped with containment as well as disposal facilities to deal with any accidental release of hazardous substances; • Immediate mitigation measures shall be taken to control and contain the release, leakage or spillage of any hazardous substance and to clean up any lands affected by the release, leakage or spillage. All waste generated shall be treated and disposed of safely; • A full containment facility shall be provided for above ground bulk storage tanks (including skid tanks). The capacity of the containment facility shall not be less than the capacity of the largest tank; • For a secondary containment facility that is fully enclosed, a leak detection system with an alarm device shall be provided within the secondary containment facility. A leak test shall be conducted before the tank is put into use. The leak test shall conform to the following guidelines:

	• The leak test method shall be able to measure a leak rate of at least 0.19 litre per hour, and be capable of testing the entire tank system, including piping; - If the tank has a loss rate in excess of 0.19 litre per hour, the tank shall be considered to be leaking; and - The leak tests shall be carried out in accordance with an established leak test method and certified by professional engineers. The test results shall be submitted to the NEA's Pollution Control Department (PCD). • A contingency plan shall be developed and put in place to deal with leaks. The contingency plan shall meet the following requirements: - To appoint a competent party or person to deal with leaks from above ground tanks; - To set up guidelines to activate the contingency plan (i.e. who, when and how to contact, emergency coordinator and confirmation of a leak); - To inform PCD as soon as leak is detected. Singapore Civil Defence Force (SCDF) shall also be informed if the chemical/ product is flammable or combustible; - To remove chemical/ product from the tank to a temporary storage by the competent party or person; - To remove the tank for inspection; - To remove the contaminated soil for proper disposal; - To carry out soil testing to ensure that all the pollutants have been removed; and - To repair or replace the tank and re-construct the secondary containment chamber if necessary. • The connection point for a filling pipe of a bulk storage tank shall be provided with measures to contain spillage.
WASTE MANAGEMENT	
Environmental Public Health (Toxic Industrial Waste) Regulations, 2000	• Adequate temporary sanitary facilities will be provided for workers to ensure no public areas will be used for sanitary purposes. • Toxic waste and contaminated soil generated from construction works will be collected for off-site disposal by a licensed toxic waste collector. • Workers will be adequately trained to handle toxic waste stored on site, and to implement emergency action plans to deal with spills and leaks of toxic waste. • Emergency response kits will be provided at all worksites.

APPENDIX B TERRESTRIAL BIODIVERSITY BASELINE

CONTENTS

LIST OF TABLES

LIST OF FIGURES

TERRESTRIAL BIODIVERSITY BASELINE

1.1 BASELINE CONDITIONS

1.1.1 METHODOLOGY

The terrestrial Biodiversity Study Area consists of all Project worksites (includes the operational footprint of the CCGT, temporary construction laydown area, cooling water intake facility and cooling water intake pipelines) and a 100 m impact zone buffer around Project worksites for habitat and flora. A 100 m buffer is used as studies[1] have found that the effects of land clearing, such as forest fragmentation and associated edge effects are observed up to 100 m from forest boundaries.

Desktop studies and site-based surveys were undertaken to describe the biotic environment within the terrestrial biodiversity study area. The coverage and methodologies of the terrestrial biodiversity baseline survey areas were conducted in accordance with the principles established in the BIA Guidelines published by NParks. The survey methodologies were also discussed and agreed upon with the relevant Technical Agencies, including NParks prior to conducting the surveys.

Flora and fauna line transect surveys were conducted in August 2025, coinciding with the breeding season for local birds (April to August). The details of the survey methodology are summarised in Table 1, and transect locations are depicted in Figure 1 and Figure 2.

TABLE 1: SUMMARY OF TERRESTRIAL BIODIVERSITY SURVEY METHODOLOGY

Survey Component	**Methodology**	**Notes**
Fauna		
Birds *(Diurnal[(a)] and Nocturnal[(b)])*	• Nine (9) line transects per fauna group • The maximum length of each transect was 200 m • The distance between each transect was 200 m	• All birds seen and heard within 50 m of either side of the transect and 50 m ahead were recorded as observations.
Herpetofauna *(Nocturnal)*		• All herpetofauna seen and heard within 10 m of either side of the transect and 10 m ahead were recorded as observations.
Mammals *(Nocturnal)*		• All mammals seen within 50 m of either side of the transect and 50 m ahead were recorded as observations.
Flora		
Vascular Plants[(c)]	• 28 line transects • Each transect measuring 2 m x 50 m	All flora species occurring within transects were recorded. Opportunistic observations of flora outside of the transects were also documented.

[1] Chatterjea K. (2014). Edge effects and exterior influences on Bukit Timah Forest, Singapore. European Journal of Geography. 5 (1):8 -31

Survey Component	Methodology	Notes
Habitat Mapping	• Remote sensing through satellite imagery to map habitats. • Confirmation of habitats from transect based flora surveys on the ground.	

Notes:
(a) Diurnal survey from 7am to 10am
(b) Nocturnal survey from 7pm to 10pm
(c) *Includes pteridophytes, climbers and vascular epiphytes*

FIGURE 1: TERRESTRIAL FAUNA TRANSECTS

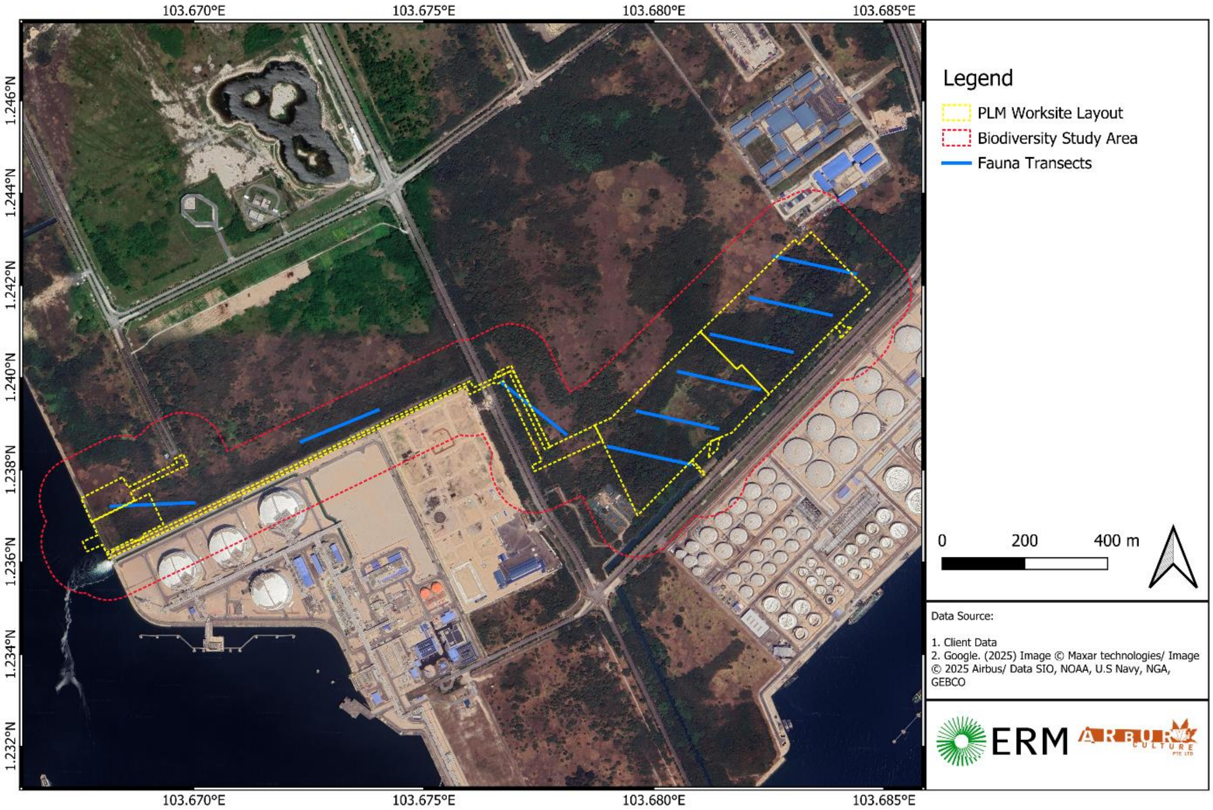
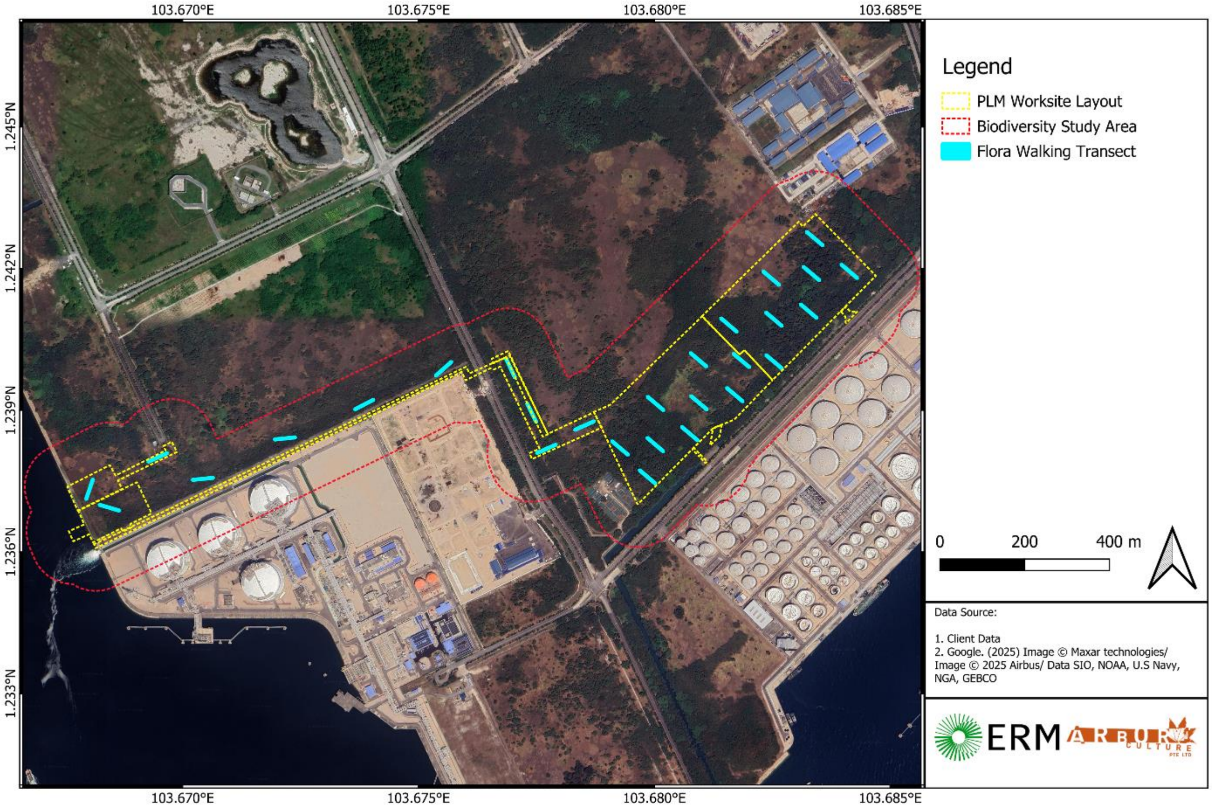


FIGURE 2: TERRESTRIAL FLORA TRANSECTS



1.1.1.1 TERMINOLOGY

Recorded flora species have been categorised into native, exotic or cryptogenic. Exotic flora species are further categorised into casual, naturalised and cultivated species. These classifications have been adopted from Chong et al. (2009)[2] and Lindsay et al. (2022)[3].

TABLE 2: DEFINITION OF ORIGIN AND EXOTIC SPECIES FOR FLORA

Origin		Definition
Native		Originated or arrived in Singapore without intentional or unintentional involvement of human activities
Exotic	Presence in Singapore is because of intentional or unintentional involvement of human activities	
	Casual	Non-native species that occur in the wild in Singapore as escapes or relics of cultivation but do not maintain self-sustaining populations
	Naturalised	Non-native species that maintain self-sustaining wild populations
	Cultivated Only	Non-native species only found in cultivation
	Not Assessed*	Species are not assessed in any checklist

[2] Chong KY, Tan HTW, Corlett RT. 2009. A Checklist of the Total Vascular Plant Flora of Singapore: Native, Naturalised and Cultivated Species. Raffles Museum of Biodiversity Research.
[3] Lindsay S, et al. 2022. Flora of Singapore: Checklist and bibliography. Gardens' Bulletin Singapore 74 (Suppl. 1): 3-860.

Origin	Definition
Cryptogenic	Uncertain whether presence in Singapore is from natural dispersal or as a result of human activities
Note: *Not a category in Chong et al. (2009) and Lindsay et al. (2022)	

Reference is made throughout this section to the Species Conservation Status, with reference to Singapore Red Data Book (RDB3)[4] and international IUCN status[5], as categorised in Table 3.

TABLE 3: DEFINITION OF NATIONAL AND GLOBAL RED-LIST CATEGORIES

Global(a)/ National(b) Red List Categories	National Criteria	IUCN Criteria
Data Deficient (DD)	Species eligible for assessment at the national level but with inadequate information to make an informed assessment	Inadequate information to make a direct or indirect assessment of its risk of extinction
Least Concern (LC)	Not approaching the threat criteria	Species does not qualify for CR, EN, VU or NT
Near Threatened (NT)	Approaching but not yet reaching the threshold for the threat criteria	Species does not qualify for CR, EN, VU or NT now, but is likely to qualify for a threatened category in the near future
Vulnerable (VU)	There are fewer than 1,000 mature individuals but more than 250 and there may or may not be any other evidence of decline, small range size or fragmentation	Species facing a high risk of extinction in the wild
Endangered (EN)	There are fewer than 250 mature individuals and no other evidence of decline or fragmentation	Species facing a very high risk of extinction in the wild
Critically Endangered (CR)	There are fewer than 50 mature individuals OR, if more than 50 but fewer than 250 mature individuals, with some evidence of decline or fragmentation	Species facing an extremely high risk of extinction in the wild

Notes:
- (a) *Based off conservation status from the International Union for Conservation of Nature (IUCN)*
- (b) *Based off conservation status from the Singapore Red Data Book 3 (SRDB3)*

[4] Davison GWH, Gan JWM, Huang D, Hwang WS, Lum SKY & Yeo DCJ (eds.) (2024) The Singapore Red Data Book: Red Lists of Singapore Biodiversity. 3rd ed. National Parks Board, Singapore.
[5] Obtained from https://www.iucnredlist.org/es

1.1.2 SUMMARY OF BASELINE FINDINGS

This report is based off the Terrestrial Baseline Survey conducted by Arborculture Pte Ltd. A high-level summary of the terrestrial biodiversity baseline findings is provided in the sections below.

1.1.2.1 HABITAT

The Terrestrial Biodiversity Study Area comprised of two (2) habitat types, reclaimed forest and grassland. Remaining area considered as non-vegetated areas e.g. infrastructure, service corridor, pavements, roads, built up areas or sea areas have not been assessed for terrestrial habitat impact. The breakdown and map of habitat types are provided in Table 4,

Table 5 and Figure 3.

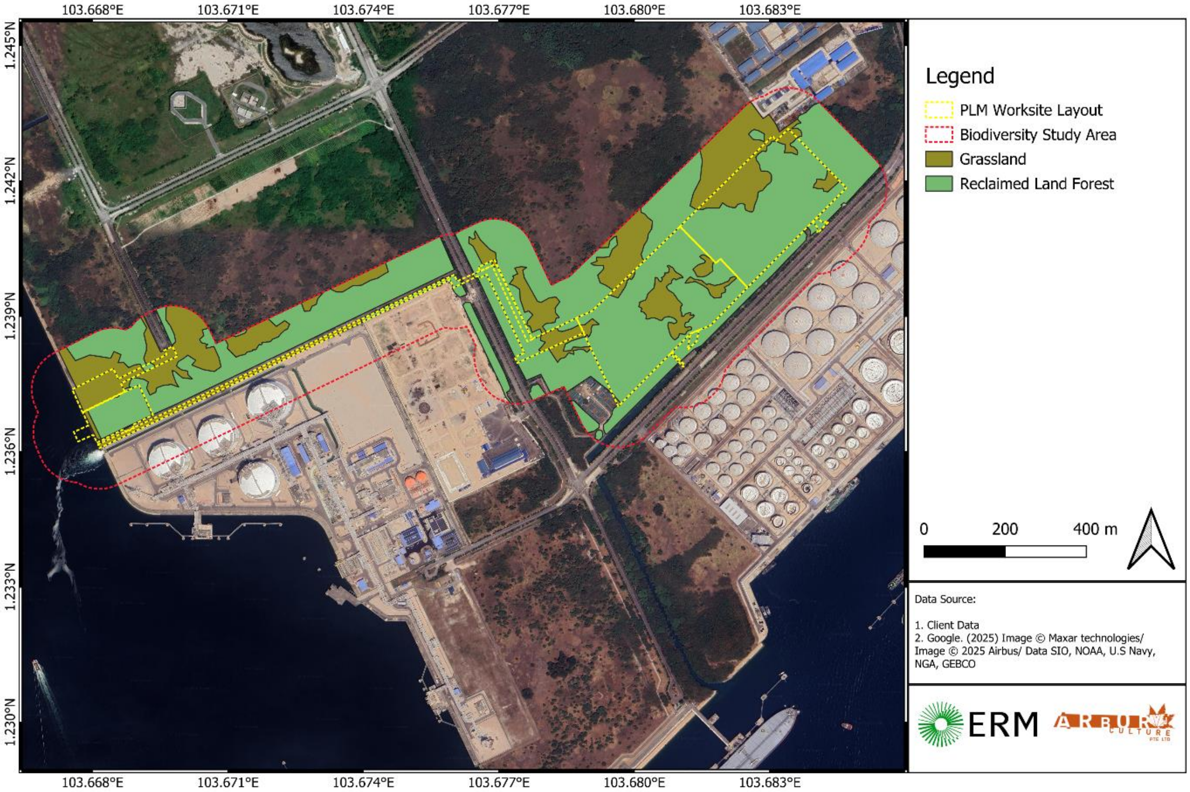
TABLE 4: HABITAT TYPES FOUND WITHIN THE BIODIVERSITY STUDY AREA

Habitat Type	Area (ha)	Percentage of Total Area
Reclaimed land forest	35.8	46.6
Grassland	13.9	18.0
Non-vegetated Areas (Service corridor/ pavements/ roads)	27.1	35.4
Total	**76.8**	**100**

TABLE 5: HABITAT TYPES FOUND WITHIN PROJECT WORKSITE (CCGT, TEMPORARY CONSTRUCTION LAYDOWN, COOLING INTAKE AND DISCHARGE INFRASTRUCTURE)

Habitat Type	Area (ha)	Percentage of Total Area
Reclaimed land forest	15.5	75.1
Grassland	5.0	24.1
Non-vegetated Areas (Service corridor/ pavements/ roads)	0.3	0.8
Total	**20.8**	**100**

FIGURE 3: HABITAT MAPPING WITHIN THE BIODIVERSITY STUDY AREA



Reclaimed land forest

Reclaimed land forest occupies the majority of the Terrestrial Biodiversity Study Area (46.6%).

In Singapore, reclaimed land forests establish when land, slated for future development, is left untouched for many years to allow the landfill to settle[6]. During this period, pioneer plant species establish, growing into new forest communities dominated by species adapted to grow in harsh environments with low soil nutrients. Species composition of reclaimed land is also dependent on the fill material used[7]. Based on available satellite imagery, the site has been left undeveloped since it was reclaimed in 2012.

Dominant species identified within the reclaimed land forest on site include the exotic Lead tree (*Leucaena leucocephala subsp. Leucocephala*) (Figure 4) and Acacia tree (*Acacia auriculiformis*) (Figure 5). Both trees are commonly found in disturbed habitats and are tolerant of poor soils, making them suited to reclaimed land conditions. The widespread occurrence of the Lead and Acacia tree forming thickets is typical of regenerating landscapes with limited canopy cover. The exotic Corky Passionflower (*Passiflora suberosa)* was also observed across almost all transects, where it was found climbing on trees. Meanwhile, the understory vegetation of the reclaimed land forest is predominantly composed of exotic species, including Lantana (*Lantana camara*) and Common Asystasia

[6] Tan HTW, Chou LM, Yeo DCJ & Ng PKL (2010) The Natural Heritage of Singapore. Third Edition. Pearson Prentice Hall, Singapore, 9 + 323 pp.
[7] Alex Thiam Koon, Yee & Chong, Kwek Yan & Neo, Louise & Tan, Hugh. (2016). Updating the classification system for the secondary forests of Singapore. 2016. 11-21.

(*Asystasia gangetica subsp. micrantha*). These species are fast growing, drought tolerant and adaptable to both semi-shaded and full sun conditions.

FIGURE 4: RECLAIMED LAND FOREST AREA DOMINATED WITH LEAD TREES

FIGURE 5: RECLAIMED LAND FOREST AREA DOMINATED WITH ACACIA TREES

TABLE 6: FREQUENTLY RECORDED FLORA SPECIES ACROSS TRANSECTS

S/N	Scientific Name	Common name	Recorded Frequency (no. transects, out of 28 Transects)	National Status	IUCN Status	Origin	Growth Form
1	*Leucaena leucocephala subsp. leucocephala*	Lead Tree	28	-	-	Exotic, naturalised, cultivated	Tree
2	*Acacia auriculiformis*	Acacia Tree	14	-	LC	Exotic, naturalised	Tree
3	*Passiflora suberosa*	Corky Passionflower	27	-	-	Exotic, naturalised, cultivated	Climber
4	*Lantana camara*	Lantana	21	-	-	Exotic, naturalised, cultivated	Shrub
5	*Asystasia gangetica subsp. micrantha*	Common Asystasia	21	-	-	Exotic, naturalised	Herb

Grassland

Grasslands are open habitats dominated by members of the grass (*Poaceae*) family, rather than large shrubs or trees. Within the Terrestrial Biodiversity Study Area, grasslands occupy approximately 18.1% of the total area, occurring within the reclaimed land forest and along the edge of the terrestrial biodiversity study area. Dominant species include the exotic Mission Grass (*Cenchrus setosus)* and native Lalang (*Imperata cylindrica*).

FIGURE 6: GRASSLAND HABITAT DOMINATED BY LALANG (LEFT) AND MISSION GRASS (RIGHT)

1.1.2.2 FLORA

A total of 97 flora species were recorded within the terrestrial biodiversity study area, of which 31 species (32%) were native, 63 species (65%) were exotic, and three (3) species (3%) were of cryptogenic origin (Table 7). For detailed flora species list, please refer to Table 8.

TABLE 7: SUMMARY OF NATIONAL CONSERVATION STATUS OF SURVEYED FLORA

Origin	National Status	Number of Species	Percentage of Species (%)[a]
Native		31	32.0
	Least Concern	28	28.9
	Critically Endangered	2	2.1
	Data Deficient	1	1.0
Exotic		63	65.0
	Cultivated	5	5.2
	Casual	1	1.0
	Naturalised	56	57.7
	Not Assessed	1	1.0
Cryptogenic		3	3.1
	Cryptogenic	3	3.1
Total Number of Species		97	100

Notes:
(a) *Percentages may not add up to 100% due to rounding.*

The majority of plant species recorded at the site are exotic (65%), which is characteristic of reclaimed land that has been left to regenerate. Given the site's proximity to the coast, conditions are favourable for the establishment of exotic herbaceous species due to wind or water dispersal; these species are often adapted well to disturbed or open environments. The establishment of exotic herbaceous species may also be attributed to propagules already present in the reclaimed fill material[8].

Among the 31 native species observed, two locally Critically Endangered (CR) species of flora were found on site. Any flora of conservation significance found on site will be transplanted out of the site prior to commencement of construction works.

A single juvenile individual of the Sea Rubber Vine (*Gymnanthera oblonga*) was opportunistically recorded near one of the flora transects, as shown in Figure 7. The Sea Rubber Vine is a climber that is rarely seen and is usually found in back mangrove zones, coastal forests[9] and lowland swamps. There are estimated to be fewer than 50 mature individuals in Singapore due to the highly fragmented nature of its remaining habitat[10].

---

[8] Gaw LYF, Richards DR (2021) Development of spontaneous vegetation on reclaimed land in Singapore measured by NDVI. PLOS ONE 16(1): e0245220. https://doi.org/10.1371/journal.pone.0245220

[9] Ang et al (2010). The status and distribution of Finalysonia obovate wall (Apocynaceae). Nature in Singapore. 3: 7-11. Retrieved from https://lkcnhm.nus.edu.sg/wp-content/uploads/sites/11/app/uploads/2017/06/2010nis7-11.pdf on 8 Oct 2025

[10] Middleton DJ & Rodda M (2019). Flora of Singapore: Volume 13 — Gentianales: Apocynaceae. Retrieved from https://www.nparks.gov.sg/-/media/sbg/flora-of-singapore/volume-13-gentianales/13,-d-,5_apocynaceae_lr1.pdf (accessed September 08, 2025)

This species was not observed in any other transects. This individual found has been transplanted out of the Project site as of December 2025.

The native genetic stock of Kelat oil (*Syzygium myrtifolium*) species are locally Critically Endangered in Singapore. Given that this individual is located on Jurong Island reclaimed land and is near streetscape, it is likely to be an escapee from present-day cultivation and does not belong to the native genetic stock. It is commonly cultivated and planted as a roadside shrub in Singapore hence for the purpose of this EIA, it is not considered to be of conservation significance.

FIGURE 7: SEA RUBBER VINE (*GYMNANTHERA OBLONGA)*

FIGURE 8: LOCATION OF SEA RUBBER VINE (*GYMNANTHERA OBLONGA, CR)* AND KELAT OIL (*SYZYGIUM MYRTIFOLIUM*)

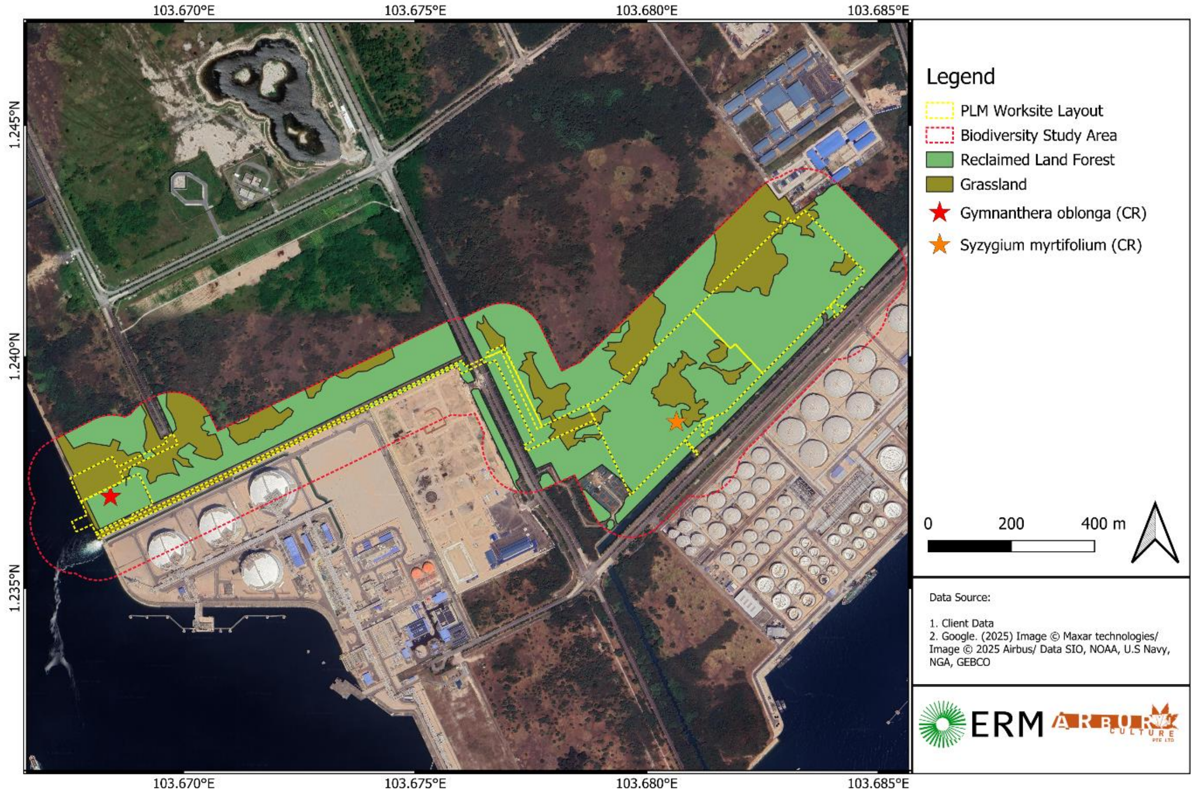


TABLE 8: FLORA SPECIES LIST

Family	Latin Name	Common Name	Origin	SRDB	IUCN
Fabaceae	*Acacia auriculiformis*	Acacia Tree	Exotic, naturalised	NA	LC
Euphorbiaceae	*Acalypha indica*	Indian Acalypha	Cryptogenic	NA	NA
Pteridaceae	*Acrostichum aureum*	Mangrove Fern, Golden Leather Fern	Native	LC	LC
Fabaceae	*Aeschynomene americana*	Shyleaf	Exotic, naturalised	NA	NA
Araceae	*Alocasia macrorrhizos*	Giant Taro	Exotic, naturalised	NA	NA
Apocynaceae	*Alstonia scholaris*	Indian Pulai	Exotic, naturalised, cultivated	NA	LC
Aspleniaceae	*Asplenium nidus var. musifolium*	Bird's Nest Fern	Native	LC	NA
Acanthaceae	*Asystasia gangetica subsp. micrantha*	Common Asystasia	Exotic, naturalised	NA	NA
Asteraceae	*Bidens alba*	Shepherd's Needles	Exotic, cultivated only	NA	NA
Anacardiaceae	*Buchanania arborescens*	Sparrows' Mango, Otak Udang	Native, cultivated	LC	LC
Fabaceae	*Calopogonium mucunoides*	Calopo	Exotic, naturalised	NA	NA
Lauraceae	*Cassytha filiformis*	Chemar Hantu, Doddler-Laurel	Native, cultivated	LC	NA
Casuarinaceae	*Casuarina equisetifolia*	Horsetail Tree, Common Rhu	Native, cultivated	LC	LC
Vitaceae	*Causonis trifolia*	Three-Leaved Wild Vine	Native	DD	NA
Poaceae	*Cenchrus purpurascens*	Swamp Foxtail	Exotic, cultivated only	NA	NA

Family	Latin Name	Common Name	Origin	SRDB	IUCN
Poaceae	*Cenchrus setosus*	Mission Grass	Exotic, naturalised	NA	NA
Fabaceae	*Centrosema molle*	Soft Butterfly Pea	Exotic, naturalised	NA	NA
Cucurbitaceae	*Coccinia grandis*	Ivy Gourd	Exotic, naturalised, cultivated	NA	NA
Lamiaceae	*Coleus monostachyus*	Monkey's Potato	Exotic, naturalised	NA	NA
Malvaceae	*Commersonia bartramia*	Brown Kurrajong	Native	LC	LC
Malvaceae	*Corchorus aestuans*	Jute	Exotic, naturalised	NA	NA
Fabaceae	*Crotalaria pallida*	Rattlebox	Exotic, naturalised	NA	NA
Asteraceae	*Cyanthillium cinereum*	Common Vernonia	Native	LC	NA
Apocynaceae	*Cynanchum tunicatum*	Dog Strangling Vine	Exotic, naturalised	NA	NA
Cyperaceae	*Cyperus aromaticus*	Navua Sedge	Exotic, naturalised	NA	NA
Cyperaceae	*Cyperus javanicus*	Java Sedge, Marsh Cyperus	Native	LC	NA
Cyperaceae	*Cyperus mindorensis*	White Kyllinga	Native	LC	NA
Davalliaceae	*Davallia denticulata var. denticulata*	Rabbit's Foot Fern	Native, cultivated	LC	NA
Fabaceae	*Desmanthus virgatus*	Wild Tantan	Exotic, naturalised	NA	LC
Poaceae	*Digitaria radicosa*	Trailing Crabgrass	Native	LC	NA
Boraginaceae	*Ehretia microphylla*	Fukien Tea Tree	Exotic, naturalised	NA	NA
Asteraceae	*Eleutheranthera ruderalis*	Ogiera, Pakaka	Exotic, naturalised	NA	NA
Euphorbiaceae	*Euphorbia hirta*	Asthma Plant	Exotic, naturalised, cultivated	NA	NA

Family	Latin Name	Common Name	Origin	SRDB	IUCN
Fabaceae	*Falcataria falcata*	Albizia Tree	Exotic, naturalised, cultivated	NA	LC
Moraceae	*Fatoua villosa*	Hairy Crabweed	Exotic, naturalised	NA	NA
Moraceae	*Ficus lyrata*	Fiddle Leaf Fig	Exotic, cultivated only	NA	LC
Cyperaceae	*Fimbristylis dichotoma*	Forked Fimbry, Common Fimbristylis	Native	LC	LC
Fabaceae	*Grona triflora*	Creeping Tick Trefoil, Three-Flower Beggarweed	Native	LC	NA
Apocynaceae	*Gymnanthera oblonga*	Sea Rubber Vine	Native	CR	NA
Cucurbitaceae	*Gymnopetalum scabrum*	-	Native	LC	NA
Malvaceae	*Hibiscus tiliaceus*	Sea Hibiscus	Native, cultivated	LC	LC
Lamiaceae	*Hyptis capitata*	Knobweed	Exotic, naturalised	NA	NA
Poaceae	*Imperata cylindrica*	Lalang	Native	LC	NA
Fabaceae	*Indigofera hendecaphylla var. hendecaphylla*	Creeping Indigo	Exotic, naturalised	NA	NA
Fabaceae	*Indigofera suffruticosa*	Guatemala Indigo, Small-Leaved Indigo	Exotic, naturalised	NA	NA
Convolvulaceae	*Ipomoea obscura*	Obscure Morning Glory	Native	LC	NA
Convolvulaceae	*Ipomoea pes-caprae*	Beach Morning Glory	Native, cultivated	LC	LC
Convolvulaceae	*Ipomoea triloba*	Three-Lobed Morning Glory	Exotic, naturalised	NA	LC
Poaceae	*Ischaemum muticum*	Seashore Centipede Grass, Rumput Kemarau	Native, cultivated	LC	LC

Family	Latin Name	Common Name	Origin	SRDB	IUCN
Verbenaceae	*Lantana camara*	Lantana, Shrub Verbena	Exotic, naturalised, cultivated	NA	NA
Fabaceae	*Leucaena leucocephala subsp. leucocephala*	Lead Tree	Exotic, naturalised, cultivated	NA	NA
Poaceae	*Melinis repens*	Red-Top, Rose Natal Grass, Natal Grass	Exotic, naturalised	NA	NA
Cucurbitaceae	*Melothria pendula*	Guadeloupe Cucumber, Creeping Cucumber	Exotic, naturalised	NA	NA
Euphorbiaceae	*Microstachys chamaelea*	Creeping Sebastiana	Cryptogenic	NA	NA
Asteraceae	*Mikania micrantha*	Mile-A-Minute Weed	Exotic, naturalised	NA	NA
Fabaceae	*Mimosa diplotricha var. diplotricha*	Giant Sensitive Plant	Exotic, naturalised, cultivated	NA	NA
Fabaceae	*Mimosa pudica*	Sensitive Plant	Exotic, naturalised, cultivated	NA	LC
Phyllanthaceae	*Moeroris debilis*	-	Exotic, naturalised	NA	NA
Moringaceae	*Moringa oleifera*	Horse-Radish Tree, Drumstick Tree	Exotic, cultivated only	NA	LC
Muntingiaceae	*Muntingia calabura*	Jamaican Cherry	Exotic, naturalised, cultivated	NA	LC
Nephrolepidaceae	*Nephrolepis biserrata*	Broad Sword Fern	Native	LC	NA
Fabaceae	*Neptunia plena*	Aquatic Sensitive Plant	Exotic, naturalised, cultivated	NA	LC
Poaceae	*Ottochloa nodosa*	Slender Panic Grass	Native	LC	NA
Oxalidaceae	*Oxalis barrelieri*	Lavender Sorrel	Exotic, naturalised, cultivated	NA	NA
Poaceae	*Panicum laxum*	Lax Panicgrass	Exotic, naturalised	NA	NA

Family	Latin Name	Common Name	Origin	SRDB	IUCN
Poaceae	*Paspalum orbiculare*	Ditch Millet	Native	LC	NA
Poaceae	*Paspalum plicatulum*	Brownseed Paspalum	Exotic, casual	NA	LC
Passifloraceae	*Passiflora foetida*	Running Pop, Love-In-A-Mist	Exotic, naturalised, cultivated	NA	NA
Passifloraceae	*Passiflora suberosa*	Corky Passionflower	Exotic, naturalised, cultivated	NA	NA
Asteraceae	*Praxelis clematidea*	Praxelis	Exotic, naturalised	NA	NA
Pteridaceae	*Pteris vittata*	Ladder Brake, Chinese Brake	Cryptogenic	NA	LC
Acanthaceae	*Ruellia tuberosa*	Minnie Root	Exotic, naturalised, cultivated	NA	NA
Poaceae	*Saccharum officinarum*	Sugarcane	Exotic, casual, cultivated	NA	NA
Fabaceae	*Senna occidentalis*	Coffee Senna	Exotic, naturalised	NA	LC
Malvaceae	*Sida acuta*	Narrow-Leaved Sida	Exotic, naturalised	NA	NA
Cleomaceae	*Sieruela rutidosperma*	Fringed Spiderflower	Exotic, naturalised, cultivated	NA	NA
Solanaceae	*Solanum americanum*	American Black Nightshade	Exotic, naturalised	NA	NA
Solanaceae	*Solanum torvum*	Turkey Berry, Terung Pipit	Exotic, naturalised	NA	NA
Bignoniaceae	*Spathodea campanulata*	African Tulip Tree	Exotic, naturalised, cultivated	NA	LC
Orchidaceae	*Spathoglottis plicata*	Spathoglottis Orchid	Native, cultivated	LC	NA
Rubiaceae	*Spermacoce remota*	Woodland False Buttonweed	Exotic, naturalised	NA	LC
Asteraceae	*Sphagneticola trilobata*	Yellow Creeping Daisy	Exotic, naturalised, cultivated	NA	NA
Loganiaceae	*Spigelia anthelmia*	West Indian Pinkroot	Exotic, naturalised	NA	NA

Family	Latin Name	Common Name	Origin	SRDB	IUCN
Poaceae	*Spinifex littoreus*	Ravan's Moustache	Exotic (not assessed)	NA	NA
Poaceae	*Sporobolus indicus var. major*	Smut Grass	Native	LC	LC
Verbenaceae	*Stachytarpheta jamaicensis*	Blue Porterweed	Exotic, naturalised	NA	LC
Fabaceae	*Stylosanthes humilis*	Townsville Stylo	Exotic, naturalised	NA	NA
Myrtaceae	*Syzygium myrtifolium*	Kelat Oil	Native, cultivated	CR	LC
Myrtaceae	*Syzygium polyanthum*	Indonesian Bayleaf	Native, cultivated	LC	NA
Fabaceae	*Tephrosia noctiflora*	Petai Balong Kecil	Exotic, naturalised	NA	NA
Combretaceae	*Terminalia catappa*	Sea Almond, Ketapang	Native, cultivated	LC	LC
Asteraceae	*Tridax procumbens*	Coat Buttons	Exotic, naturalised, cultivated	NA	NA
Araceae	*Typhonium trilobatum*	Begal Arum	Exotic, naturalised	NA	NA
Poaceae	*Urochloa maxima*	Guinea Grass, Rumput Benggala	Exotic, naturalised	NA	NA
Fabaceae	*Vigna marina*	Beach Pea	Native	LC	LC
Asteraceae	*Wollastonia biflora*	Sea Daisy, Sea Ox-Eye	Native, cultivated	LC	NA
Rhamnaceae	*Ziziphus mauritiana*	Indian Jujube, Chinese Date	Exotic, cultivated only	NA	LC

1.1.2.3 FAUNA

A total of 36 fauna species were recorded per Table 9, of which 30 were bird species, three (3) were mammal species and three (3) were herpetofauna species. Of the 36 species of fauna found, 31 species were native (86.1%), four (4) were exotic (8.3%) and one (1) was of cryptogenic origin (3.1%). Four species of conservation significance (i.e. NT status or above) were identified, including the locally vulnerable Oriental Magpie-robin (*Copsychus saularis*) and Changeable Hawk-eagle (*Nisaetus cirrhatus*). No IUCN species of conservation significance were found on site, with the exception of the Javan Myna (*Acridotheres javanicus*), which is globally Vulnerable but is exotic and extremely common in Singapore, hence it has not been included within the assessment below. For detailed fauna species list, please refer to Table 11.

The findings for each fauna group are described in the sections below.

TABLE 9: SUMMARY OF NATIONAL CONSERVATION STATUS OF SURVEYED FAUNA

Origin	National Status	Number of Species	Percentage of Species (%)[a]
Native		31	86.1
	Least Concern	27	75.0
	Near Threatened	2	5.6
	Vulnerable	2	5.6
Exotic		4	11.1
	NA (Non-native)	4	11.1
Cryptogenic		1	2.8
	Cryptogenic	1	2.8
Total Number of Species		36	100

Notes:
(a) Percentages may not add up to 100% due to rounding

TABLE 10: RECORDED FAUNA SPECIES OF CONSERVATION SIGNIFICANCE

Taxon	Scientific Name	Common name	National Status	IUCN Status
Avifauna	*Copsychus saularis*	Oriental Magpie-robin	VU	LC
	Nisaetus cirrhatus	Changeable Hawk-eagle	VU	LC

Avifauna

The field survey recorded 30 bird species, of which 27 species were native and resident, and three (3) were exotic. Most species recorded were locally common (least concern) with the exception of four (4) species. The Oriental Magpie-robin (*Copsychus saularis,* RDB3 VU, IUCN LC) was once highly endangered but is now considered a common resident found within forest edge, gardens, parks, wooded areas and mangroves in Singapore[11,12], where it feeds on variety of insects, larva and flies and can be seen foraging on the ground. The Changeable Hawk-eagle (*Nisaetus cirrhatus,* RDB3 VU, IUCN LC) is also classified as a common resident in Singapore and can be found across many wooded areas across Singapore where it can tolerate and nest in degraded habitats as long as tall trees such as the *Casuarina equisetifolia* tree[13]. Other notable avifauna species of local conservation significance include the Golden-bellied Gerygone (*Gerygone sulphurea,* RDB3 NT, IUCN LC) and Rufous-tailed Tailorbird (*Orthotomus sericeus,* RDB3 NT, IUCN LC). The former is classified as a very common resident in Singapore and is found in most habitats with trees, including highly urbanised landscapes[14], while the latter is an uncommon resident of secondary forest and forest edge habitats.

Overall, suitable nesting and foraging habitats were present within the terrestrial biodiversity study area provided by trees, grassland and scrub.

Herpetofauna

Three species of herpetofauna were recorded, this includes the native Common Wolf Snake (*Lycodon capucinus*, RDB3 LC, IUCN LC), Spiny-tailed House Gecko (*Hemidactylus frenatus*, RDB3 LC, IUCN LC) and exotic Changeable Lizard (*Calotes versicolor*, IUCN LC).

No species of conservation significance were identified.

Mammals

Three (3) species of mammals were recorded, this includes the native Asian House Shrew (*Suncus murinus*, RDB3 LC, IUCN LC), Lesser Dog-faced Fruit Bat (*Cynopterus brachyotis*, RDB3 LC, IUCN LC) and Rats (*Rattus spp* of uncertain origin and conservation status). The shrew can be found within forested and urban environments, where they feed on insects and worms in leaf litter, while the Lesser Dog-faced Fruit Bat is one of the most widespread and common bats in Singapore, and can be found roosting in buildings, trees and under leaves.

No species of conservation significance were identified.

---

[11] Wee, Y. C. (2006). Forty years of birding and ornithological research in Singapore. *Birding Asia*, *5*, 12-15.
[12] Oriental Magpie-Robin – Birds of Singapore
[13] Changeable Hawk-Eagle – Birds of Singapore
[14] Golden-bellied Gerygone – Birds of Singapore

TABLE 11: FAUNA SPECIES LIST

Family	Latin Name	Common Name	Origin	SRDB	IUCN
Sturnidae	*Acridotheres javanicus*	Javan Myna	Exotic	NA	VU
Aegithinidae	*Aegithina tiphia*	Common Iora	Native	LC	LC
Apodidae	*Aerodramus sp.*	Aerodramus Swiftlet	Native	LC	NA
Nectariniidae	*Anthreptes malacensis*	Brown-throated Sunbird	Native	LC	LC
Cuculidae	*Cacomantis sonneratii*	Banded Bay Cuckoo	Native	LC	LC
Agamidae	*Calotes versicolor*	Changeable Lizard	Exotic	NA	LC
Caprimulgidae	*Caprimulgus macrurus*	Large-tailed Nightjar	Native	LC	LC
Cuculidae	*Chrysococcyx minutillus*	Little Bronze Cuckoo	Native	LC	LC
Nectariniidae	*Cinnyris ornatus*	Ornate Sunbird	Native	LC	NA
Cisticolidae	*Cisticola juncidis*	Zitting Cisticola	Native	LC	LC
Muscicapidae	*Copsychus saularis*	Oriental Magpie-robin	Native	VU	LC
Corvidae	*Corvus splendens*	House Crow	Exotic	NA	LC
Pteropodidae	*Cynopterus brachyotis*	Lesser Dog-faced Fruit Bat	Native	LC	LC
Picidae	*Dendrocopos moluccensis*	Sunda Pygmy Woodpecker	Native	LC	LC
Picidae	*Dinopium javanense*	Common Flameback	Native	LC	LC

Family	Latin Name	Common Name	Origin	SRDB	IUCN
Cuculidae	*Eudynamys scolopaceus*	Asian Koel	Native	LC	LC
Coraciidae	*Eurystomus orientalis*	Oriental Dollarbird	Native	LC	LC
Columbidae	*Geopelia striata*	Zebra Dove	Native	LC	LC
Acanthizidae	*Gerygone sulphurea*	Golden-bellied Gerygone	Native	NT	LC
Coraciiformes	*Halcyon smyrnensis*	White-throated Kingfisher	Native	LC	LC
Gekkonidae	*Hemidactylus frenatus*	Spiny-tailed House Gecko	Native	LC	LC
Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	Native	LC	LC
Colubridae	*Lycodon capucinus*	Common Wolf Snake	Native	LC	LC
Accipitridae	*Nisaetus cirrhatus*	Changeable Hawk-eagle	Native	VU	LC
Oriolidae	*Oriolus chinensis*	Black-naped Oriole	Native	LC	LC
Cisticolidae	*Orthotomus ruficeps*	Ashy Tailorbird	Native	LC	LC
Cisticolidae	*Orthotomus sericeus*	Rufous-tailed Tailorbird	Native	LC	LC
Cisticolidae	*Orthotomus sutorius*	Common Tailorbird	Native	LC	LC
Pycnonotidae	*Pycnonotus goiavier*	Yellow-vented Bulbul	Native	LC	LC
Pycnonotidae	*Pycnonotus jocosus*	Red-whiskered Bulbul	Exotic	NA	LC

Family	Latin Name	Common Name	Origin	SRDB	IUCN
Muridae	*Rattus sp.*	Rat	Uncertain	NA	NA
Rhipiduridae	*Rhipidura javanica*	Malaysian Pied Fantail	Native	LC	LC
Columbidae	*Spilopelia chinensis*	Spotted Dove	Native	LC	LC
Soricidae	*Suncus murinus*	Asian House Shrew	Native	LC	LC
Coraciiformes	*Todiramphus chloris*	Collared Kingfisher	Native	LC	LC
Columbidae	*Treron vernans*	Pink-necked Green Pigeon	Native	LC	LC

APPENDIX C MARINE WATER QUALITY BASELINE REPORT

Hydrobiology

CCGT MARINE WATER AND SEDIMENT QUALITY SAMPLING

BRISBANE | PERTH | **SINGAPORE** | PAPUA NEW GUINEA

FOR ENVIRONMENTAL RESOURCES MANAGEMENT (S) PTE LTD

S25060

—

[OCTOBER 2025]

THIS COMPANY IS REGISTERED FOR GST.

STREET
Singapore Water Exchange
84 Toh Guan Road East
#04-08/09
Singapore 608501

REGISTERED
11 Collyer Quay
#05-06C
The Arcade
Singapore 049317

CONTACT
singapore@hydrobiology.com

www.hydrobiology.com

DOCUMENT CONTROL INFORMATION

DATE PRINTED	JOB NUMBER	REPORT NUMBER
02 October 2025	S25060	1

PROJECT TITLE	CCGT Marine Water Quality and Sampling Quality Sampling
PROJECT SUBTITLE	Final Report
PROJECT MANAGER	Arshad Yusof
FILENAME	S25060_Final Report_v2-0

STATUS	ORIGINATOR/S	REVIEWED	AUTHORISED	DATE
V1-0	CK / JO / AY / DD	HL	HL	02 October 2025
V2-0	JO / AY / DD			24 October 2025

DISTRIBUTION

FILENAME	DESCRIPTION	ISSUED TO	ISSUED BY
S25060_Final Report_v1-0	Baseline surveys final report	Rae Ann (ERM)	Yusof Arshad

Contents

Tables

Figures

EXECUTIVE SUMMARY

This baseline report presents the findings from marine water quality surveys conducted on 28 July 2025 and 05 August 2025. Key results are summarized below:

- Marine water quality
  - Nitrate (NO_3-N) concentrations exceeded the ASEAN Marine Water Quality Criterion of 0.06 mg/L across multiple events:
    - Spring flood tide: WSQ1, WSQ2 and WSQ5 recorded concentrations of 0.081-0.082 mg/L.
    - Spring ebb tide: All sampling locations recorded concentrations of 0.068-0.089 mg/L
    - Neap flood tide: WSQ1, WSQ2 and WSQ5 recorded concentrations of 0.081-0.090 mg/L.
    - Neap ebb tide: WSQ1, WSQ2, WSQ4 and WSQ5 recorded concentrations of 0.078-0.095 mg/L.
- Plankton Communities
  - The dominant zooplankton group identified was Family Paracalanidae copepods, comprising 22%-67% of total abundance across all replicates.
  - The dominant phytoplankton species were:
    - *Skeletonema* sp., accounting for ~60%-100% of total abundance across replicates.
    - *Chaetoceros* sp., accounting for ~5%-35% across replicates.
- Sediment Quality
  - Polycyclic aromatic hydrocarbons (PAHs) were generally below detection limits.
- Macrobenthos Communities
  - The dominant macrobenthos community was minute marine snails (Gastropoda), accounting for ≥82.6% of the total overall individuals identified.
  - The dominant gastropoda families were:
    - Turritellidae, accounting for ~42.4% of the snails found at WSQ1.
    - Columbellidae, accounting for ~39.8% of the snails found at WSQ3.

1. INTRODUCTION

Environmental Resources Management (S) Pte Ltd (ERM) engaged Hydrobiology Singapore Pte Ltd (Hydrobiology) to conduct baseline marine water quality sampling, prior to the Energy Market Authority's (EMA) proposed construction works of a 670MW Combined Cycle Gas Turbine (CCGT) Plant at Meranti Road, Jurong Island.

This baseline marine quality report, prepared by Hydrobiology, presents the findings derived from *in-situ* field measurements and *ex-situ* laboratory analyses. The surveys were conducted on 28 July 2025 and 05 August 2025, covering four tidal conditions: spring flood, spring ebb, neap flood, and neap ebb tides.

2. METHODOLOGY

Samples were collected from a total of five sites as shown in **Figure 2-1**. Two surveys were conducted, the first on 28 July 2025 to acquire spring tide water quality readings, and the other on 05 August 2025 for neap tide water quality readings.

Figure 2-1 Map of marine water quality sampling points.

2.1 MARINE WATER QUALITY

Marine water samples were collected at mid-depth and sent to Marchwood Laboratory Services (MLS), a Singapore Laboratory Accreditation Scheme (SAC-SINGLAS) accredited laboratory, for analysis of the parameters listed in **Table 2-1**. In addition, *in-situ* water quality profiling was conducted throughout the water column at each site using Secchi disk, LI-1500 Light Sensor Logger, and YSI ProDSS Multiparameter Digital Water Quality Meter.

Table 2-1 Water quality parameters sampled and analysed.

Parameter	Units	Detection Limits	Depth
Temperature	°C	N/A	Profiled at 1m intervals, up to 10m below sea level
Salinity	ppt	0.01	
Turbidity	NTU	1	
pH	N/A	0.01	
Dissolved Oxygen	mg/L	0.1	
Light (PAR)	$\mu mols^{-1}m^{-2}$	N/A	
Secchi Depth	m	N/A	

Parameter	Units	Detection Limits	Depth
Total suspended Solids (TSS)	mg/L	1 mg/L	Mid-depth
Nitrate as NO3-N	mg/L	0.01 mg/L	
Nitrite as NO2-N	mg/L	0.01 mg/L	
Phosphate as PO4-P	mg/L	0.01 mg/L	
Total Nitrogen, TN	mg/L	0.01 mg/L	
Total Phosphorus, TP	mg/L	0.01 mg/L	
Total Ammonia Nitrogen	mg/L	0.01 mg/L	
Total Organic Carbon (TOC)	mg/L	0.01 mg/L	
Total Petroleum Hydrocarbons (TPH)	mg/L	0.01 mg/L	
Biochemical Oxygen Demand (BOD)	mg/L	2.0 mg/L	
Cadmium, Cd	µg/L	5 µg/L	
Chromium, Cr	µg/L	5 µg/L	
Copper, Cu	µg/L	5 µg/L	
Lead, Pb	µg/L	5 µg/L	
Mercury, Hg	µg/L	0.1 µg/L	
Nickel, Ni	µg/L	5 µg/L	
Zinc, Zn	µg/L	5 µg/L	
Faecal coliforms	MPN/100mL	2 MPN/100mL	
Enterococci	CFU/100mL	2 CFU/100mL	

2.2 PLANKTON SAMPLING

Triplicate plankton samples were collected at each location to account for both phytoplankton and zooplankton in terms of abundance and species composition. Phytoplankton were collected using a 53 µm tow net while zooplankton were collected using a 250 µm tow net.

2.3 SEDIMENT SAMPLING

Sediment samples were collected at each site using a Van Veen sampler and sent to MLS for analysis of the parameters listed in .

Table 2-2 Test parameters for sediments and their respective test methods.

Test parameters	Test methods
Heavy metals (mg/kg) (As, Cd, Cr, Cu, Ni, Pb, Zn, Al, Ba, Fe, V and Hg)	USEPA 3051A (2007) / APHA 3120B/ APHA 3125B / USEPA 245.1
Total organic carbon (TOC) (%)	BS EN 13137:2001/ Accredited In-House Method MLS-SOP-SED-007
Total petroleum hydrocarbons (TPH) (mg/kg)	USEPA 8440 (1996)
Polycyclic aromatic hydrocarbons (PAH)* (mg/kg)	USEPA 8270E (Jun 2018)
Particle size distribution (PSD) (%)	BS1377: Part 2:1990

*The 16 PAH compounds consist of Acenaphthene, Acenaphthylene, Anthracene, Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(ghi)perylene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene, Pyrene

2.4 MACROBENTHOS SAMPLING

Macrobenthos samples were collected at WSQ1 and WSQ3 using a Van Veen grab sampler. Three replicates were taken, with a combined sample mass of at least 3 kg per site. The samples were then sieved through a 250 μm mesh aperture for further analysis.

3. BASELINE RESULTS

3.1 MARINE WATER QUALITY

Water sampling was conducted across 20 sampling events, covering both spring and neap tides under flood and ebb tidal conditions at five locations (**Figure 2-1**). Secchi disk depths are presented in **Table 3-1**. **Table 3-2** to **Table 3-7** present *in-situ* water quality data. *Ex-situ* water quality results are provided in **Table 3-8** (spring tidal conditions) and (neap tidal conditions). The full laboratory reports are presented in **Appendix A**.

The key findings related to marine water quality are presented below:

- Nitrate (NO_3-N) concentrations exceeded the ASEAN Marine Water Quality Criterion of 0.06 mg/L during several events:
  - Spring flood tide: WSQ1, WSQ2 and WSQ5 recorded concentrations of 0.081-0.082 mg/L.
  - Spring ebb tide: All locations recorded concentrations of 0.068-0.089 mg/L
  - Neap flood tide: WSQ1, WSQ2 and WSQ5 recorded concentrations of 0.081-0.090 mg/L.
  - Neap ebb tide: WSQ1, WSQ2, WSQ4 and WSQ5 concentrations of 0.078-0.095 mg/L.
- Faecal coliform concentrations exceeded the ASEAN MWQC of 100 MPN/100mL during one event:
  - WSQ4 (neap ebb tide): 110 MPN/100mL.
- Enterococci concentrations exceed the ASEAN MWQC of 35 cfu/100mL during one event:
  - WSQ4 (neap ebb tide): 38 cfu/100mL.

Figure 3-1 Site conditions of WSQ1-WSQ4, taken during spring and neap tide sampling

Table 3-1 Sampling details for spring and neap, flood and ebb tides and their respective Secchi disk depths.

Site	Date	Time (H)	Weather	Wind Speed (km/h) : Direction	Sea Conditions	Water Depth at Site	Secchi Disk Depth
Spring Flood							
WSQ1	28 July 2025	1318	Sunny	15 : SSE	Calm, clear	19.0 m	2.2 m
WSQ2	28 July 2025	0908	Sunny	4 : SE	Calm, clear	16.3 m	1.6 m
WSQ3	28 July 2025	1140	Sunny	13 : SE	Calm, clear	14.3 m	2.0 m
WSQ4	28 July 2025	1037	Slightly cloudy	7 : SE	Calm, clear	17.3 m	2.2 m
WSQ5	28 July 2025	1226	Sunny	15 : SSE	Calm, clear	20.0 m	2.2 m
Spring Ebb							

Site	Date	Time (H)	Weather	Wind Speed (km/h) : Direction	Sea Conditions	Water Depth at Site	Secchi Disk Depth
WSQ1	28 July 2025	1450	Partly cloudy	14 : SW	Calm, clear	20.0 m	2.1 m
WSQ2	28 July 2025	1650	Sunny	10 : S	Calm, clear	17.0 m	2.1 m
WSQ3	28 July 2025	1542	Sunny	16 : S	Calm, slick surface	17.0 m	2.0 m
WSQ4	28 July 2025	1612	Sunny	15 : S	Calm, clear	16.0 m	2.1 m
WSQ5	28 July 2025	1515	Sunny	15 : SSE	Calm, clear	26.0 m	2.0 m
Neap Ebb							
WSQ1	05 August 2025	1340	Slightly cloudy	5 : S	Slightly choppy	17.6 – 21.0 m	2.4 m
WSQ2	05 August 2025	1025	Cloudy	12 : S	Calm, clear	19.0 m	2.1 m
WSQ3	05 August 2025	1205	Cloudy	9 : S	Calm, currents	13.5 m	1.9 – 2.1 m
WSQ4	05 August 2025	1120	Cloudy	6 : S	Calm, clear	18.0 m	2.2 m
WSQ5	05 August 2025	1320	Partly cloudy	15 : S	Slightly choppy, clear	22.0 m	2.0 m
Neap Flood							
WSQ1	05 August 2025	1452	Slightly cloudy	15 : S	Calm, clear	18.0 m	2.4 m
WSQ2	05 August 2025	1715	Cloudy	5 : S	Calm, clear	17.0 m	2.4 m
WSQ3	05 August 2025	1550	Cloudy	7 : SE	Calm, slick surface	10.0 m	1.9 m

Site	Date	Time (H)	Weather	Wind Speed (km/h) : Direction	Sea Conditions	Water Depth at Site	Secchi Disk Depth
WSQ4	05 August 2025	1640	Cloudy	4 : SE	Calm, clear	19.0 m	2.2 m
WSQ5	05 August 2025	1525	Cloudy	6 : SE	Calm, clear	23.0 m	2.6 m

Table 3-2 In-situ temperature readings across all tidal conditions and monitoring sites.

	WSQ1 Spring Flood	WSQ2 Spring Flood	WSQ3 Spring Flood	WSQ4 Spring Flood	WSQ5 Spring Flood	WSQ1 Spring Ebb	WSQ2 Spring Ebb	WSQ3 Spring Ebb	WSQ4 Spring Ebb	WSQ5 Spring Ebb
Depth	**Temperature (° C)**									
~ 0.5 m	30.056	29.991	30.281	30.242	30.171	30.132	30.506	30.457	31.153	30.292
~ 1.5 m	30.199	30.025	30.522	30.290	30.142	30.199	30.525	30.495	31.322	30.255
~ 2.5 m	30.148	30.030	30.270	30.308	30.136	30.159	30.448	30.315	31.197	30.224
~ 3.5 m	30.146	30.033	30.247	30.299	30.146	30.209	30.252	30.284	30.949	30.206
~ 4.5 m	30.155	30.031	30.244	30.236	30.138	30.193	30.246	30.269	30.565	30.174
~ 5.5 m	30.144	30.033	30.218	30.232	30.127	30.177	30.222	30.243	30.506	30.162
~ 6.5 m	30.146	30.031	30.214	30.229	30.115	30.157	30.137	30.255	30.396	30.156
~ 7.5 m	30.146	30.030	30.222	30.239	30.133	30.157	30.148	30.245	-	30.162
~ 8.5 m	30.149	-	30.201	30.224	30.125	-	-	30.244	-	-
	WSQ1 Neap Flood	**WSQ2 Neap Flood**	**WSQ3 Neap Flood**	**WSQ4 Neap Flood**	**WSQ5 Neap Flood**	**WSQ1 Neap Ebb**	**WSQ2 Neap Ebb**	**WSQ3 Neap Ebb**	**WSQ4 Neap Ebb**	**WSQ5 Neap Ebb**
Depth	**Temperature (°C)**									
~ 0.5 m	30.416	30.062	30.283	30.227	30.509	30.741	29.817	30.314	30.465	30.444
~ 1.5 m	30.434	30.086	30.293	30.236	30.570	30.236	29.930	30.322	30.539	30.487
~ 2.5 m	30.438	30.081	30.297	30.242	30.355	30.238	29.920	30.324	30.467	30.269
~ 3.5 m	30.276	30.059	30.296	30.240	30.182	30.318	29.909	30.330	30.448	30.193
~ 4.5 m	30.218	30.050	30.308	30.246	30.104	30.258	29.916	30.332	30.409	30.179
~ 5.5 m	30.229	30.045	30.314	30.241	30.115	30.307	29.883	30.333	30.325	30.145
~ 6.5 m	30.245	30.046	30.314	30.242	30.089	30.282	29.883	30.332	30.278	30.125
~ 7.5 m	30.208	30.046	30.314	30.236	30.055	30.241	29.889	30.332	30.273	30.11
~ 8.5 m	-	30.045	-	30.237	30.053	30.213	29.914	-	30.276	30.113

Table 3-3 In-situ salinity readings across all tidal conditions and monitoring sites.

	WSQ1 Spring Flood	WSQ2 Spring Flood	WSQ3 Spring Flood	WSQ4 Spring Flood	WSQ5 Spring Flood	WSQ1 Spring Ebb	WSQ2 Spring Ebb	WSQ3 Spring Ebb	WSQ4 Spring Ebb	WSQ5 Spring Ebb
Depth	**Salinity (ppt)**									
~ 0.5 m	29.81	29.61	29.85	29.80	29.69	29.72	29.66	29.71	29.69	29.72
~ 1.5 m	29.69	29.69	29.71	29.76	29.69	29.67	29.67	29.74	29.72	29.72
~ 2.5 m	29.70	29.71	29.76	29.75	29.69	29.67	29.66	29.74	29.70	29.72
~ 3.5 m	29.70	29.70	29.76	29.75	29.68	29.67	29.67	29.73	29.72	29.72
~ 4.5 m	29.70	29.70	29.76	29.75	29.68	29.67	29.66	29.73	29.73	29.72
~ 5.5 m	29.70	29.70	29.76	29.75	29.68	29.67	29.67	29.73	29.73	29.72
~ 6.5 m	29.70	29.70	29.76	29.75	29.69	29.67	29.68	29.73	29.73	29.72
~ 7.5 m	29.70	29.70	29.76	29.75	29.69	29.67	29.67	29.73	-	29.72
~ 8.5 m	29.70	-	29.76	29.75	29.69	-	-	29.73	-	-
	WSQ1 Neap Flood	**WSQ2 Neap Flood**	**WSQ3 Neap Flood**	**WSQ4 Neap Flood**	**WSQ5 Neap Flood**	**WSQ1 Neap Ebb**	**WSQ2 Neap Ebb**	**WSQ3 Neap Ebb**	**WSQ4 Neap Ebb**	**WSQ5 Neap Ebb**
Depth	**Salinity (ppt)**									
~ 0.5 m	28.79	29.32	29.15	29.17	28.72	28.58	29.04	29.11	29.04	28.79
~ 1.5 m	28.83	29.35	29.15	29.19	28.75	28.73	28.96	29.12	29.07	28.75
~ 2.5 m	28.84	29.37	29.15	29.22	28.84	28.73	28.97	29.12	29.09	28.83
~ 3.5 m	28.85	29.42	29.16	29.22	28.92	28.86	28.97	29.12	29.09	28.88
~ 4.5 m	28.89	29.45	29.15	29.23	28.95	28.77	28.97	29.12	29.11	28.92
~ 5.5 m	28.90	29.46	29.15	29.23	28.95	28.86	28.96	29.12	29.13	28.94
~ 6.5 m	28.95	29.46	29.15	29.23	28.96	28.86	28.96	29.12	29.14	28.95
~ 7.5 m	28.94	29.47	29.15	29.23	29.01	28.87	28.96	29.12	29.14	28.94
~ 8.5 m	-	29.47	-	29.23	29.00	28.88	28.96	-	29.14	28.93

Table 3-4 In-situ turbidity readings across all tidal conditions and monitoring sites.

	WSQ1 Spring Flood	WSQ2 Spring Flood	WSQ3 Spring Flood	WSQ4 Spring Flood	WSQ5 Spring Flood	WSQ1 Spring Ebb	WSQ2 Spring Ebb	WSQ3 Spring Ebb	WSQ4 Spring Ebb	WSQ5 Spring Ebb
Depth	**Turbidity (NTU)**									
~ 0.5 m	2.18	6.70	3.61	6.01	2.35	4.62	4.49	2.08	4.53	2.24
~ 1.5 m	2.19	4.51	2.28	3.00	2.42	2.24	0.89	1.54	4.28	2.77
~ 2.5 m	2.52	4.49	2.48	2.54	2.36	2.22	1.06	1.62	1.13	2.73
~ 3.5 m	2.58	4.44	2.54	2.75	2.28	2.15	1.42	1.78	1.25	2.89
~ 4.5 m	2.36	4.29	2.68	2.93	2.43	2.50	1.40	1.74	1.12	2.88
~ 5.5 m	2.44	4.15	2.75	2.59	2.47	2.32	1.39	1.94	1.25	2.66
~ 6.5 m	2.74	4.29	2.69	2.45	2.44	2.4	1.51	1.75	1.31	2.74
~ 7.5 m	2.72	4.43	2.43	3.12	2.27	2.42	1.61	1.95	-	3.02
~ 8.5 m	2.48	-	2.51	2.90	2.46	-	-	2.06	-	-
	WSQ1 Neap Flood	**WSQ2 Neap Flood**	**WSQ3 Neap Flood**	**WSQ4 Neap Flood**	**WSQ5 Neap Flood**	**WSQ1 Neap Ebb**	**WSQ2 Neap Ebb**	**WSQ3 Neap Ebb**	**WSQ4 Neap Ebb**	**WSQ5 Neap Ebb**
Depth	**Turbidity (NTU)**									
~ 0.5 m	1.75	2.75	4.38	4.80	1.55	2.82	3.63	3.89	3.11	1.30
~ 1.5 m	1.56	3.49	4.12	3.81	1.53	1.48	2.73	4.08	3.16	1.29
~ 2.5 m	1.50	3.74	4.21	4.03	1.69	1.51	2.88	4.31	3.33	1.73
~ 3.5 m	1.56	4.84	4.29	4.10	1.64	1.39	2.73	3.95	3.19	1.82
~ 4.5 m	1.61	5.09	4.36	3.91	1.75	1.46	2.88	3.63	3.42	2.01
~ 5.5 m	1.51	5.39	4.41	4.23	1.86	1.34	2.69	3.96	3.81	2.08
~ 6.5 m	1.52	5.09	4.50	4.22	1.59	1.42	2.58	4.12	3.87	2.04
~ 7.5 m	1.58	4.93	12.85	4.09	2.05	1.34	2.59	5.02	4.10	1.88
~ 8.5 m	-	5.16	-	4.60	1.96	1.37	2.83	-	3.84	1.94

Table 3-5 In-situ pH readings across all tidal conditions and monitoring sites.

	WSQ1 Spring Flood	WSQ2 Spring Flood	WSQ3 Spring Flood	WSQ4 Spring Flood	WSQ5 Spring Flood	WSQ1 Spring Ebb	WSQ2 Spring Ebb	WSQ3 Spring Ebb	WSQ4 Spring Ebb	WSQ5 Spring Ebb
Depth	**pH**									
~ 0.5 m	7.77	7.58	8.06	7.85	7.86	7.68	7.95	7.90	7.87	7.70
~ 1.5 m	7.82	7.69	8.06	7.85	8.02	7.73	8.01	8.01	7.69	7.75
~ 2.5 m	7.84	7.88	8.02	7.86	8.02	7.86	8.03	7.98	7.80	7.78
~ 3.5 m	7.85	7.69	8.05	7.86	8.05	7.84	8.03	8.00	7.83	7.8
~ 4.5 m	7.90	7.76	8.05	7.86	8.05	7.85	8.02	7.99	7.85	7.82
~ 5.5 m	7.85	7.79	8.02	7.86	8.05	7.85	8.01	7.98	7.85	7.84
~ 6.5 m	7.88	7.81	8.03	7.86	8.04	7.86	7.99	7.93	7.85	7.85
~ 7.5 m	7.89	7.83	8.04	7.86	8.03	7.86	8.00	7.94	-	7.85
~ 8.5 m	7.88	-	8.03	7.86	8.02	-	-	7.95	-	-
	WSQ1 Neap Flood	**WSQ2 Neap Flood**	**WSQ3 Neap Flood**	**WSQ4 Neap Flood**	**WSQ5 Neap Flood**	**WSQ1 Neap Ebb**	**WSQ2 Neap Ebb**	**WSQ3 Neap Ebb**	**WSQ4 Neap Ebb**	**WSQ5 Neap Ebb**
Depth	**pH**									
~ 0.5 m	7.47	7.91	7.74	7.43	7.16	7.51	7.5	7.63	7.77	7.79
~ 1.5 m	7.54	7.96	7.88	7.73	7.45	7.79	7.55	7.77	7.87	7.80
~ 2.5 m	7.55	7.96	7.88	7.88	7.55	7.82	7.60	7.82	7.88	7.80
~ 3.5 m	7.55	7.96	7.87	7.93	7.61	7.81	7.69	7.84	7.88	7.81
~ 4.5 m	7.58	7.96	7.87	7.93	7.65	7.81	7.74	7.85	7.88	7.84
~ 5.5 m	7.61	7.96	7.87	7.95	7.74	7.80	7.78	7.85	7.89	7.85
~ 6.5 m	7.65	7.95	7.87	7.95	7.79	7.81	7.83	7.85	7.89	7.87
~ 7.5 m	7.66	7.95	7.87	7.94	7.82	7.83	7.86	7.85	7.89	7.91
~ 8.5 m	-	7.95	-	7.95	7.81	7.87	7.87	-	7.89	7.90

Table 3-6 In-situ dissolved oxygen readings across all tidal conditions and monitoring sites.

	WSQ1 Spring Flood	WSQ2 Spring Flood	WSQ3 Spring Flood	WSQ4 Spring Flood	WSQ5 Spring Flood	WSQ1 Spring Ebb	WSQ2 Spring Ebb	WSQ3 Spring Ebb	WSQ4 Spring Ebb	WSQ5 Spring Ebb
Depth	**Dissolved Oxygen mg/L**									
~ 0.5 m	6.37	6.52	6.34	6.34	7.34	6.39	6.34	6.41	6.37	6.19
~ 1.5 m	6.16	6.17	6.47	6.30	6.15	6.32	6.30	6.37	6.64	6.17
~ 2.5 m	6.12	6.08	6.26	6.25	6.11	6.12	6.25	6.25	6.60	6.15
~ 3.5 m	6.11	6.11	6.29	6.24	6.11	6.20	6.16	6.20	6.53	6.15
~ 4.5 m	6.11	6.10	6.27	6.21	6.11	6.18	6.15	6.17	6.38	6.12
~ 5.5 m	6.10	6.09	6.23	6.21	6.10	6.17	6.13	6.14	6.34	6.11
~ 6.5 m	6.10	6.08	6.23	6.21	6.09	6.13	6.09	6.14	6.26	6.11
~ 7.5 m	6.10	6.08	6.25	6.21	6.09	6.13	6.10	6.13	-	6.11
~ 8.5 m	6.10	-	6.23	6.20	6.09	-	-	6.13	-	-
	WSQ1 Neap Flood	**WSQ2 Neap Flood**	**WSQ3 Neap Flood**	**WSQ4 Neap Flood**	**WSQ5 Neap Flood**	**WSQ1 Neap Ebb**	**WSQ2 Neap Ebb**	**WSQ3 Neap Ebb**	**WSQ4 Neap Ebb**	**WSQ5 Neap Ebb**
Depth	**Dissolved Oxygen mg/L**									
~ 0.5 m	6.78	6.22	6.13	6.22	6.79	6.87	6.36	6.16	6.13	6.81
~ 1.5 m	6.77	6.08	6.02	6.17	6.80	6.66	6.12	6.01	6.02	6.80
~ 2.5 m	6.73	6.06	6.01	6.07	6.61	6.53	6.11	5.99	6.00	6.57
~ 3.5 m	6.43	6.03	6.01	6.05	6.34	6.39	6.10	5.98	5.99	6.40
~ 4.5 m	6.26	6.00	6.00	6.02	6.20	6.46	6.09	5.98	5.98	6.30
~ 5.5 m	6.24	5.99	5.99	6.03	6.18	6.36	6.09	5.98	5.95	6.23
~ 6.5 m	6.21	5.98	5.98	6.02	6.14	6.31	6.08	5.97	5.94	6.19
~ 7.5 m	6.20	5.97	5.97	6.02	6.06	6.28	6.08	5.97	5.93	6.19
~ 8.5 m	-	5.97	-	6.02	6.07	6.24	6.08	-	5.93	6.19

Table 3-7 In-situ light (PAR) readings across all tidal conditions and monitoring sites.

	WSQ1 Spring Flood	WSQ2 Spring Flood	WSQ3 Spring Flood	WSQ4 Spring Flood	WSQ5 Spring Flood	WSQ1 Spring Ebb	WSQ2 Spring Ebb	WSQ3 Spring Ebb	WSQ4 Spring Ebb	WSQ5 Spring Ebb
Depth	**Light (PAR) (µmol s^{-1} m^{-2})**									
~ 1 m	1044	341.64	186.28	1756.8	425.42	1383.8	1805.1	1779.8	1506.8	1796.8
~ 2 m	430.09	154.77	77.531	1007.9	269.16	836.48	634.07	646.36	218.86	705.63
~ 3 m	193.28	53.923	34.768	187.75	114.94	609.85	442.33	238.32	70.521	322.62
~ 4 m	74.111	10.362	19.783	73.311	50.51	252.5	389.01	88.347	40.128	166.72
~ 5 m	42.174	3.5487	11.182	48.318	30.661	110.43	280.38	40.505	24.555	52.095
~ 6 m	16.323	1.3381	5.8721	20.43	14.228	51.449	96.499	18.339	10.94	26.368
~ 7 m	6.3226	0.69093	2.1443	8.8052	12.073	33.355	67.644	8.5012	5.4413	15.809
~ 8 m	3.1358	0.25352	0.80811	3.3978	5.5522	10.064	43.893	2.7586	3.0372	5.4002
~ 9 m	1.3003	0.16177	0.30293	1.9117	2.0785	3.288	25.292	1.3176	0.9567	3.8687
~ 10 m	0.97336	0.076823	0.1319	0.89705	0.68112	1.5481	12.989	0.4453	0.48947	2.9937
	WSQ1 Neap Flood	**WSQ2 Neap Flood**	**WSQ3 Neap Flood**	**WSQ4 Neap Flood**	**WSQ5 Neap Flood**	**WSQ1 Neap Ebb**	**WSQ2 Neap Ebb**	**WSQ3 Neap Ebb**	**WSQ4 Neap Ebb**	**WSQ5 Neap Ebb**
Depth	**Light (PAR) (µmol s^{-1} m^{-2})**									
~ 1 m	1231.1	572.24	1397.2	179.42	2338.4	2753.4	358.94	1258.4	1288.5	1220.9
~ 2 m	439.24	96.516	462.01	39.175	26.595	1043.2	138.27	319.78	1036.3	633.04
~ 3 m	191.48	38.596	133.2	11.829	639.84	731.57	45.772	206.24	1070.1	239.78
~ 4 m	96.767	8.1009	94.586	7.8772	189.33	499.73	29.617	115.13	316.29	90.758
~ 5 m	40.767	16.439	55.69	4.1281	100.53	315.02	13.621	65.905	170.54	51.692
~ 6 m	22.695	9.342	35.121	1.8571	43.476	144.15	7.9886	32.748	198.43	20.638
~ 7 m	12.55	3.7386	22.625	0.95606	19.123	68.508	3.5289	18.451	28.572	17.787
~ 8 m	6.7406	1.0531	16.83	0.48033	8.9848	37.717	1.8408	11.697	9.5283	12.785
~ 9 m	4.1435	0.45369	6.9483	0.2706	4.4072	24.761	1.8708	6.76	2.9484	8.3357
~ 10 m	2.0817	0.19053	3.4677	0.11089	2.3082	14.557	1.0733	5.36	0.76931	4.4095

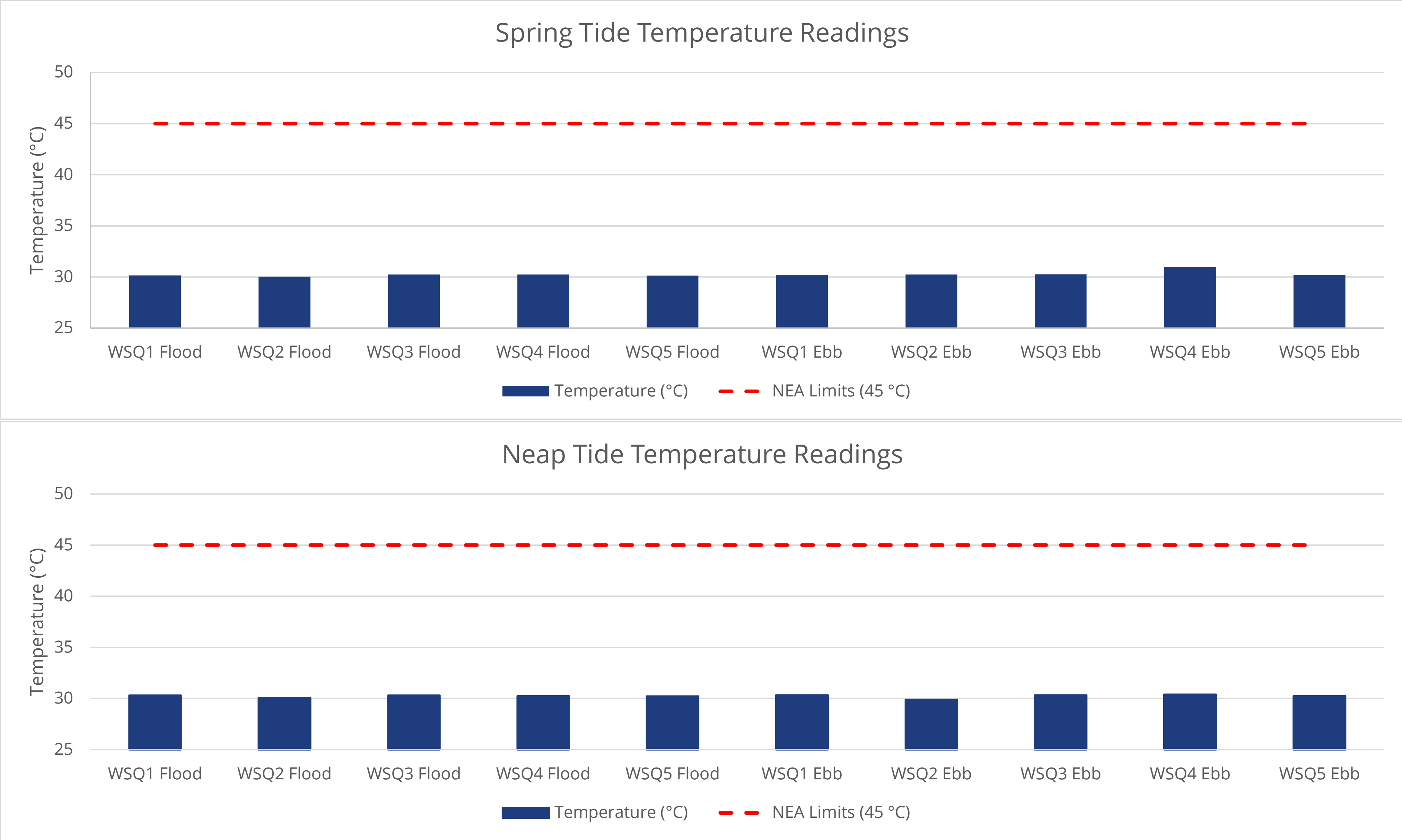
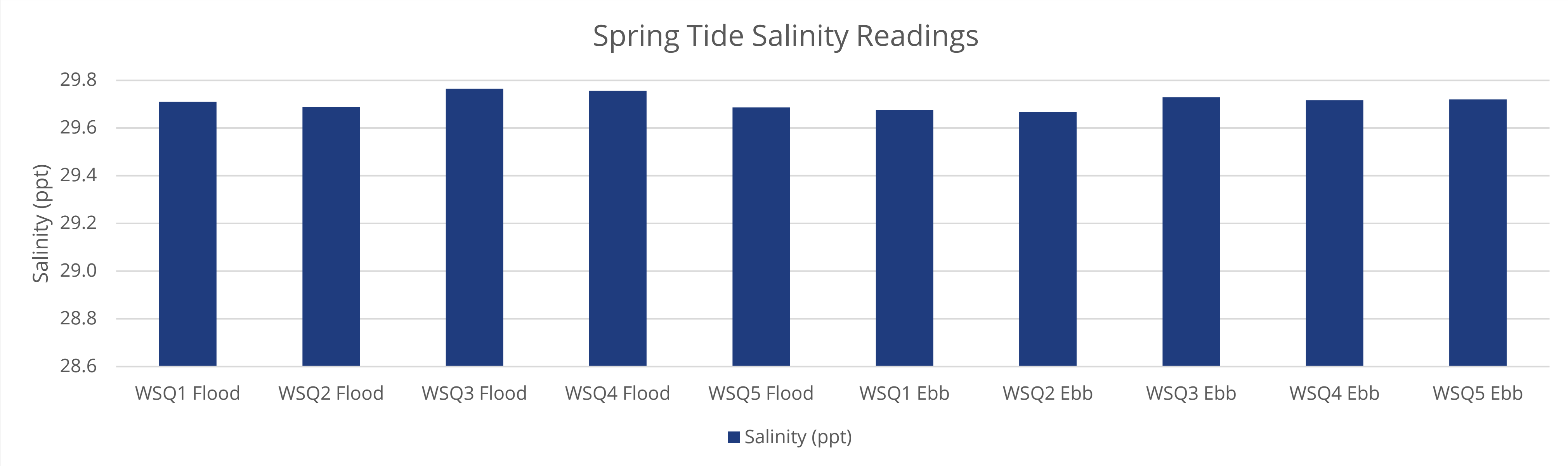


Figure 3-2 Average readings for temperature across spring and neap, flood and ebb tidal conditions sampling site.

Note: "*NEA*" refers to "*National Environmental Agency (NEA)*" of Singapore and the allowable limits for trade effluent discharge under the category of "watercourse".



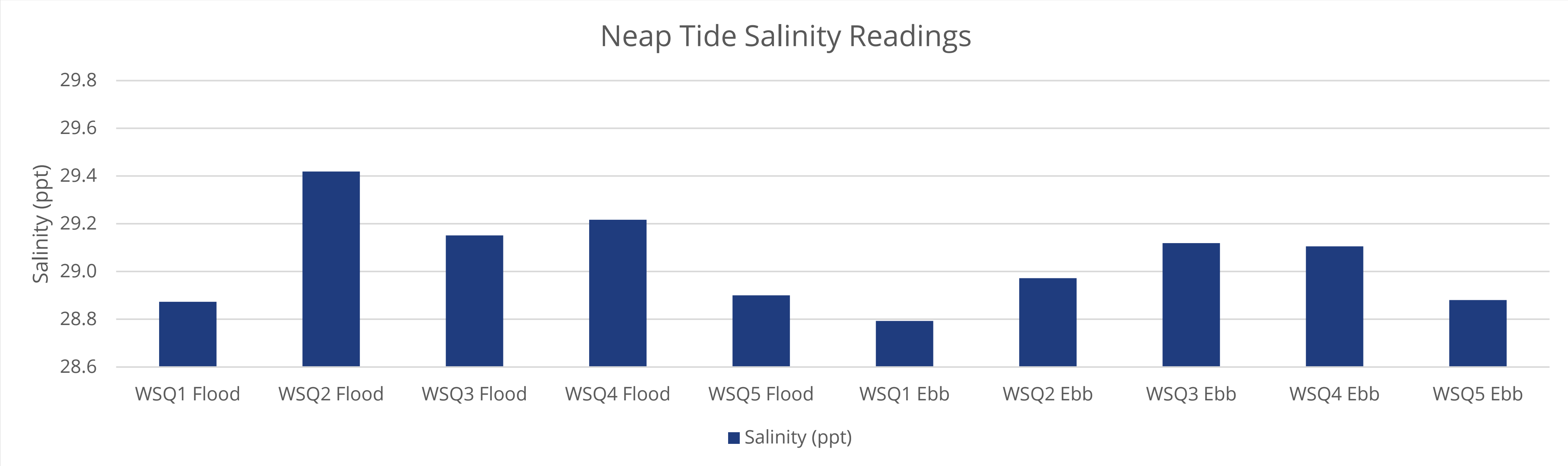
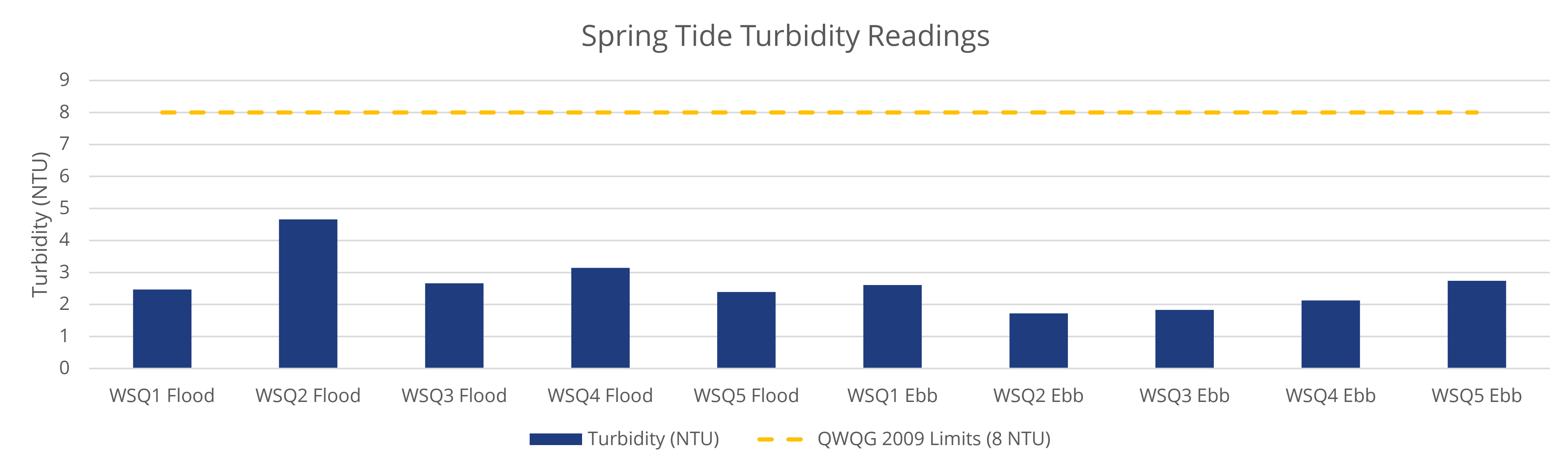


Figure 3-3 Average tide readings for salinity across spring and neap, flood and ebb tidal conditions at each sampling site.



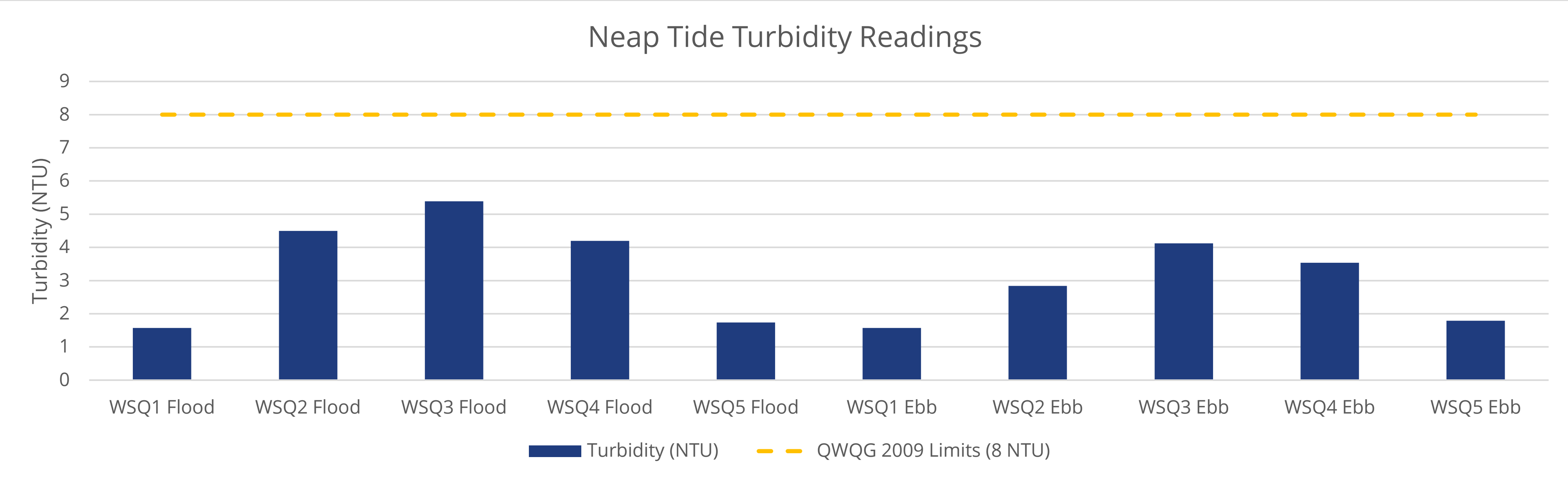
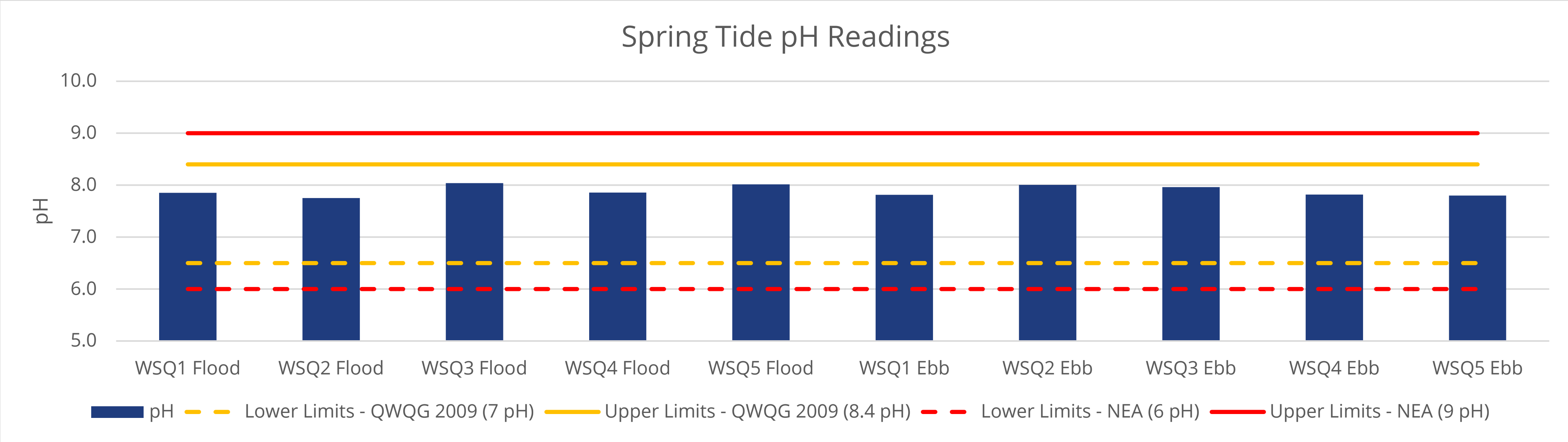


Figure 3-4 Average tide readings for turbidity across spring and neap, flood and ebb tidal conditions at each sampling site.

Note: *"QWQG 2009"* refers to *"Queensland Water Quality Guidelines 2009"*,



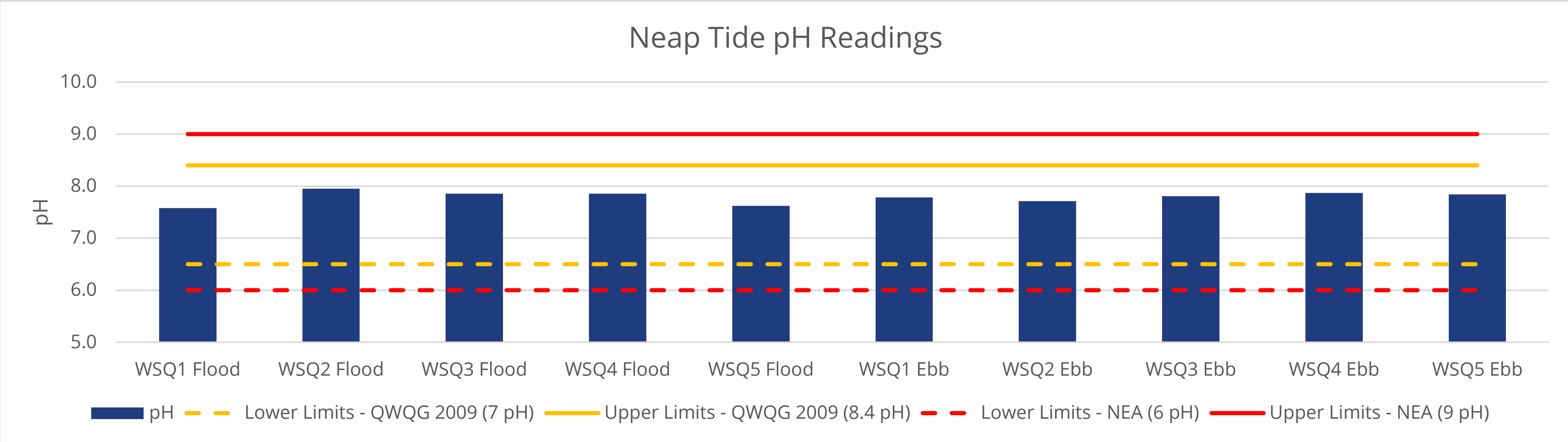
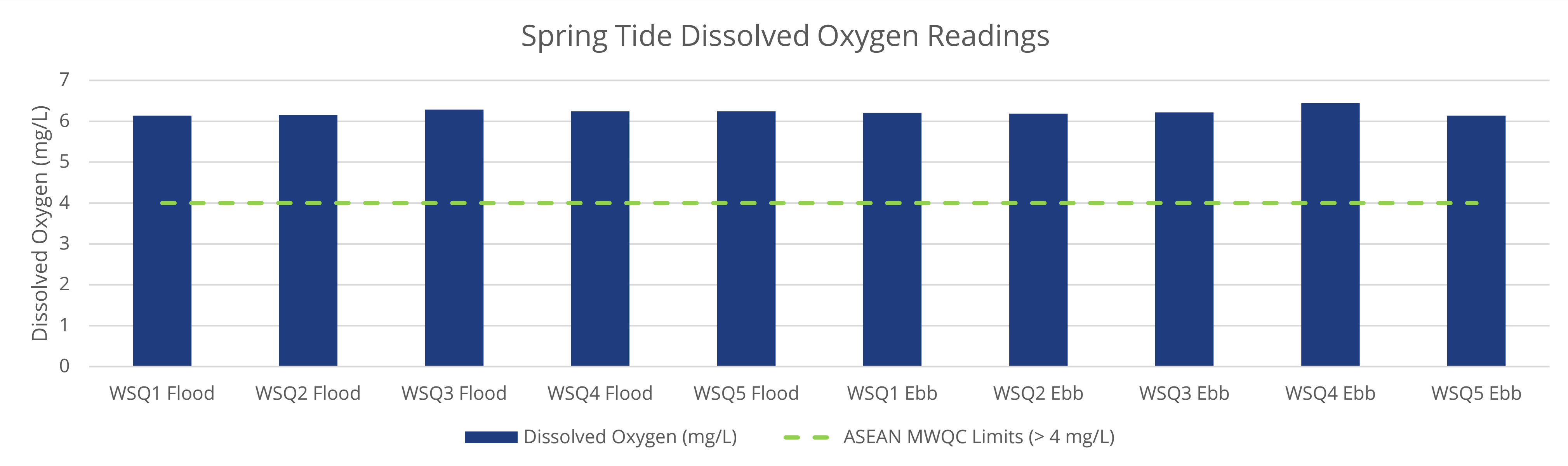


Figure 3-5 Average tide readings for pH across spring and neap, flood and ebb tidal conditions at each sampling site.

Note: "*QWQG 2009*" refers to "*Queensland Water Quality Guidelines 2009*", Table 3.31a. "*NEA*" refers to "*National Environmental Agency (NEA)*" of Singapore and the allowable limits for trade effluent discharge under the category of "watercourse"



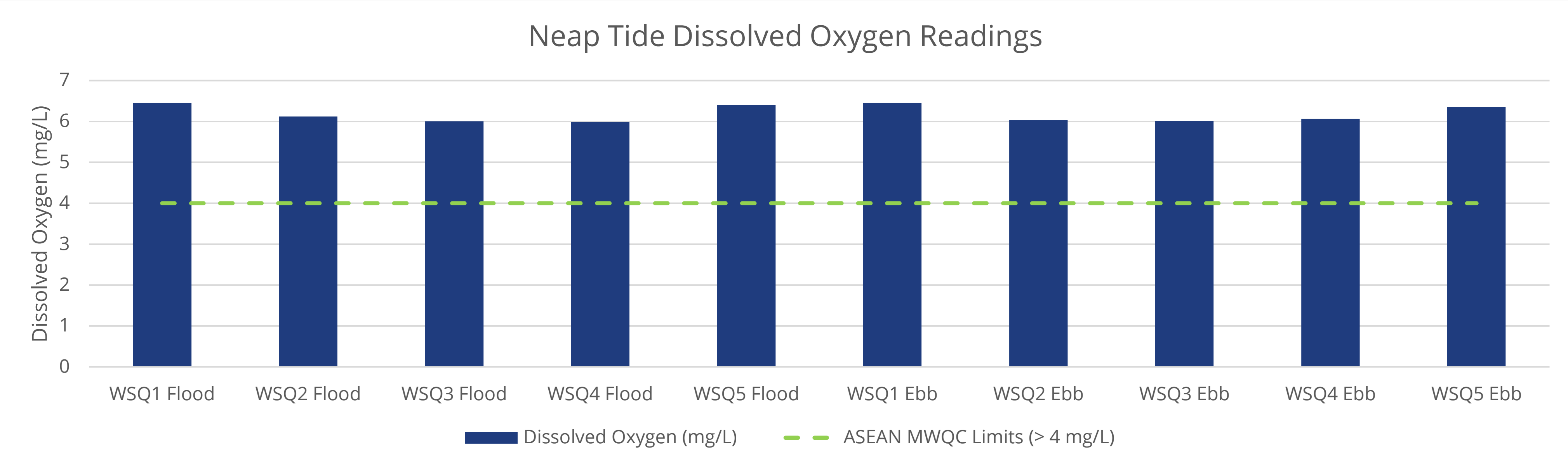


Figure 3-6 Average tide readings for dissolved oxygen across spring and neap, flood and ebb tidal conditions at each sampling site.

Note: "*ASEAN MWQC*" refers to "*ASEAN Marine Water Quality guidelines*"

Table 3-8 *Ex-situ* water quality results for spring flood and ebb tides compared against ASEAN MWQC.

Parameter	Unit	NEA Criteria[4]	ASEAN MWQC[5]	WSQ1 Spring Flood	WSQ2 Spring Flood	WSQ3 Spring Flood	WSQ4 Spring Flood	WSQ5 Spring Flood	WSQ1 Spring Ebb	WSQ2 Spring Ebb	WSQ3 Spring Ebb	WSQ4 Spring Ebb	WSQ5 Spring Ebb
Cadmium, Cd	µg/L	100	10	ND	ND	ND	ND	0.13	0.11	ND	ND	ND	ND
Chromium, Cr	µg/L	1000	48	0.32	0.41	0.42	0.50	0.67	0.42	1.04	0.47	0.53	0.45
Copper, Cu	µg/L	100	2.9	0.81	0.56	0.63	0.65	0.73	0.53	1.03	0.83	0.68	0.63
Lead, Pb	µg/L	100	8.5	0.11	ND	ND	ND	ND	ND	0.16	ND	ND	ND
Mercury, Hg	µg/L	50	0.16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel, Ni	µg/L	1000		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc, Zn	µg/L	1000	50	1.29	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrite, NO2–N	mg/L		0.055	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate, NO3–N	mg/L		0.06	**0.082**	**0.081**	0.020	0.032	**0.082**	**0.080**	**0.085**	**0.076**	**0.068**	**0.089**
Total Nitrogen, TN	mg/L			0.15	0.30	0.18	0.13	0.13	0.22	0.15	0.23	0.12	0.18
Total Phosphorus, TP	mg/L			0.013	0.021	0.018	0.010	ND	ND	ND	0.016	ND	ND
Phosphate, PO4–P	mg/L	5	0.015	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ammonia, NH3–N	mg/L		0.07	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Ammonia, (NH3 + NH4)	mg/L			ND	0.011	0.010	ND	ND	0.011	ND	ND	0.011	ND
Total Organic Carbon, TOC	mg/L			2.29	2.24	2.09	2.12	2.19	2.15	2.19	2.38	2.36	2.29
Biochemical Oxygen Demand (BOD_5)	mg/L			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Suspended Solids, TSS	mg/L		≤ 10%*	4.20	6.90	7.10	6.80	4.80	4.20	3.60	6.80	2.90	9.20
Oil & Grease	mg/L		0.14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Faecal Coliforms	MPN / 100 mL		100.00	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Parameter	Unit	NEA Criteria[4]	ASEAN MWQC[5]	WSQ1 Spring Flood	WSQ2 Spring Flood	WSQ3 Spring Flood	WSQ4 Spring Flood	WSQ5 Spring Flood	WSQ1 Spring Ebb	WSQ2 Spring Ebb	WSQ3 Spring Ebb	WSQ4 Spring Ebb	WSQ5 Spring Ebb
Enterococci	cfu / 100 mL		35	ND	ND	6	4	ND	ND	ND	ND	ND	ND

Note:
1. * Permissible 10% maximum increase over seasonal average concentrations.
2. "ND" = Not detected.
3. Red highlights with white bold font indicate levels exceeding ASEAN MWQC values.
4. National Environmental Agency (NEA) of Singapore allowable limits for trade effluent discharge under the category of "watercourse".
5. ASEAN Marine Water Quality guidelines.

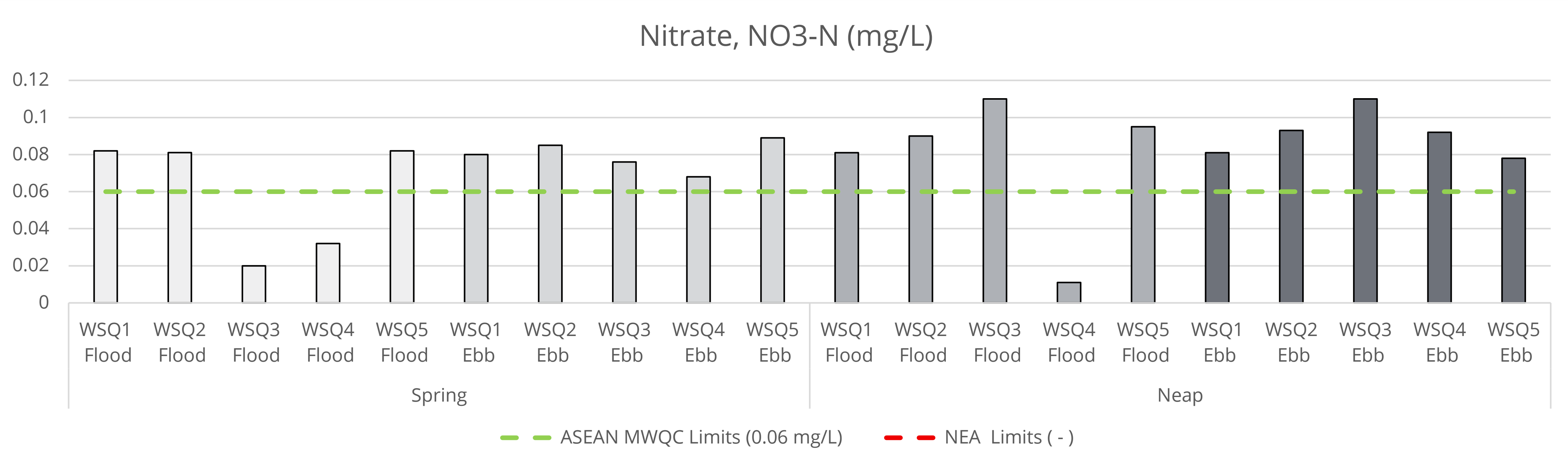
Table 3-9 *Ex-situ* water quality results for neap flood and ebb tides compared against ASEAN MWQC.

Parameter	Unit	NEA Criteria[4]	ASEAN MWQC[5]	WSQ1 Neap Flood	WSQ2 Neap Flood	WSQ3 Neap Flood	WSQ4 Neap Flood	WSQ5 Neap Flood	WSQ1 Neap Ebb	WSQ2 Neap Ebb	WSQ3 Neap Ebb	WSQ4 Neap Ebb	WSQ5 Neap Ebb
Cadmium, Cd	μg/L	100	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, Cr	μg/L	1000	48	0.20	0.30	0.25	0.26	0.26	0.21	0.19	0.18	0.22	0.19
Copper, Cu	μg/L	100	2.9	1.03	0.96	0.66	0.88	0.53	1.15	0.69	0.68	0.72	0.60
Lead, Pb	μg/L	100	8.5	ND	ND	ND	ND	0.10	0.26	ND	ND	ND	ND
Mercury, Hg	μg/L	50	0.16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel, Ni	μg/L	1000		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc, Zn	μg/L	1000	50	2.12	6.45	1.50	2.13	1.30	2.86	0.89	1.16	1.84	1.72
Nitrite, NO2–N	mg/L		0.055	0.022	0.016	0.020	0.020	0.015	ND	ND	0.012	0.021	0.017
Nitrate, NO3–N	mg/L		0.06	**0.081**	**0.090**	**0.11**	0.011	**0.095**	**0.081**	**0.093**	**0.11**	**0.092**	**0.078**
Total Nitrogen, TN	mg/L			0.19	0.16	0.20	0.18	0.22	0.17	0.18	0.19	0.19	0.17
Total Phosphorus, TP	mg/L			0.021	0.016	0.022	0.019	0.018	0.019	0.015	0.017	0.023	0.017
Phosphate, PO4–P	mg/L	5	0.015	ND	0.011	0.011	ND	ND	ND	ND	0.010	0.012	ND
Ammonia, NH3–N	mg/L		0.07	ND	ND	ND	0.019	ND	ND	ND	ND	ND	ND

Parameter	Unit	NEA Criteria[4]	ASEAN MWQC[5]	WSQ1 Neap Flood	WSQ2 Neap Flood	WSQ3 Neap Flood	WSQ4 Neap Flood	WSQ5 Neap Flood	WSQ1 Neap Ebb	WSQ2 Neap Ebb	WSQ3 Neap Ebb	WSQ4 Neap Ebb	WSQ5 Neap Ebb
Total Ammonia, (NH3 + NH4)	mg/L			ND	ND	ND	0.024	ND	ND	ND	ND	0.011	ND
Total Organic Carbon, TOC	mg/L			2.16	2.02	2.02	2.10	2.20	2.27	2.13	2.23	2.15	2.15
Biochemical Oxygen Demand (BOD)	mg/L			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Suspended Solids, TSS	mg/L		≤ 10%*	2.40	7.70	9.20	8.30	5.70	5.40	4.10	8.80	7.80	3.60
Oil & Grease	mg/L		0.14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Faecal Coliforms	MPN / 100 mL		100.00	20	2	28	24	6	3	1	48	**110**	8
Enterococci	cfu / 100 mL		35	4	6	14	14	12	8	ND	20	**38**	18

Note:

1. * Permissible 10% maximum increase over seasonal average concentrations.
2. “ND” = Not detected.
3. Red highlights with white bold font indicate levels exceeding ASEAN MWQC values.
4. National Environmental Agency (NEA) of Singapore allowable limits for trade effluent discharge under the category of “watercourse”.
5. ASEAN Marine Water Quality guidelines.



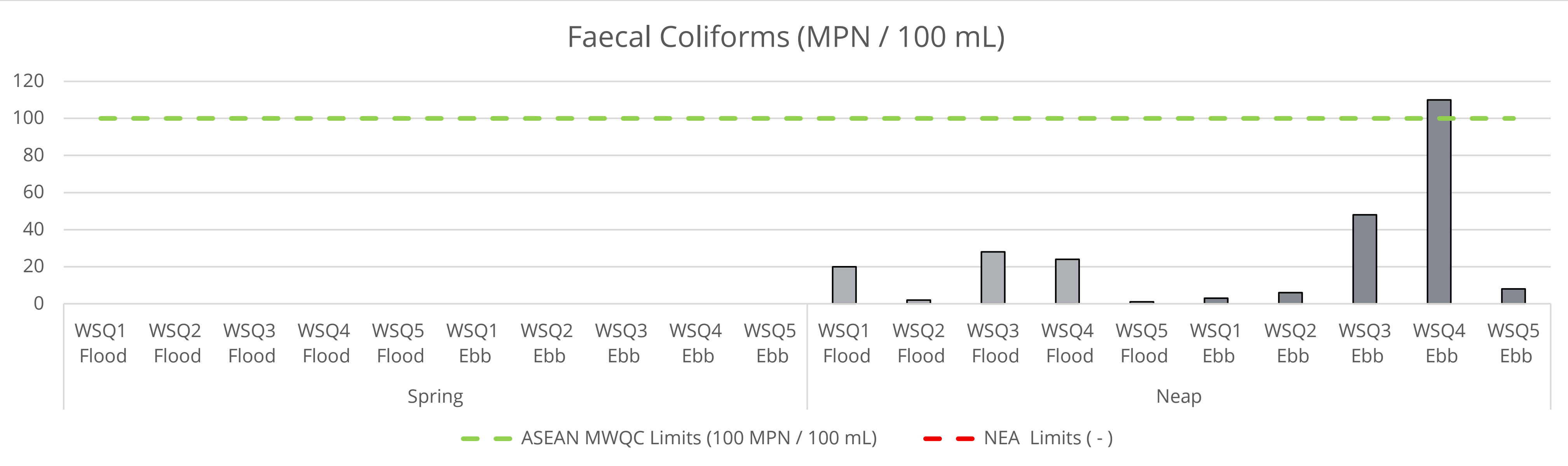


Figure 3-7 Laboratory analysis for nitrate and faecal coliform concentration levels in comparison to ASEAN MWQC and NEA limits.

Note: “*ASEAN MWQC*” refers to “*ASEAN Marine Water Quality guidelines*”. “*NEA*” refers to “*National Environmental Agency (NEA)*” of Singapore and the allowable limits for trade effluent discharge under the category of “watercourse”

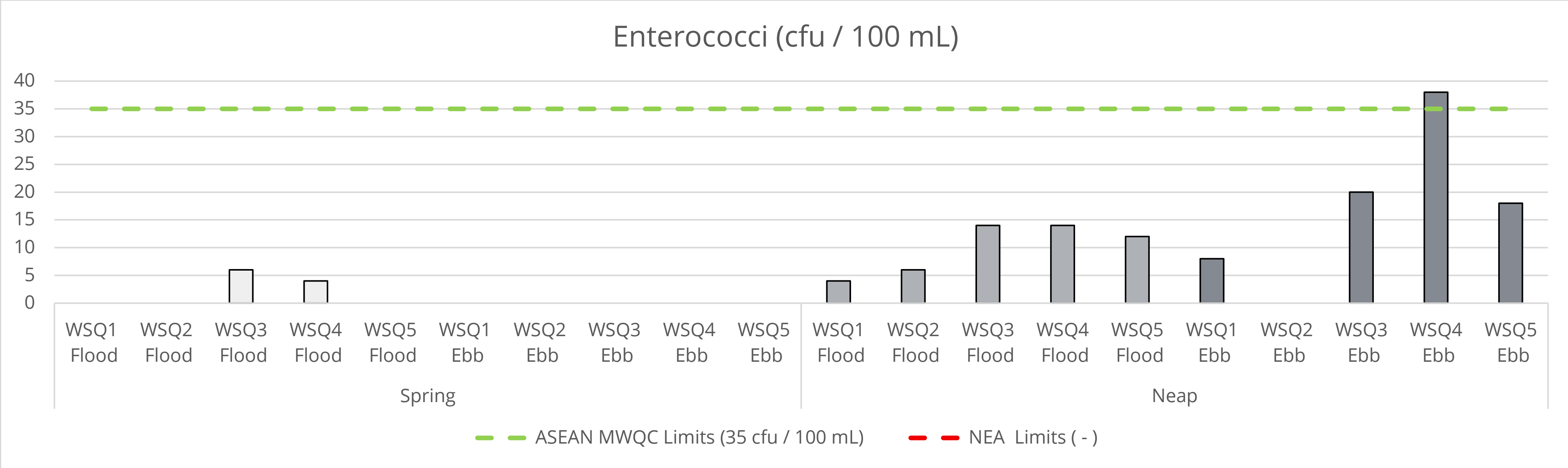


Figure 3-8 Laboratory analysis for enterococci concentration levels in comparison to ASEAN MWQC and NEA limits.

Note: "*ASEAN MWQC*" refers to "*ASEAN Marine Water Quality guidelines*". "*NEA*" refers to "*National Environmental Agency (NEA)*" of Singapore and the allowable limits for trade effluent discharge under the category of "watercourse"

3.2 PLANKTON

A total of five zooplankton phyla belonging to Annelida, Arthropoda, Mollusca, Chordata and Rotifera with 13 species were identified across five sampling sites. The dominant zooplankton Family was Paracalanidae copepods, accounting for 22-67% of total abundance across all replicates. **Table 3-10** summarizes the findings of zooplankton phyla.

A total of two phytoplankton phyla belonging to Dinophyta and Ochrophyta with nine species were identified species five sampling sites. Three unidentified species were recorded at WSQ1 in the third replicate. The dominant phytoplankton species identified were:

- *Skeletonema* sp., contributing approximately 60%-100% across replicates.
- *Chaetoceros* sp., contributing approximately 5%-35% across replicates.

A summary of phytoplankton findings is provided in **Table 3-11**.

Detailed laboratory reports on zooplankton and phytoplankton are provided in **Appendix B**.

Table 3-10 Zooplankton diversity collected at each station.

Zooplankton							
Phyla	**Lower Taxon**	WSQ1 Replicate 1		WSQ1 Replicate 2		WSQ1 Replicate 3	
		Count	Percentage	Count	Percentage	Count	Percentage
Annelida	Polychaete worm	1	2.4%				
Arthropoda	F. Paracalanidae copepod	20	48.8%	27	67.5%	23	60.5%
	Acartia sp.	5	12.2%	4	10.0%	4	10.5%
	Euterpina sp.			1	2.5%		
	Cirriped			1	2.5%	2	5.3%
	Copepod nauplii	4	9.8%	2	5.0%	3	7.9%
	Oithona sp.	6	14.6%	2	5.0%	6	15.8%
	Shrimp Larvae	3	7.3%				
	Harpaticoid copepod	2	4.9%	3	7.5%		
Total Count		**41**		**40**		**38**	
Lab Volume		**1050**		**1030**		**1050**	
Volume Counted		**30 mL**		**30 mL**		**30 mL**	

Zooplankton							
Phyla	**Lower Taxon**	WSQ2 Replicate 1		WSQ2 Replicate 2		WSQ2 Replicate 3	
		Count	Percentage	Count	Percentage	Count	Percentage
Annelida	Polychaete worm	3	8.8%				
Arthropoda	F. Paracalanidae copepod	8	23.5%	9	29%	14	42.4%
	Acartia sp.	7	20.6%	4	12.9%	5	15.2%
	Cirriped	1	2.9%	2	6.5%	2	6.1%
	Copepod nauplii	5	14.7%	5	16.1%	4	12.1%
	Oithona sp.	7	20.6%	10	32.3%	6	18.2%
	Harpaticoid copepod	2	5.9%	1	3.2%	2	6.1%
Mollusca	Gastropod	1	2.9%				
Total Count		**34**		**31**		**33**	
Lab Volume		**980**		**1000**		**1000**	
Volume Counted		**300 mL**		**500 mL**		**250 mL**	

Zooplankton							
Phyla	**Lower Taxon**	WSQ3 Replicate 1		WSQ3 Replicate 2		WSQ3 Replicate 3	
		Count	Percentage	Count	Percentage	Count	Percentage
Annelida	Polychaete worm	2	4.5%			3	6.0%
Arthropoda	*F. Paracalanidae* copepod	13	29.5%	9	22.5%	13	26.0%
	Acartia sp.	5	11.5%	1	2.5%	2	4.0%
	Euterpina sp.					2	4.0%
	Cirriped	20	45.5%	13	32.5%	15	30.0%
	Copepod nauplii			13	32.5%	10	20.0%
	Oithona sp.	2	4.5%	4	10.0%	4	8.0%
	Harpaticoid copepod	2	4.5%				
Mollusca	Gastropod					1	2.0%
Total Count		**44**		**40**		**50**	
Lab Volume		**980**		**1100**		**1100**	
Volume Counted		**50 mL**		**150 mL**		**200 mL**	

Zooplankton							
Phyla	**Lower Taxon**	WSQ4 Replicate 1		WSQ4 Replicate 2		WSQ4 Replicate 3	
		Count	Percentage	Count	Percentage	Count	Percentage
Annelida	Polychaete worm	2	5.0%	1	1.9%	2	3.9%
Arthropoda	F. Paracalanidae copepod	15	37.5%	20	38.5%	14	27.5%
	Acartia sp.	2	5.0%	5	9.5%	1	2.0%
	Euterpina sp.			3	5.8%	1	2.0%
	Cirriped	12	30.0%	7	13.5%	7	13.7%
	Copepod nauplii	5	12.5%	12	23.1%	25	49.0%
	Oithona sp.			3	5.8%		
	Shrimp Larvae					1	2.0%
	Harpaticoid copepod	2	5.0%	1	1.9%		
Chordata	*Appendicularia* sp.	1	2.5%				
Mollusca	Gastropod	1	2.5%				
Total Count		**40**		**52**		**51**	
Lab Volume		**990**		**950**		**1000**	
Volume Counted		**100 mL**		**100 mL**		**100 mL**	

Zooplankton							
Phyla	**Lower Taxon**	WSQ5 Replicate 1		WSQ5 Replicate 2		WSQ5 Replicate 3	
		Count	Percentage	Count	Percentage	Count	Percentage
Annelida	Polychaete worm	1	2.2%	1	2.4%		
Arthropoda	F. Paracalanidae copepod	15	32.6%	11	26.2%	16	43.2%
	Acartia sp.	3	6.5%	4	9.5%	3	8.1%
	Temora sp.	2	4.3%	2	4.8%	2	5.4%
	Cirriped	6	13.0%	6	14.3%	10	27.0%
	Copepod nauplii	4	8.7%	7	16.7%	6	16.2%
	Oithona sp.	9	19.6%	4	9.5%		
	Shrimp Larvae	3	6.5%				
	Harpaticoid copepod			5	11.9%		
Mollusca	Gastropod	3	6.5%				
Rotifera	Rotifer species			2	4.8%		
Total Count		**46**		**42**		**37**	
Lab Volume		**910**		**990**		**880**	
Volume Counted		**100 mL**		**200 mL**		**100 mL**	

Table 3-11 Phytoplankton diversity collected at each station.

Phytoplankton							
Phyla	**Lower Taxon**	WSQ1 Replicate 1		WSQ1 Replicate 2		WSQ1 Replicate 3	
		Count	Percentage	Count	Percentage	Count	Percentage
Dinophyta	*Dinophysis* sp.	1	0.5%				
Ochrophyta	*Chaetoceros* sp.	61	29.2%	50	23.1%	23	11.1%
	Cyclotella sp.	2	1.0%			2	1.0%
	Ditylum sp.			2	0.9%	4	1.9%
	Odontella sp.	3	1.4%			1	0.5%
	Pleurosigma sp.			1	0.5%	1	0.5%
	Skeletonema sp.	142	67.9%	163	75.5%	173	83.6%
Unknown	Unknown					3	1.4%
Total Count		**209**		**216**		**207**	
No. of organisms per 1 mL		**1,045**		**1,080**		**1,035**	

Phytoplankton							
Phyla	**Lower Taxon**	WSQ2 Replicate 1		WSQ2 Replicate 2		WSQ2 Replicate 3	
		Count	Percentage	Count	Percentage	Count	Percentage
Ochrophyta	*Chaetoceros* sp.	28	11.6%	41	17.7%	53	22.6%
	Cyclotella sp.			2	0.9%		
	Ditylum sp.			2	0.9%	3	1.3%
	Odontella sp.					1	0.4%
	Skeletonema sp.	213	88.4%	186	80.5%	178	75.7%
Total Count		**241**		**231**		**235**	
No. of organisms per 1 mL		**5,477**		**4,125**		**4,896**	

Phytoplankton							
Phyla	**Lower Taxon**	WSQ3 Replicate 1		WSQ3 Replicate 2		WSQ3 Replicate 3	
		Count	Percentage	Count	Percentage	Count	Percentage
Ochrophyta	*Chaetoceros* sp.	59	26.1%	2	0.9%	8	3.6%
	Ditylum sp.					2	0.9%
	Rhizosolenia sp.			1	0.5%		
	Skeletonema sp.	167	73.9%	213	98.6%	211	95.5%
Total Count		**226**		**216**		**221**	
No. of organisms per 1 mL		**6,647**		**5,023**		**5,667**	

Phytoplankton							
Phyla	**Lower Taxon**	WSQ4 Replicate 1		WSQ4 Replicate 2		WSQ4 Replicate 3	
		Count	Percentage	Count	Percentage	Count	Percentage
Dinophyta	*Dinophysis* sp.					1	0.5%
	Chaetoceros sp.			20	9.5%	35	16.7%
	Ditylum sp.			4	1.9%	5	2.4%
	Skeletonema sp.	219	100.0%	187	88.6%	168	80.4%
Total Count		**219**		**211**		**209**	
No. of organisms per 1 mL		**9,522**		**8,115**		**8,038**	

Phytoplankton							
Phyla	**Lower Taxon**	WSQ5 Replicate 1		WSQ5 Replicate 2		WSQ5 Replicate 3	
		Count	Percentage	Count	Percentage	Count	Percentage
Dinophyta	*Dinophysis* sp.						
Ochrophyta	*Coscinodiscus* sp.	2	1.1%			4	1.8%
	Chaetoceros sp.	63	36.0%	80		32	14.3%
	Cyclotella sp.	1	0.6%	1	0.5%	2	0.9%
	Ditylum sp.	5	2.9%	1	0.5%		
	Odontella sp.			1	0.5%		
	Pleurosigma sp.			1	0.5%	1	0.4%
	Rhizosolenia sp.						
	Skeletonema sp.	104	59.4%	136	61.8%	184	82.25%
Total Count		**175**		**220**		**223**	
No. of organisms per 1 mL		**875**		**1,100**		**1,115**	

3.3 SEDIMENT QUALITY

Sediment sampling was conducted on 05 August 2025, with one Van Veen grab sample collected from each location (**Figure 2-1**). Sample descriptions with their respective particle size distribution can be found in **Table 3-12**.**Table 3-13** represents sediment quality results, including polycyclic aromatic hydrocarbons (PAHs) which were largely below detection limits across all sites.

Where applicable, sediment quality results were compared against intervention values according to Dutch Pollution Standards (Esdat Environmental Database Management Software, 2000) and MPA guidelines (Maritime and Port Authority of Singapore, 2014), and these values can reflect soil contamination and suggest soil functionality.

All comprehensive laboratory reports on sediment quality are provided in **Appendix C**.

Table 3-12 Particle size distribution for sites WSQ1-WSQ5

Site	Sample Description	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
	Particle size range (mm)	0.0001-0.002	0.002-0.06	0.06-2	2-60
WSQ1	Greenish grey, slightly sandy silt	38	59	3	0
WSQ2	Greenish grey, very gravelly silty sand	5	8	47	40
WSQ3	Light brownish grey slightly gravelly, slightly silty sand	3	3	92	2
WSQ4	Dark greenish grey slightly gravelly silty sand with shell fragments	7	10	81	2
WSQ5	Light brownish grey slightly gravelly slightly silty sand	2	2	94	2

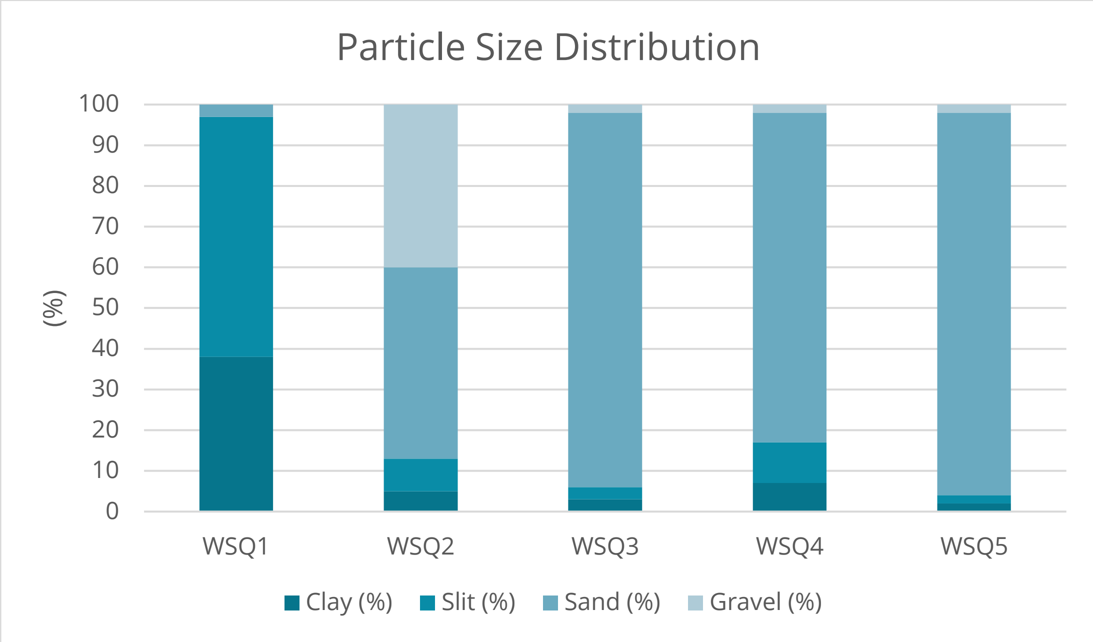


Figure 3-9 Graphical particle size distribution for sites WSQ1-WSQ5

No parameters exceeded intervention values in the Dutch Pollution Standards and MPA guidelines (**Table 3**), and no PAH compounds were detected in the sediment collected from all 5 sampling locations.

No PAH compounds were detected across all stations. This is a positive indication given the industrial context of Jurong Island, where multiple petrochemical facilities are located. The absence of PAHs may suggest effective management of industrial effluents and adherence to discharge regulations. However, it is also possible that more recent layers of cleaner sediment have been deposited over historical contamination, masking potential legacy inputs. Sediment coring is therefore recommended for future monitoring to differentiate between recent and historical deposition patterns. Complementary water sampling is also advisable, as hydrocarbons are often present in the water column or surface microlayer rather than within sediments.

The metals of potential concern, Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb), and Zinc (Zn), were all recorded at concentrations far below both DIV and MPA thresholds. The absence of metal exceedances suggests that sediment quality is not likely to present risks to benthic organisms or to interfere with sediment disposal activities.

Some other parameters that were detected but were not included in the Dutch intervention values (DIV) or MPA guidelines include Total Organic Carbon (TOC), Iron (Fe), Vanadium (V) and Aluminum (Al). TOC is the sum of particulate organic carbon (POC) and dissolved organic carbon (DOC). Some possible sources of TOC are wood debris, decomposed plants and animals, ashes, or hydrocarbon from oil, tars, and plastics. TOC values at WSQ1–WSQ4 ranged from 0.45–0.61%, which can imply low organic enrichment and proper waste disposal. In WSQ5, no TOC was detected (with detection limit of 0.3%). The uniformly low TOC across sites may reflect strong hydrodynamic flushing typical of Singapore Strait waters (Chen et al., 2005) and low retention of organic matter in this industrial coastal setting.

No significant trend was observed between sampling sites for Fe, V and Al.

Table 3-13 Sediment quality results for sampling sites WSQ1 to WSQ5.

Parameter	Unit	Dutch Intervention Values (DIV)	MPA Guidelines[3]	WSQ1	WSQ2	WSQ3	WSQ4	WSQ5	LOR[1]
Total Organic Carbon (TOC)	%	-	-	0.51	0.61	0.45	0.59	ND	**0.3**
Total Petroleum Hydrocarbons (TPH)	mg/kg	-	-	52.0	47.5	24.7	24.4	10.9	**10**
Aluminium, Al	mg/kg	-	-	12,579	5,997	2,646	4,346	1,584	**0.15**
Arsenic, As	mg/kg	55	30	8.78	20.7	5.60	7.40	5.66	**1.25**
Barium, Ba	mg/kg	625	-	28.0	9.50	4.62	8.08	4.25	**0.01**
Cadmium, Cd	mg/kg	12	1	0.45	0.46	0.16	0.18	0.15	**0.075**
Chromium, Cr	mg/kg	380	50	12.7	12.5	4.97	6.93	4.05	**0.05**
Copper, Cu	mg/kg	190	55	17.5	6.14	2.72	4.24	2.59	**0.2**
Iron, Fe	mg/kg	-	-	22,330	21,903	8,449	10,018	7,272	**0.1**
Nickel, Ni	mg/kg	210	35	8.53	6.33	2.87	3.79	1.85	**0.25**
Lead, Pb	mg/kg	530	65	21.7	16.5	7.85	9.56	4.75	**1**
Vanadium, V	mg/kg	-	-	16.5	21.2	6.45	11.6	6.44	**0.1**
Zinc, Zn	mg/kg	720	150	85.4	39.0	20.6	29.2	10.1	**0.1**

Parameter	Unit	Dutch Intervention Values (DIV)	MPA Guidelines[3]	WSQ1	WSQ2	WSQ3	WSQ4	WSQ5	LOR[1]
Mercury, Hg	mg/kg	10	0.8	0.061	0.040	0.023	0.027	ND	**0.01**
Polycyclic Aromatic Hydrocarbons (PAHs)									
Acenaphthene	mg/kg	-	-	ND[2]	ND	ND	ND	ND	**0.1**
Acenaphthylene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Anthracene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Benzo(a)anthracene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Benzo(a)pyrene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Benzo(b)fluoranthene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Benzo(ghi)perylene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Benzo(k)fluoranthene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Chrysene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Dibenz(ah)anthracene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Fluoranthene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Fluorene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**

Parameter	Unit	Dutch Intervention Values (DIV)	MPA Guidelines[3]	WSQ1	WSQ2	WSQ3	WSQ4	WSQ5	LOR[1]
Indeno(1,2,3cd)pyrene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Naphthalene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Phenanthrene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**
Pyrene	mg/kg	-	-	ND	ND	ND	ND	ND	**0.1**

Note:
1. LOR = Limit of Reporting. This value may also represent Detection Limit required for the project.
2. "ND" = Not detected. The data reported is less than the LOR.
3. While MPA guidelines are applicable for dumping of dredged materials, it provides a local guidance for marine sediment chemical characteristics.

3.4 MACROBENTHOS

A total of 398 macrobenthos individuals belonging to four (4) invertebrate classes (i.e., Malacostraca, Ophiuroidea, Bivalvia, Gastropoda), grouped into 37 invertebrate families, were recorded across the two macrobenthos sampling stations (**Table 3-14**). Of these, eight families fall under Gastropoda (aquatic snails), four families were classified under Bivalvia (bivalves), one family (indeterminate) under Malacostraca (Brachyura; true crabs), and one family (indeterminate) under Ophiuroidea (brittle stars). For the overall abundance across the surveyed stations, computed values ranged from a minimum of 15 individuals to a maximum of 218 individuals.

Macrobenthos communities were dominated by minute marine snails (Gastropoda) across sampling stations, in which computed relative abundances (RA; %) across WSQ1 and WSQ3 reached ≥82.6% (**Figure 3-11**). Comparing the resulting macrobenthos abundance across stations (**Figure 3-10**), WSQ3 had a higher mean abundance (99.6 individuals) as opposed to WSQ1 (30.4 individuals). Macrobenthos collected from WSQ3 were dominantly comprised of minute columbellid snails (Columbellidae; 39.7 individuals; 39.8%), triphorid snails (Triphoridae; 11.3 individuals; 11.4%), and minute pyramidellid snails (Pyramidellidae; 8.0 individuals; 8.0%). On the other hand, macrobenthos found in WSQ1 were mainly composed of turritellid snails (Turritellidae; 13.0 individuals; 42.4%), nassariid snails (Nassariidae; 3.7 individuals; 12.0%), and tellinid bivalves (Tellinidae; 3.0 individuals; 9.8%). Additionally, **Table 3-15** and **Figure 3-12** shows the estimated macroinvertebrate density across sites and the provides supplementary information on the macrobenthic community composition; with the highest and lowest macrobenthos densities being recorded in WSQ3 (2,491.6 individuals m^{-2}) and WSQ1 (766.4 individuals m^{-2}), respectively.

Table 3-14 List of Macrobenthos Taxa with Corresponding Mean Abundance (no. of individuals) Recorded across Macrobenthos Sampling Stations

SN	Phylum	Class	Order	Family	Sampling Station	
					WSQ1	WSQ3
1	Arthropoda	Malacostraca	Decapoda	Family indet	0.3	0.0
2	Echinodermata	Ophiuroidea	Order indet	Family indet	1.0	0.0
3	Mollusca	Bivalvia	Arcida	Arcidae	0.0	0.3
4	Mollusca	Bivalvia	Cardiida	Tellinidae	3.0	0.0
5	Mollusca	Bivalvia	Lucinida	Lucinidae	1.0	1.0
6	Mollusca	Gastropoda	Caenogastropoda	Cerithiidae	0.7	2.0
7	Mollusca	Gastropoda	Caenogastropoda	Cerithiopsidae	0.0	0.3
8	Mollusca	Gastropoda	Caenogastropoda	Epitoniidae	0.0	2.0
9	Mollusca	Gastropoda	Caenogastropoda	Triphoridae	1.0	11.3
10	Mollusca	Gastropoda	Caenogastropoda	Turritellidae	13.0	0.3
11	Mollusca	Gastropoda	Lepetellida	Fissurellidae	0.3	2.3
12	Mollusca	Gastropoda	Littorinimorpha	Cypraeidae	0.0	3.7
13	Mollusca	Gastropoda	Littorinimorpha	Ovulidae	0.0	3.7
14	Mollusca	Gastropoda	Littorinimorpha	Rissoidae	0.0	2.0
15	Mollusca	Gastropoda	Littorinimorpha	Vermetidae	1.3	4.0
16	Mollusca	Gastropoda	Littorinimorpha	Eulimidae	0.3	2.0
17	Mollusca	Gastropoda	Littorinimorpha	Naticidae	0.3	0.0
18	Mollusca	Gastropoda	Neogastropoda	Muricidae	0.7	0.0
19	Mollusca	Gastropoda	Neogastropoda	Columbellidae	1.3	39.7
20	Mollusca	Gastropoda	Neogastropoda	Fasciolariidae	0.3	2.0
21	Mollusca	Gastropoda	Neogastropoda	Marginellidae	0.0	1.7
22	Mollusca	Gastropoda	Neogastropoda	Nassariidae	3.7	3.7
23	Mollusca	Gastropoda	Neogastropoda	Olividae	0.0	1.3
24	Mollusca	Gastropoda	Neogastropoda	Turridae	0.3	2.7
25	Mollusca	Gastropoda	Neogastropoda	Turridae	0.0	0.3
26	Mollusca	Gastropoda	Patellogastropoda	Lottiidae	1.0	0.0
27	Mollusca	Gastropoda	Patellogastropoda	Patellidae	0.0	1.0
28	Mollusca	Gastropoda	Pylopulmonata	Pyramidellidae	0.3	8.0
29	Mollusca	Gastropoda	Ringiculimorpha	Ringiculidae	0.3	0.3
30	Mollusca	Gastropoda	Trochida	Colloniidae	0.0	0.3
31	Mollusca	Gastropoda	Trochida	Skeneidae	0.3	3.7
	Subtotal (Malacostraca Abundance)				0.3 **(1.1)**	0.0 **(0.0)**
	Subtotal (Ophiuroidea Abundance)				1.0 **(3.3)**	0.0 **(0.0)**
	Subtotal (Bivalvia Abundance)				4.0 **(13.0)**	1.3 **(1.3)**
	Subtotal (Gastropoda Abundance)				25.1 **(82.6)**	98.3 **(98.7)**
	Total (Macrobenthos Abundance)				**30.4**	**99.6**
	Total (Taxa Richness)				**20**	**25**

Notes: Values in parentheses reflect relative abundance (RA; %); indet = taxon is indeterminable beyond a certain taxonomic level

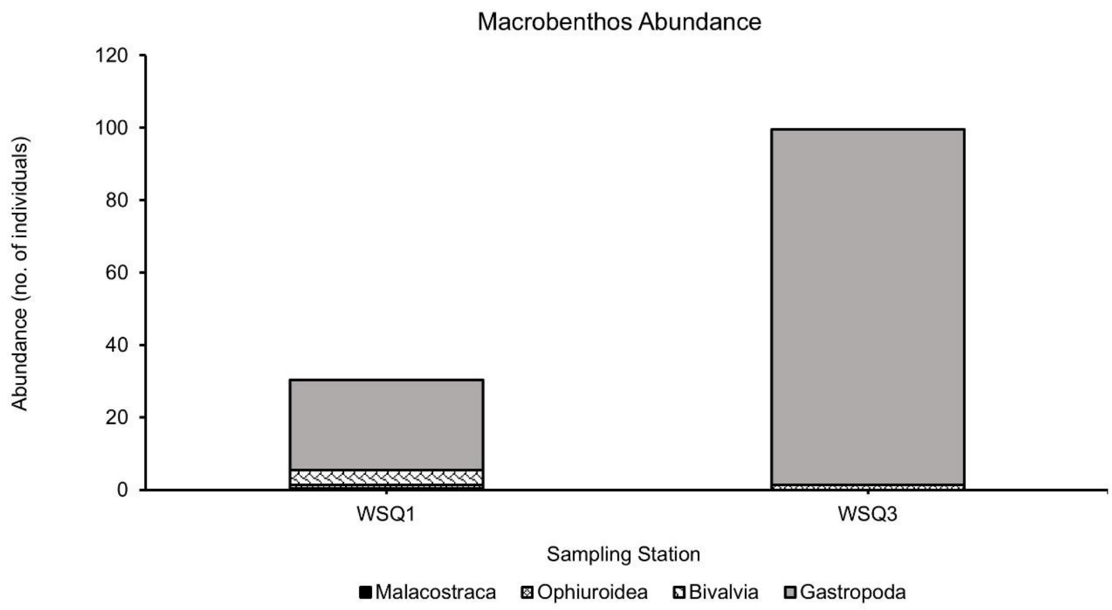


Figure 3-10 Bar Graph Showing the Mean Abundance (no. of individuals) of Macrobenthos Groups Recorded across Macrobenthos Sampling Stations

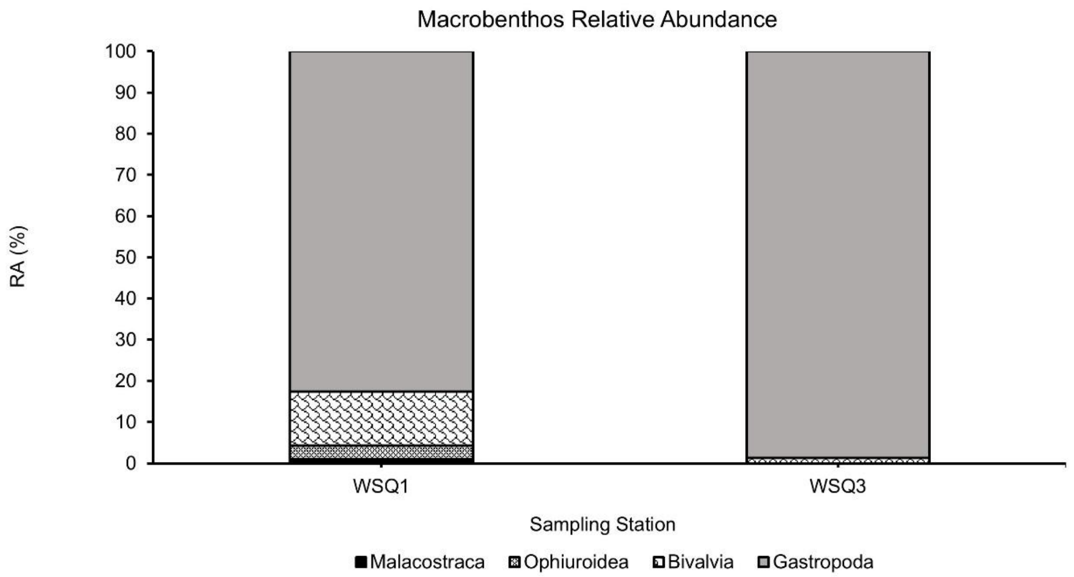


Figure 3-11 Bar Graph Showing the Relative Abundance (RA; %) of Macrobenthos Groups Recorded across Macrobenthos Sampling Stations

Table 3-15 List of Macrobenthos Taxa with Corresponding Mean Density (individuals m^{-2}) Recorded across Macrobenthos Sampling Stations

SN	Phylum	Class	Order	Family	Sampling Station	
					WSQ1	WSQ3
1	Arthropoda	Malacostraca	Decapoda	Family indet	8.3	0.0
2	Echinodermata	Ophiuroidea	Order indet	Family indet	25.0	0.0
3	Mollusca	Bivalvia	Arcida	Arcidae	0.0	8.3
4	Mollusca	Bivalvia	Cardiida	Tellinidae	75.0	0.0
5	Mollusca	Bivalvia	Lucinida	Lucinidae	25.0	25.0
6	Mollusca	Gastropoda	Caenogastropoda	Cerithiidae	16.7	50.0
7	Mollusca	Gastropoda	Caenogastropoda	Cerithiopsidae	0.0	8.3
8	Mollusca	Gastropoda	Caenogastropoda	Epitoniidae	0.0	50.0
9	Mollusca	Gastropoda	Caenogastropoda	Triphoridae	25.0	283.3
10	Mollusca	Gastropoda	Caenogastropoda	Turritellidae	325.0	8.3
11	Mollusca	Gastropoda	Lepetellida	Fissurellidae	8.3	58.3
12	Mollusca	Gastropoda	Littorinimorpha	Cypraeidae	0.0	91.7
13	Mollusca	Gastropoda	Littorinimorpha	Ovulidae	0.0	91.7
14	Mollusca	Gastropoda	Littorinimorpha	Rissoidae	0.0	50.0
15	Mollusca	Gastropoda	Littorinimorpha	Vermetidae	33.3	100.0
16	Mollusca	Gastropoda	Littorinimorpha	Eulimidae	8.3	50.0
17	Mollusca	Gastropoda	Littorinimorpha	Naticidae	8.3	0.0
18	Mollusca	Gastropoda	Neogastropoda	Muricidae	16.7	0.0
19	Mollusca	Gastropoda	Neogastropoda	Columbellidae	33.3	991.7
20	Mollusca	Gastropoda	Neogastropoda	Fasciolariidae	8.3	50.0
21	Mollusca	Gastropoda	Neogastropoda	Marginellidae	0.0	41.7
22	Mollusca	Gastropoda	Neogastropoda	Nassariidae	91.7	91.7
23	Mollusca	Gastropoda	Neogastropoda	Olividae	0.0	33.3
24	Mollusca	Gastropoda	Neogastropoda	Turridae	8.3	66.7
25	Mollusca	Gastropoda	Neogastropoda	Turridae	0.0	8.3
26	Mollusca	Gastropoda	Patellogastropoda	Lottiidae	25.0	0.0
27	Mollusca	Gastropoda	Patellogastropoda	Patellidae	0.0	25.0
28	Mollusca	Gastropoda	Pylopulmonata	Pyramidellidae	8.3	200.0
29	Mollusca	Gastropoda	Ringiculimorpha	Ringiculidae	8.3	8.3
30	Mollusca	Gastropoda	Trochida	Colloniidae	0.0	8.3
31	Mollusca	Gastropoda	Trochida	Skeneidae	8.3	91.7
	Total (Macrobenthos Density)				**766.4**	**2,491.6**

Notes: indet = taxon is indeterminable beyond a certain taxonomic level; macrobenthos density (individuals m^{-2}) were derived from the computed macrobenthos abundance, using of a multiplier (k = 25) extrapolated from the actual area sampled by the Van Veen grab (i.e., 400 cm^2), to standardize and achieve the density values expressed on a 1 m^2 (=10,000 cm^2) sampling area.

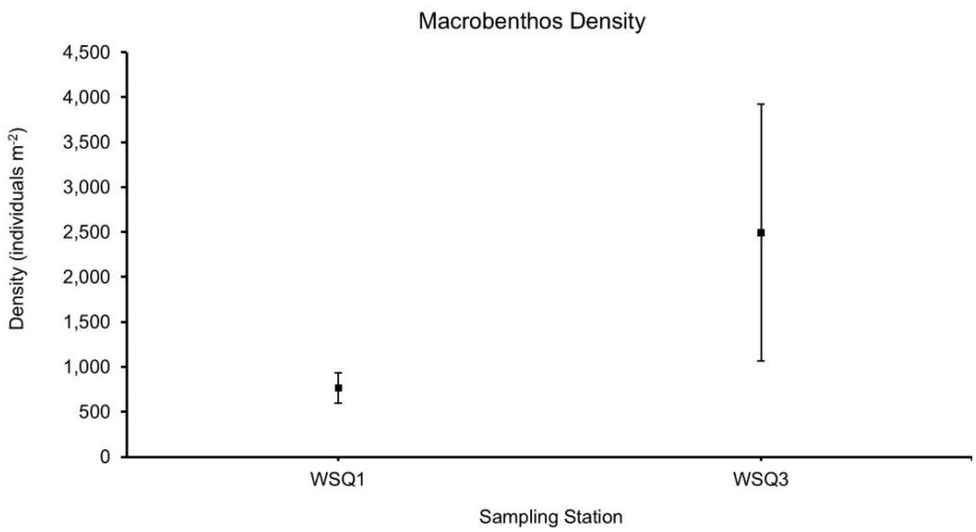


Figure 3-12 Graph Showing the Mean Density (individuals m^{-2}) (± SD) of Macrobenthos Recorded across Macrobenthos Sampling Stations

In terms of taxa richness across sampling stations, WSQ3 had a comparatively higher recorded number of total taxa (25 taxa) than WSQ1 (20 taxa). Calculated Shannon Diversity Index (H') values ranged from 0.54 (very low) to 2.47 (low) (**Table 3-16**); with WSQ3 achieving a greater (H') mean value (2.20) as opposed to WSQ1 (1.43) (Baliton et al., 2020) (Fernando, 1998). Also, there were six (6) notable taxa only observed in WSQ1, namely: Decapoda (Family indet), Ophiuroidea (Family indet), tellinid bivalves (Tellinidae), naticid snails (Naticidae), muricid snails (Muricidae), and lottiid limpets (Lottiidae). WSQ3, on the other hand, supported 11 gastropod taxa which were not documented in WSQ1, including arcid bivalves (Arcidae), cerithiopsid snails (Cerithiopsidae), wentletrap snails (Epitoniidae), cowries (Cypraeidae), ovulid snails (Ovulidae), rissoid snails (Rissoidae), marginellid snails (Marginellidae), olivid snails (Olividae), turrid snails (Turridae), colloniid snails (Colloniidae), and patellid limpets (Patellidae). For the illustrative photographs of the recorded macrobenthos taxa across site, refer to **Figure 3-13**.

Table 3-16 Shannon Diversity Index (H') Values for Recorded Macrobenthos across Macrobenthos Sampling Stations

SN	Site	Replicate	H'	Rating	H' (Mean)	Rating
1	WSQ1	1	0.54	Very Low	1.43	Very Low
		2	1.27	Very Low		
		3	2.47	Low		
2	WSQ3	1	2.22	Low	2.20	Low
		2	2.28	Low		
		3	2.10	Low		

Note: Shannon Diversity Index (H') ratings/ assessment are based on Shannon (1948).

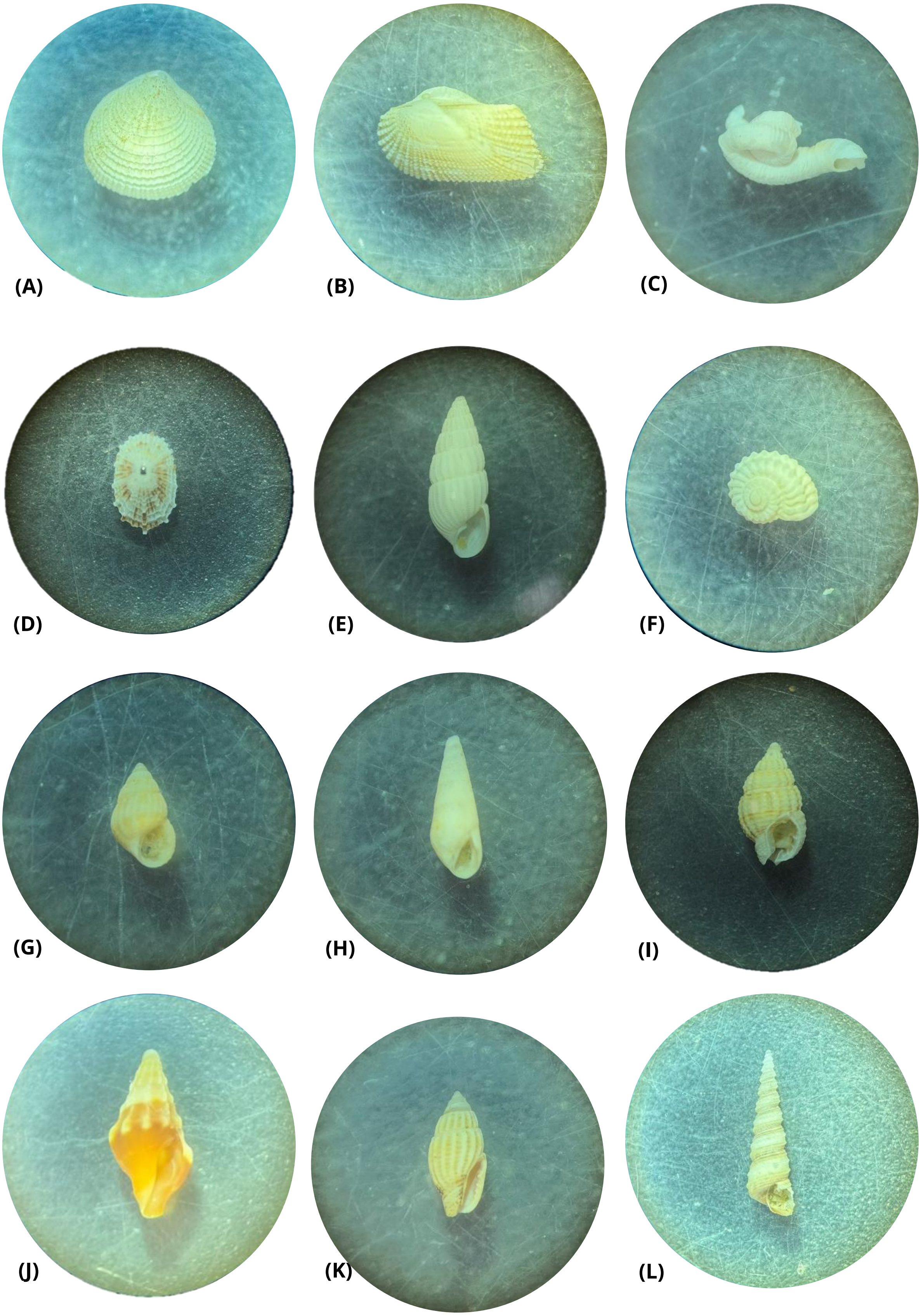


Figure 3-13 Representative Photographs of the Macrobenthos Taxa Recorded across Macrobenthos Sampling Stations: (A) Lucinidae, (B) Arcidae, (C) Vermetidae, (D) Fissurellidae, (E) Pyramidellidae, (F) Skeneidae, (G) Rissoidae, (H) Eulimidae, (I) Nassariidae, (J) Turritellidae, (K) Columbellidae, (L) Turritellidae

4.REFERENCES

Baliton, R., Landicho, L., Cabahug, R., Paelmo, R., Laruan, K., Rodriguez, R., Visco, R. & Castillo, A., (2020). Ecological services of agroforestry systems in selected upland farming communities in the Philippines. *Biodiversitas Journal of Biological Diversity*, *21(2)*, 707–717. 10.13057/biodiv/d210237.

Chen, M., Murali, K., Khoo, B., Lou, J., & Kumar, K. (2005). Circulation modelling in the Strait of Singapore. *Journal of Coastal Research*, *215*, 960–972. https://doi.org/10.2112/04-0412.1

Department of Environment and Heritage Protection. (2013). QUEENSLAND WATER QUALITY GUIDELINES 2009. https://environment.des.qld.gov.au/__data/assets/pdf_file/0020/95150/water-quality-guidelines.pdf

Esdat Environmental Database Management Software. (2000). Circular on target values and intervention values for soil remediation. In *www.esdat.com*.

Fernando, E.S. (1998). Forest Formations and Flora in the Philippines: Handout in FBS 21. (Unpublished)

Maritime and Port Authority of Singapore. (2014). *GENERAL GUIDELINES ON THE REQUIREMENTS FOR APPLICATION ON DREDGING AND DUMPING WORKS*. https://www.mpa.gov.sg/docs/mpalibraries/mpa-documents-files/oms/general-guidelines-on-the-requirements-for-application-on-dredging-and-dumping-works-(18-sep-2014).pdf

National Environmental Agency. (2023). ALLOWABLE LIMITS FOR TRADE EFFLUENT DISCHARGE TO WATERCOURSE OR CONTROLLED WATERCOURSE. https://www.nea.gov.sg/our-services/pollution-control/water-quality/allowable-limits-for-trade-effluent-discharge-to-watercourse-or-controlled-watercourse

APPENDIX A. MARINE WATER QUALITY LAB REPORTS

TEST REPORT

Our Reference No.	:	**R250 7113/1**	Date Received	:	29/07/2025
Project Code / Ref.	:	-	Date Commenced	:	29/07/2025
			Date Reported	:	06/08/2025

Customer Ref. No. : -
Customer Name : Hydrobiology Singapore Pte Ltd
Customer Address : 84 Toh Guan Road East #03-03
Singapore Water Exchange
Singapore 608501

Attention To : Mr Yusof Arshad

Sample Description : 10 Water Samples as per received

RESULTS : Refer to Page 2 to Page 3

Tan Thuan Piang
Senior Technical Manager

Terms & Conditions:

1) This report shall not be reproduced except in full, unless approval in writing has been given by MLS.
2) The results in this report only apply to the sample received/analysed.
3) MLS agrees to use reasonable diligence in the performance of the service.

Marchwood Laboratory Services Pte Ltd: Co. Reg No. : 201422686C
Main (Office and Laboratory): 116 Tuas South Ave 2, West Point Bizhub Singapore 637163 ☎ : +65 6790 0118 Fax : +65 6790 0091
Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 ☎ : +65 6262 3736 (Lab) ☎ : +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

R250 7113/1

RESULTS

Test Parameter	Unit	Test Method	CCGT WSQ1 SPRING FLOOD	CCGT WSQ2 SPRING FLOOD	CCGT WSQ3 SPRING FLOOD	CCGT WSQ4 SPRING FLOOD	CCGT WSQ5 SPRING FLOOD
			28/07/2025	28/07/2025	28/07/2025	28/07/2025	28/07/2025
			1323 hrs	0955 hrs	1158 hrs	1052 hrs	1253 hrs
Cadmium as Cd	µg/L	APHA 3125B	ND	ND	ND	ND	0.13
Chromium as Cr (trivalent and hexavalent)	µg/L	APHA 3125B	0.32	0.41	0.42	0.50	0.67
Copper as Cu	µg/L	APHA 3125B	0.81	0.56	0.63	0.65	0.73
Lead as Pb	µg/L	APHA 3125B	0.11	ND	ND	ND	ND
Mercury as Hg	µg/L	APHA 3125B	ND	ND	ND	ND	ND
Nickel as Ni	µg/L	APHA 3125B	ND	ND	ND	ND	ND
Zinc as Zn	µg/L	APHA 3125B	1.29	ND	ND	ND	ND
Nitrite as NO2-N	mg/L	APHA 4500-NO2 (I)	ND	ND	ND	ND	ND
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	0.082	0.081	0.020	0.032	0.082
Total Nitrogen as TN	mg/L	APHA 4500-P (J)	0.15	0.30	0.18	0.13	0.13
Total Phosphorus as TP	mg/L	APHA 4500-P (J)	0.013	0.021	0.018	0.010	ND
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	ND	ND	ND	ND	ND
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	ND	ND	ND	ND	ND
Total Ammonia (NH3 + NH4)	mg/L	APHA 4500-NH3 (H)	ND	0.011	0.010	ND	ND
Total Organic Carbon, TOC	mg/L	APHA 5310B	2.29	2.24	2.09	2.12	2.19
Biochemical Oxygen Demand, BOD	mg/L	APHA 5210B	ND	ND	ND	ND	ND
Total Suspended Solids, TSS	mg/L	APHA 2540D	4.20	6.90	7.10	6.80	4.80
Oil & Grease	mg/L	Accredited In-house Method MLS-SOP-WQ-033 Rev 1 (adapted from APHA 5520C)	ND	ND	ND	ND	ND
Faecal Coliforms	MPN/100mL	APHA 9221E	ND	ND	ND	ND	ND
Enterococci	cfu/100mL	APHA 9230C	ND	ND	6	4	ND

Note:

1. APHA is a Standard Method for Determination of Water and Wastewater (APHA 24th Edition, 2023)
2. LOR = Limit of Reporting.
3. "ND" = Not detected. The data reported is less than the LOR.

RESULTS

Test Parameter	Unit	Test Method	CCGT WSQ1 SPRING EBB	CCGT WSQ2 SPRING EBB	CCGT WSQ3 SPRING EBB	CCGT WSQ4 SPRING EBB	CCGT WSQ5 SPRING EBB	Client's Detection Limit
			28/07/2025	28/07/2025	28/07/2025	28/07/2025	28/07/2025	
			1505 hrs	1655 hrs	1547 hrs	1625 hrs	1530 hrs	
Cadmium as Cd	µg/L	APHA 3125B	0.11	ND	ND	ND	ND	0.1
Chromium as Cr (trivalent and hexavalent)	µg/L	APHA 3125B	0.42	1.04	0.47	0.53	0.45	0.1
Copper as Cu	µg/L	APHA 3125B	0.53	1.03	0.83	0.68	0.63	0.5
Lead as Pb	µg/L	APHA 3125B	ND	0.16	ND	ND	ND	0.1
Mercury as Hg	µg/L	APHA 3125B	ND	ND	ND	ND	ND	0.05
Nickel as Ni	µg/L	APHA 3125B	ND	ND	ND	ND	ND	1
Zinc as Zn	µg/L	APHA 3125B	ND	ND	ND	ND	ND	0.5
Nitrite as NO2-N	mg/L	APHA 4500-NO2 (I)	ND	ND	ND	ND	ND	0.01
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	0.080	0.085	0.076	0.068	0.089	0.01
Total Nitrogen as TN	mg/L	APHA 4500-P (J)	0.22	0.15	0.23	0.12	0.18	0.01
Total Phosphorus as TP	mg/L	APHA 4500-P (J)	ND	ND	0.016	ND	ND	0.01
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	ND	ND	ND	ND	ND	0.01
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	ND	ND	ND	ND	ND	0.01
Total Ammonia (NH3 + NH4)	mg/L	APHA 4500-NH3 (H)	0.011	ND	ND	0.011	ND	0.01
Total Organic Carbon, TOC	mg/L	APHA 5310B	2.15	2.19	2.38	2.36	2.29	1
Biochemical Oxygen Demand, BOD	mg/L	APHA 5210B	ND	ND	ND	ND	ND	1
Total Suspended Solids, TSS	mg/L	APHA 2540D	4.20	3.60	6.80	2.90	9.20	1
Oil & Grease	mg/L	Accredited In-house Method MLS-SOP-WQ-033 Rev 1 (adapted from APHA 5520C)	ND	ND	ND	ND	ND	0.1
Faecal Coliforms	MPN/100mL	APHA 9221E	ND	ND	ND	ND	ND	1.8
Enterococci	cfu/100mL	APHA 9230C	ND	ND	ND	ND	ND	1

Note:

1. APHA is a Standard Method for Determination of Water and Wastewater (APHA 24th Edition, 2023)
2. LOR = Limit of Reporting.
3. "ND" = Not detected. The data reported is less than the LOR.

MLS

TEST REPORT

Our Reference No.	:	**R250 7425**
Project Code / Ref.	:	-
Date Received	:	06/08/2025
Date Commenced	:	06/08/2025
Date Reported	:	14/08/2025

Customer Ref. No.	:	-
Customer Name	:	Hydrobiology Singapore Pte Ltd
Customer Address	:	84 Toh Guan Road East #03-03 Singapore Water Exchange Singapore 608501
Attention To	:	Mr Yusof Arshad
Sample Description	:	10 Water Samples as per received
RESULTS	:	Refer to Page 2 to Page 3

Tan Thuan Piang
Senior Technical Manager

Terms & Conditions:

1) This report shall not be reproduced except in full, unless approval in writing has been given by MLS.
2) The results in this report only apply to the sample received/analysed.
3) MLS agrees to use reasonable diligence in the performance of the service.

Marchwood Laboratory Services Pte Ltd: Co. Reg No. : 201422686C
Main (Office and Laboratory): 116 Tuas South Ave 2, West Point Bizhub Singapore 637163 ☎ : +65 6790 0118 Fax : +65 6790 0091
Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 ☎ : +65 6262 3736 (Lab) ☎ : +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

R250 7425

RESULTS

Test Parameter	Unit	Test Method	CCGT WSQ1 NEAP FLOOD	CCGT WSQ2 NEAP FLOOD	CCGT WSQ3 NEAP FLOOD	CCGT WSQ4 NEAP FLOOD	CCGT WSQ5 NEAP FLOOD
			05/08/2025	05/08/2025	05/08/2025	05/08/2025	05/08/2025
			1452 hrs	1715 hrs	1550 hrs	1640 hrs	1525 hrs
Cadmium as Cd	µg/L	APHA 3125B	ND	ND	ND	ND	ND
Chromium as Cr (trivalent and hexavalent)	µg/L	APHA 3125B	0.20	0.30	0.25	0.26	0.26
Copper as Cu	µg/L	APHA 3125B	1.03	0.96	0.66	0.88	0.53
Lead as Pb	µg/L	APHA 3125B	ND	ND	ND	ND	0.10
Mercury as Hg	µg/L	APHA 3125B	ND	ND	ND	ND	ND
Nickel as Ni	µg/L	APHA 3125B	ND	ND	ND	ND	ND
Zinc as Zn	µg/L	APHA 3125B	2.12	6.45	1.50	2.13	1.30
Nitrite as NO2-N	mg/L	APHA 4500-NO2 (I)	0.022	0.016	0.020	0.020	0.015
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	0.081	0.090	0.11	0.11	0.095
Total Nitrogen as TN	mg/L	APHA 4500-P (J)	0.19	0.16	0.20	0.18	0.22
Total Phosphorus as TP	mg/L	APHA 4500-P (J)	0.021	0.016	0.022	0.019	0.018
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	ND	0.011	0.011	ND	ND
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	ND	ND	ND	0.019	ND
Total Ammonia (NH3 + NH4)	mg/L	APHA 4500-NH3 (H)	ND	ND	ND	0.024	ND
Total Organic Carbon, TOC	mg/L	APHA 5310B	2.16	2.02	2.02	2.10	2.20
Biochemical Oxygen Demand, BOD	mg/L	APHA 5210B	ND	ND	ND	ND	ND
Total Suspended Solids, TSS	mg/L	APHA 2540D	2.40	7.70	9.20	8.30	5.70
Oil & Grease	mg/L	Accredited In-house Method MLS-SOP-WQ-033 Rev 1 (adapted from APHA 5520C)	ND	ND	ND	ND	ND
Faecal Coliforms	MPN/100mL	APHA 9221E	20	2	28	24	6
Enterococci	cfu/100mL	APHA 9230C	4	6	14	14	12

Note:

1. APHA is a Standard Method for Determination of Water and Wastewater (APHA 24th Edition, 2023)
2. LOR = Limit of Reporting.
3. "ND" = Not detected. The data reported is less than the LOR.

MLS

R250 7425

RESULTS

Test Parameter	Unit	Test Method	CCGT WSQ1 NEAP EBB	CCGT WSQ2 NEAP EBB	CCGT WSQ3 NEAP EBB	CCGT WSQ4 NEAP EBB	CCGT WSQ5 NEAP EBB	Client's Detection Limit
			05/08/2025	05/08/2025	05/08/2025	05/08/2025	05/08/2025	
			1348 hrs	1025 hrs	1205 hrs	1122 hrs	1320 hrs	
Cadmium as Cd	µg/L	APHA 3125B	ND	ND	ND	ND	ND	0.1
Chromium as Cr (trivalent and hexavalent)	µg/L	APHA 3125B	0.21	0.19	0.18	0.22	0.19	0.1
Copper as Cu	µg/L	APHA 3125B	1.15	0.69	0.68	0.72	0.60	0.5
Lead as Pb	µg/L	APHA 3125B	0.26	ND	ND	ND	ND	0.1
Mercury as Hg	µg/L	APHA 3125B	ND	ND	ND	ND	ND	0.05
Nickel as Ni	µg/L	APHA 3125B	ND	ND	ND	ND	ND	1
Zinc as Zn	µg/L	APHA 3125B	2.86	0.89	1.16	1.84	1.72	0.5
Nitrite as NO2-N	mg/L	APHA 4500-NO2 (I)	ND	ND	0.012	0.021	0.017	0.01
Nitrate as NO3-N	mg/L	APHA 4500-NO3 (I)	0.081	0.093	0.11	0.092	0.078	0.01
Total Nitrogen as TN	mg/L	APHA 4500-P (J)	0.17	0.18	0.19	0.19	0.17	0.01
Total Phosphorus as TP	mg/L	APHA 4500-P (J)	0.019	0.015	0.017	0.023	0.017	0.01
Phosphate as PO4-P	mg/L	APHA 4500-P (G)	ND	ND	0.010	0.012	ND	0.01
Ammonia as NH3-N	mg/L	APHA 4500-NH3 (H)	ND	ND	ND	ND	ND	0.01
Total Ammonia (NH3 + NH4)	mg/L	APHA 4500-NH3 (H)	ND	ND	ND	0.011	ND	0.01
Total Organic Carbon, TOC	mg/L	APHA 5310B	2.27	2.13	2.23	2.15	2.15	1
Biochemical Oxygen Demand, BOD	mg/L	APHA 5210B	ND	ND	ND	ND	ND	1
Total Suspended Solids, TSS	mg/L	APHA 2540D	5.40	4.10	8.80	7.80	3.60	1
Oil & Grease	mg/L	Accredited In-house Method MLS-SOP-WQ-033 Rev 1 (adapted from APHA 5520C)	ND	ND	ND	ND	ND	0.1
Faecal Coliforms	MPN/100mL	APHA 9221E	3	1	48	110	8	1.8
Enterococci	cfu/100mL	APHA 9230C	8	ND	20	38	18	1

Note:

1. APHA is a Standard Method for Determination of Water and Wastewater (APHA 24th Edition, 2023)
2. LOR = Limit of Reporting.
3. "ND" = Not detected. The data reported is less than the LOR.

APPENDIX B. PLANKTON LAB REPORTS

TEST REPORT

Our Reference No.	:	**R250 7113/2**	Date Received	:	29/07/2025
Project Code / Ref.	:	-	Date Commenced	:	29/07/2025
			Date Reported	:	06/08/2025

Customer Ref. No. : -
Customer Name : Hydrobiology Singapore Pte Ltd
Customer Address : 84 Toh Guan Road East #03-03
Singapore Water Exchange
Singapore 608501

Attention To : Mr Yusof Arshad

Sample Description : 15 Water Samples as per received

Test Parameter : Phytoplankton Total Count
: Zooplankton Total Count

Test Method : APHA 10200F&G

RESULTS : Refer to Page 2 to Page 7

Chai Wan Yin
Senior Executive Biologist

Terms & Conditions:
1) This report shall not be reproduced except in full, unless approval in writing has been given by MLS.
2) The results in this report only apply to the sample received/analysed.
3) MLS agrees to use reasonable diligence in the performance of the service.

Marchwood Laboratory Services Pte Ltd: Co. Reg No. : 201422686C
Main (Office and Laboratory): 116 Tuas South Ave 2, West Point Bizhub Singapore 637163 ☎ : +65 6790 0118 Fax : +65 6790 0091
Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 ☎ : +65 6262 3736 (Lab) ☎ : +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

R250 7113/1

RESULTS

Zooplankton

Phyla	Lower taxon	CCGT_WSQ1_ZOO_REP 1		CCGT_WSQ1_ZOO_REP 2		CCGT_WSQ1_ZOO_REP 3	
		S11	Percentage	S12	Percentage	S13	Percentage
Annelida	Polychaete worm	1	2.4%		0.0%		0.0%
Arthropoda	F.Paracalanidae copepod	20	48.8%	27	67.5%	23	60.5%
	Acartia sp.	5	12.2%	4	10.0%	4	10.5%
	Euterpina.sp		0.0%	1	2.5%		0.0%
	Cirriped		0.0%	1	2.5%	2	5.3%
	Copepod nauplii	4	9.8%	2	5.0%	3	7.9%
	Oithona sp.	6	14.6%	2	5.0%	6	15.8%
	Shrimp Larvae	3	7.3%		0.0%		0.0%
	Harpaticoid copepod	2	4.9%	3	7.5%		0.0%
Mollusca	Gastropod		0.0%		0.0%		0.0%
Total counted		41	100.0%	40	100.0%	38	100.0%
Lab volume		1050		1030		1050	
Volume counted (mL)		30		30		30	
Count per ml		1		1		1	

Phyla	Lower taxon	CCGT_WSQ2_ZOO_REP 1		CCGT_WSQ2_ZOO_REP 2		CCGT_WSQ2_ZOO_REP 3	
		S14	Percentage	S15	Percentage	S16	Percentage
Annelida	Polychaete worm	3	8.8%		0.0%		0.0%
Arthropoda	F.Paracalanidae copepod	8	23.5%	9	29.0%	14	42.4%
	Acartia sp.	7	20.6%	4	12.9%	5	15.2%
	Euterpina.sp		0.0%		0.0%		0.0%
	Cirriped	1	2.9%	2	6.5%	2	6.1%
	Copepod nauplii	5	14.7%	5	16.1%	4	12.1%
	Oithona sp.	7	20.6%	10	32.3%	6	18.2%
	Shrimp Larvae		0.0%		0.0%		0.0%
	Harpaticoid copepod	2	5.9%	1	3.2%	2	6.1%
Mollusca	Gastropod	1	2.9%		0.0%		0.0%
Total counted		34	100.0%	31	100.0%	33	100.0%
Lab volume		980		1000		1000	
Volume counted (mL)		300		500		250	
Count per ml		<1		<1		<1	

Note:

1. APHA is a Standard Method for Determination of Water and Wastewater (APHA 24th Edition, 2023)

RESULTS

Zooplankton

Phyla	Lower taxon	CCGT_WSQ3_ZOO_REP 1		CCGT_WSQ3_ZOO_REP 2		CCGT_WSQ3_ZOO_REP 3	
		S17	Percentage	S18	Percentage	S19	Percentage
Annelida	Polychaete worm	2	4.5%		0.0%	3	6.0%
Arthropoda	F.Paracalanidae copepod	13	29.5%	9	22.5%	13	26.0%
	Acartia sp.	5	11.4%	1	2.5%	2	4.0%
	Euterpina.sp		0.0%		0.0%	2	4.0%
	Cirriped	20	45.5%	13	32.5%	15	30.0%
	Copepod nauplii		0.0%	13	32.5%	10	20.0%
	Oithona sp.	2	4.5%	4	10.0%	4	8.0%
	Shrimp Larvae		0.0%		0.0%		0.0%
	Harpaticoid copepod	2	4.5%		0.0%		0.0%
Chordata	*Appendicularia.sp*						
Mollusca	Gastropod		0.0%		0.0%	1	2.0%
Total counted		44	100.0%	40	100.0%	50	100.0%
Lab volume		980		1100		1100	
Volume counted (mL)		50		150		200	
Count per ml		<1		<1		<1	

Phyla	Lower taxon	CCGT_WSQ4_ZOO_REP 1		CCGT_WSQ4_ZOO_REP 2		CCGT_WSQ4_ZOO_REP 3	
		S20	Percentage	S21	Percentage	S22	Percentage
Annelida	Polychaete worm	2	5.0%	1	1.9%	2	3.9%
Arthropoda	F.Paracalanidae copepod	15	37.5%	20	38.5%	14	27.5%
	Acartia sp.	2	5.0%	5	9.6%	1	2.0%
	Euterpina.sp		0.0%	3	5.8%	1	2.0%
	Cirriped	12	30.0%	7	13.5%	7	13.7%
	Copepod nauplii	5	12.5%	12	23.1%	25	49.0%
	Oithona sp.		0.0%	3	5.8%		0.0%
	Shrimp Larvae		0.0%		0.0%	1	2.0%
	Harpaticoid copepod	2	5.0%	1	1.9%		0.0%
Chordata	*Appendicularia.sp*	1	2.5%		0.0%		0.0%
Mollusca	Gastropod	1	2.5%		0.0%		0.0%
Total counted		40	100.0%	52	100.0%	51	100.0%
Lab volume		990		950		1000	
Volume counted (mL)		100		100		100	
Count per ml		<1		<1		<1	

Note:

1. APHA is a Standard Method for Determination of Water and Wastewater (APHA 24th Edition, 2023)

R250 7113/1

RESULTS

Zooplankton

Phyla	Lower taxon	CCGT_WSQ5_ZOO_REP 1		CCGT_WSQ_ZOO_REP 2		CCGT_WSQ5_ZOO_REP 3	
		S23	Percentage	S24	Percentage	S25	Percentage
Annelida	Polychaete worm	1	2.2%	1	2.4%		0.0%
Arthropoda	F.Paracalanidae copepod	15	32.6%	11	26.2%	16	43.2%
	Acartia sp.	3	6.5%	4	9.5%	3	8.1%
	Euterpina.sp		0.0%		0.0%		0.0%
	Temora sp.	2	4.3%	2	4.8%		0.0%
	Cirriped	6	13.0%	6	14.3%	2	5.4%
	Copepod nauplii	4	8.7%	7	16.7%	10	27.0%
	Oithona sp.	9	19.6%	4	9.5%	6	16.2%
	Shrimp Larvae	3	6.5%		0.0%		0.0%
	Harpaticoid copepod		0.0%	5	11.9%		0.0%
Chordata	*Appendicularia.sp*		0.0%		0.0%		0.0%
Mollusca	Gastropod	3	6.5%		0.0%		0.0%
Rotifera	Rotifer species		0.0%	2	4.8%		0.0%
Total counted		46	100.0%	42	100.0%	37	100.0%
Lab volume		910		990		880	
Volume counted (mL)		100		200		100	
Count per ml		<1		<1		<1	

Note:

1. APHA is a Standard Method for Determination of Water and Wastewater (APHA 24th Edition, 2023)

R250 7113/1

Phytoplankton

Phyla	Lower taxon	CCGT WSQ1 PHYTO REP 1		CCGT WSQ1 PHYTO REP 2		CCGT WSQ1 PHYTO REP 3	
		S26	Percentage	S27	Percentage	S28	Percentage
Dinophyta	*Dinophysis sp.*	1	0.5%		0.0%		0.0%
Ochrophyta	*Coscinodiscus* sp.		0.0%		0.0%		0.0%
	Chaetoceros sp.	61	29.2%	50	23.1%	23	11.1%
	Cyclotella sp.	2	1.0%		0.0%	2	1.0%
	Ditylum sp.		0.0%	2	0.9%	4	1.9%
	Odontella sp.	3	1.4%		0.0%	1	0.5%
	Pleurosigma.sp		0.0%	1	0.5%	1	0.5%
	Rhizosolenia.sp		0.0%		0.0%		0.0%
	Skeletonema.sp	142	67.9%	163	75.5%	173	83.6%
Unknown	Unknown		0.0%		0.0%	3	1.4%
Total counted		209	100.0%	216	100.0%	207	100.0%
Total count	No. of organism per 1 ml	1,045		1,080		1,035	

Phyla	Lower taxon	CCGT WSQ2 PHYTO REP 1		CCGT WSQ2 PHYTO REP 2		CCGT WSQ2 PHYTO REP 3	
		S29	Percentage	S30	Percentage	S31	Percentage
Dinophyta	*Dinophysis sp.*		0.0%		0.0%		0.0%
Ochrophyta	*Coscinodiscus* sp.		0.0%		0.0%		0.0%
	Chaetoceros sp.	28	11.6%	41	17.7%	53	22.6%
	Cyclotella sp.		0.0%	2	0.9%		0.0%
	Ditylum sp.		0.0%	2	0.9%	3	1.3%
	Odontella sp.		0.0%		0.0%	1	0.4%
	Pleurosigma.sp		0.0%		0.0%		0.0%
	Rhizosolenia.sp		0.0%		0.0%		0.0%
	Skeletonema.sp	213	88.4%	186	80.5%	178	75.7%
Unknown	Unknown		0.0%		0.0%		0.0%
Total counted		241	100.0%	231	100.0%	235	100.0%
Total count	No. of organism per 1 ml	5,477		4,125		4,896	

Note:

1. APHA is a Standard Method for Determination of Water and Wastewater (APHA 24th Edition, 2023)

Phytoplankton

Phyla	Lower taxon	CCGT WSQ3 PHYTO REP 1		CCGT WSQ3 PHYTO REP 2		CCGT WSQ3 PHYTO REP 3	
		S32	Percentage	S33	Percentage	S34	Percentage
Dinophyta	*Dinophysis sp.*		0.0%		0.0%		0.0%
Ochrophyta	*Coscinodiscus* sp.		0.0%		0.0%		0.0%
	Chaetoceros sp.	59	26.1%	2	0.9%	8	3.6%
	Cyclotella sp.		0.0%		0.0%		0.0%
	Ditylum sp.		0.0%		0.0%	2	0.9%
	Odontella sp.		0.0%		0.0%		0.0%
	Pleurosigma.sp		0.0%		0.0%		0.0%
	Rhizosolenia.sp		0.0%	1	0.5%		0.0%
	Skeletonema.sp	167	73.9%	213	98.6%	211	95.5%
Unknown	Unknown		0.0%		0.0%		0.0%
Total counted		226	100.0%	216	100.0%	221	100.0%
Total count	No. of organism per 1 ml	6,647		5,023		5,667	

Phyla	Lower taxon	CCGT WSQ4 PHYTO REP 1		CCGT WSQ4 PHYTO REP 2		CCGT WSQ4 PHYTO REP 3	
		S35	Percentage	S36	Percentage	S37	Percentage
Dinophyta	*Dinophysis sp.*		0.0%		0.0%	1	0.5%
Ochrophyta	*Coscinodiscus* sp.		0.0%		0.0%		0.0%
	Chaetoceros sp.		0.0%	20	9.5%	35	16.7%
	Cyclotella sp.		0.0%		0.0%		0.0%
	Ditylum sp.		0.0%	4	1.9%	5	2.4%
	Odontella sp.		0.0%		0.0%		0.0%
	Pleurosigma.sp		0.0%		0.0%		0.0%
	Rhizosolenia.sp		0.0%		0.0%		0.0%
	Skeletonema.sp	219	100.0%	187	88.6%	168	80.4%
Unknown	Unknown		0.0%		0.0%		0.0%
Total counted		219	100.0%	211	100.0%	209	100.0%
Total count	No. of organism per 1 ml	9,522		8,115		8,038	

Note:

1. APHA is a Standard Method for Determination of Water and Wastewater (APHA 24th Edition, 2023)

R250 7113/1

Phytoplankton

Phyla	Lower taxon	CCGT WSQ5 PHYTO REP 1		CCGT WSQ5 PHYTO REP 2		CCGT WSQ5 PHYTO REP 3	
		S38	Percentage	S39	Percentage	S40	Percentage
Dinophyta	*Dinophysis sp.*		0.0%		0.0%		0.0%
Ochrophyta	*Coscinodiscus* sp.	2	1.1%		0.0%	4	1.8%
	Chaetoceros sp.	63	36.0%	80	36.4%	32	14.3%
	Cyclotella sp.	1	0.6%	1	0.5%	2	0.9%
	Ditylum sp.	5	2.9%	1	0.5%		0.0%
	Odontella sp.		0.0%	1	0.5%		0.0%
	Pleurosigma.sp		0.0%	1	0.5%	1	0.4%
	Rhizosolenia.sp		0.0%		0.0%		0.0%
	Skeletonema.sp	104	59.4%	136	61.8%	184	82.5%
Unknown	Unknown		0.0%		0.0%		0.0%
Total counted		175	100.0%	220	100.0%	223	100.0%
Total count	No. of organism per 1 ml	875		1,100		1,115	

Note:

1. APHA is a Standard Method for Determination of Water and Wastewater (APHA 24th Edition, 2023)

APPENDIX C.
SEDIMENT QUALITY LAB REPORTS

TEST REPORT

Our Reference No.	:	**R250 7426/1**	Date Received	:	06/08/2025
Project Code / Ref.	:	-	Date Commenced	:	06/08/2025
			Date Reported	:	14/08/2025

Customer Ref. No. : 20250715-01R4 (Hydrobiology)
Customer Name : Hydrobiology Singapore Pte Ltd
Customer Address : 84 Toh Guan Road East #03-03
Singapore Water Exchange
Singapore 608501

Attention To : Mr. Yusof Arshad

Sample Description : 5 Sediment samples as per received.

RESULTS : Refer to Page 2 to Page 3

Tan Thuan Piang
Senior Technical Manager

Marchwood Laboratory Services Pte Ltd: Co. Reg No. : 201422686C
Main (Office and Laboratory): 116 Tuas South Ave 2, West Point Bizhub Singapore 637163 Tel: +65 6790 0118 Fax: +65 6790 0091
Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 Tel: +65 6262 3736 (Lab) Tel: +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

RESULTS

SN			Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	LOR
Sample Location/ Description			CCGT WSQ1	CCGT WSQ2	CCGT WSQ3	CCGT WSQ4	CCGT WSQ5	
Sample Depth			21m	19m	13.5m	18m	22m	
Date (dd/mm/yy)			05/08/2025	05/08/2025	05/08/2025	05/08/2025	05/08/2025	
Time (hrs)			1408 hrs	1045 hrs	1225 hrs	1142 hrs	1340 hrs	
Test Parameter	**Unit**	**Test Method**						
Total Organic Carbon (TOC)	%	Accredited In-house Method MLS-SOP-SED-007 Rev 1 (by Suspension)	0.51	0.61	0.45	0.59	ND	0.3
Total Petroleum Hydrocarbons (TPH)	mg/kg	USEPA 8440 (1996)	52.0	47.5	24.7	24.4	10.9	10
Aluminium as Al	mg/kg	USEPA 3051A/ APHA 3120B	12,579	5,997	2,646	4,346	1,584	0.15
Arsenic as As	mg/kg	USEPA 3051A/ APHA 3120B	8.78	20.7	5.60	7.40	5.66	1.25
Barium as Ba	mg/kg	USEPA 3051A/ APHA 3120B	28.0	9.50	4.62	8.08	4.25	0.01
Cadmium as Cd	mg/kg	USEPA 3051A/ APHA 3120B	0.45	0.46	0.16	0.18	0.15	0.075
Chromium as Cr	mg/kg	USEPA 3051A/ APHA 3120B	12.7	12.5	4.97	6.93	4.05	0.05
Copper as Cu	mg/kg	USEPA 3051A/ APHA 3120B	17.5	6.14	2.72	4.24	2.59	0.2
Iron as Fe	mg/kg	USEPA 3051A/ APHA 3120B	22,330	21,903	8,449	10,018	7,272	0.1
Nickel as Ni	mg/kg	USEPA 3051A/ APHA 3120B	8.53	6.33	2.87	3.79	1.85	0.25
Lead as Pb	mg/kg	USEPA 3051A/ APHA 3120B	21.7	16.5	7.85	9.56	4.75	1
Vanadium as V	mg/kg	USEPA 3051A/ APHA 3120B	16.5	21.2	6.45	11.6	6.44	0.1
Zinc as Zn	mg/kg	USEPA 3051A/ APHA 3120B	85.4	39.0	20.6	29.2	10.1	0.1
Mercury as Hg	mg/kg	USEPA 3051A/ USEPA 245.1 (FIMS) (1994)	0.061	0.040	0.023	0.027	ND	0.01

Note:

1. APHA is a standard method for Determination of Water and Waste Water (APHA 24th Edition, 2023)
2. LOR = Limit of Reporting. This value may also represent Detection Limit required for the project.
3. "ND" = Not detected. The data reported is less than the LOR.

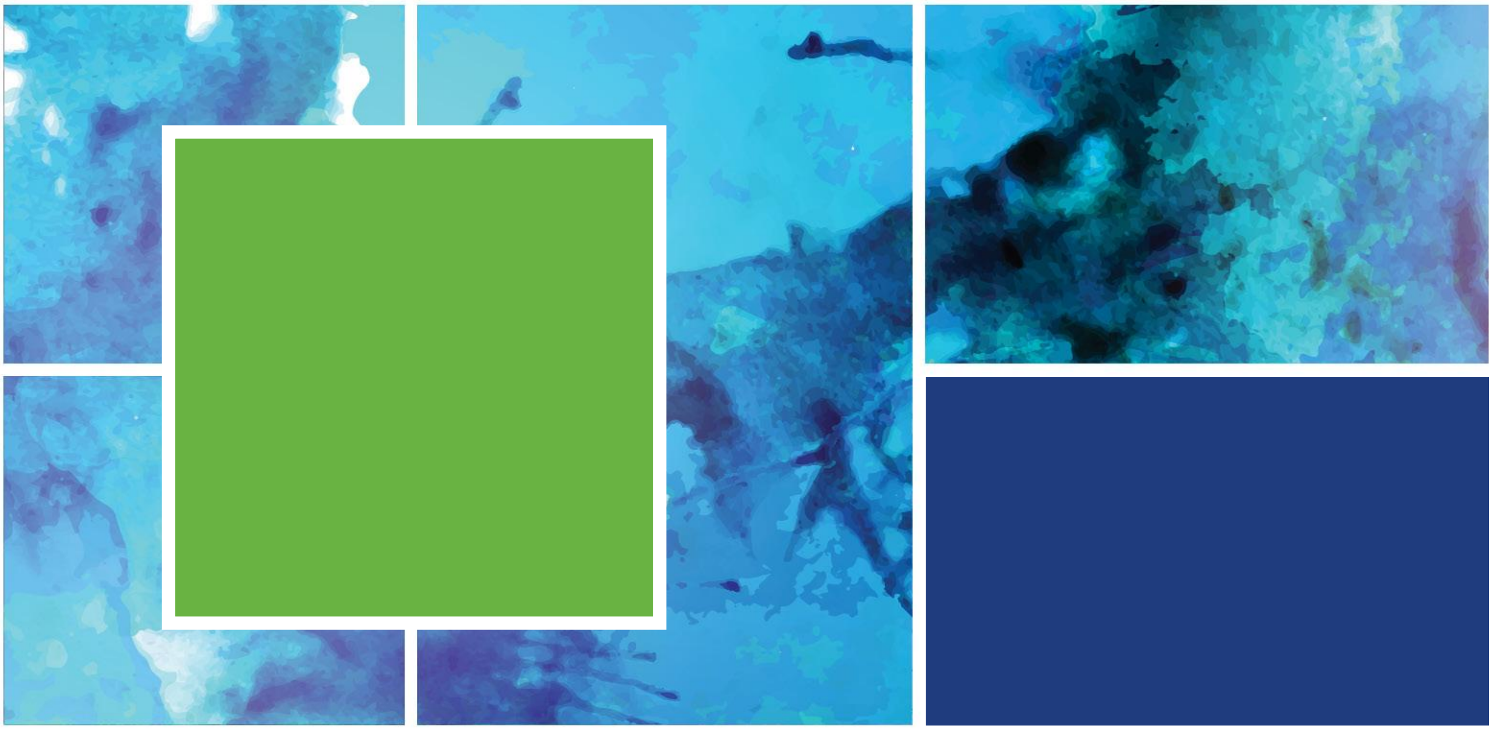
RESULTS

SN			Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	LOR
Sample Location/ Description			CCGT WSQ1	CCGT WSQ2	CCGT WSQ3	CCGT WSQ4	CCGT WSQ5	
Sample Depth			21m	19m	13.5m	18m	22m	
Date (dd/mm/yy)			05/08/2025	05/08/2025	05/08/2025	05/08/2025	05/08/2025	
Time (hrs)			1408 hrs	1045 hrs	1225 hrs	1142 hrs	1340 hrs	
Test Parameter	**Unit**	**Test Method**						
Polycyclic Aromatic Hydrocarbons (PAHs)								
Acenaphthene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Acenaphthylene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Anthracene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Benzo(a)anthracene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Benzo(a)pyrene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Benzo(b)fluoranthene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Benzo(ghi)perylene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Benzo(k)fluoranthene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Chrysene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Dibenz(ah)anthracene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Fluoranthene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Fluorene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Indeno(1,2,3cd)pyrene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Naphthalene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Phenanthrene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1
Pyrene	mg/kg	USEPA 8270E (Jun 2018)	ND	ND	ND	ND	ND	0.1

Note:

1. APHA is a standard method for Determination of Water and Waste Water (APHA 24th Edition, 2023)
2. LOR = Limit of Reporting. This value may also represent Detection Limit required for the project.
3. "ND" = Not detected. The data reported is less than the LOR.

APPENDIX D. PARTICLE SIZE DISTRIBUTION LAB REPORTS



TEST REPORT

Our Reference No.	:	**R250 7426/2**	Date Received	:	06/08/2025
Project Code / Ref.	:	-	Date Commenced	:	06/08/2025
			Date Reported	:	19/08/2025

Customer Ref. No. : 20250715-01R4 (Hydrobiology)
Customer Name : Hydrobiology Singapore Pte Ltd
Customer Address : 84 Toh Guan Road East #03-03
Singapore Water Exchange
Singapore 608501

Attention To : Mr. Yusof Arshad

Sample Description : 5 Sediment samples as per received.

RESULTS : Refer to Page 2 to Page 6

Tan Thuan Piang
Senior Technical Manager

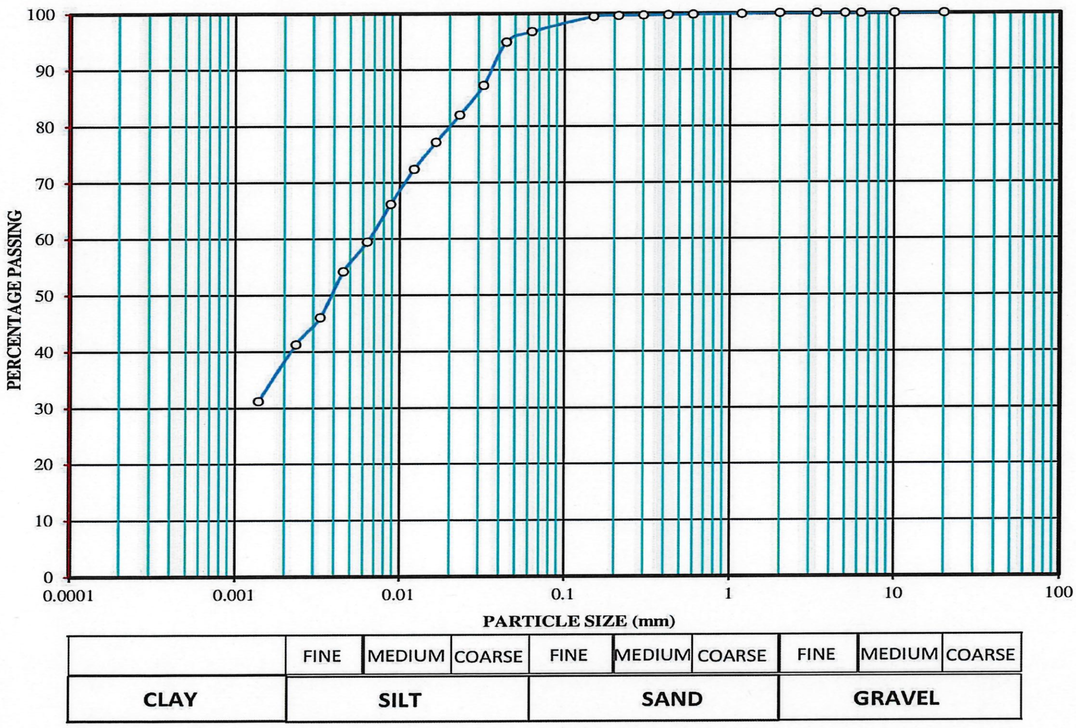
Terms & Conditions:
1) This report shall not be reproduced except in full, unless approval in writing has been given by MLS.
2) The results in this report only apply to the sample received/analysed.
3) MLS agrees to use reasonable diligence in the performance of the service.

Marchwood Laboratory Services Pte Ltd: Co. Reg No. : 201422686C
Main (Office and Laboratory): 116 Tuas South Ave 2, West Point Bizhub Singapore 637163 ☎ : +65 6790 0118 Fax : +65 6790 0091
Branch (Site and Laboratory): 216 Tuas South Ave 2, West Point Bizhub Singapore 637213 ☎ : +65 6262 3736 (Lab) ☎ : +65 6262 3726 / 3776 (Site)
Website: www.mls.sg

R250 7426/2

RESULTS FOR PARTICLE SIZE DISTRIBUTION

Test Method	**:**	**BS 1377-2:2022:CL.10**
SN	:	Sample 1
Sample Location/ Description	:	CCGT WSQ1
Sample Depth	:	21m
Date (dd/mm/yy)	:	05/08/2025
Time (hrs)		1408 hrs



SAMPLE NO	DEPTH (m)	GRAVEL %	SAND %	SILT %	CLAY %	SAMPLE DESCRIPTION
"S01"	-	0	3	59	38	Greenish grey slightly Sandy SILT

Particle Density, SG (Mg/m³) : 2.65 (Assumed)

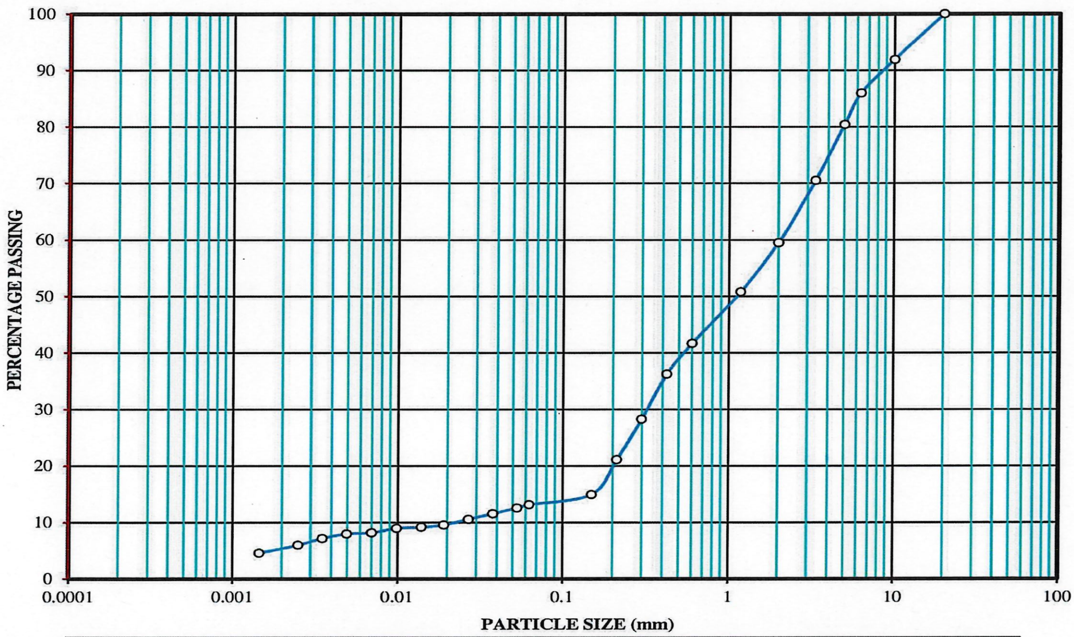
Note:

1. The above test were subcontracted to external lab.

R250 7426/2

RESULTS FOR PARTICLE SIZE DISTRIBUTION

Test Method	**:**	**BS 1377-2:2022:CL.10**
SN	:	Sample 2
Sample Location/ Description	:	CCGT WSQ2
Sample Depth	:	19m
Date (dd/mm/yy)	:	05/08/2025
Time (hrs)		1045 hrs



CLAY	SILT			SAND			GRAVEL		
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE

SAMPLE NO	DEPTH (m)	GRAVEL %	SAND %	SILT %	CLAY %	SAMPLE DESCRIPTION
"S02"	-	40	47	8	5	Greenish grey very Gravelly silty SAND

Particle Density, SG (Mg/m³) : 2.65 (Assumed)

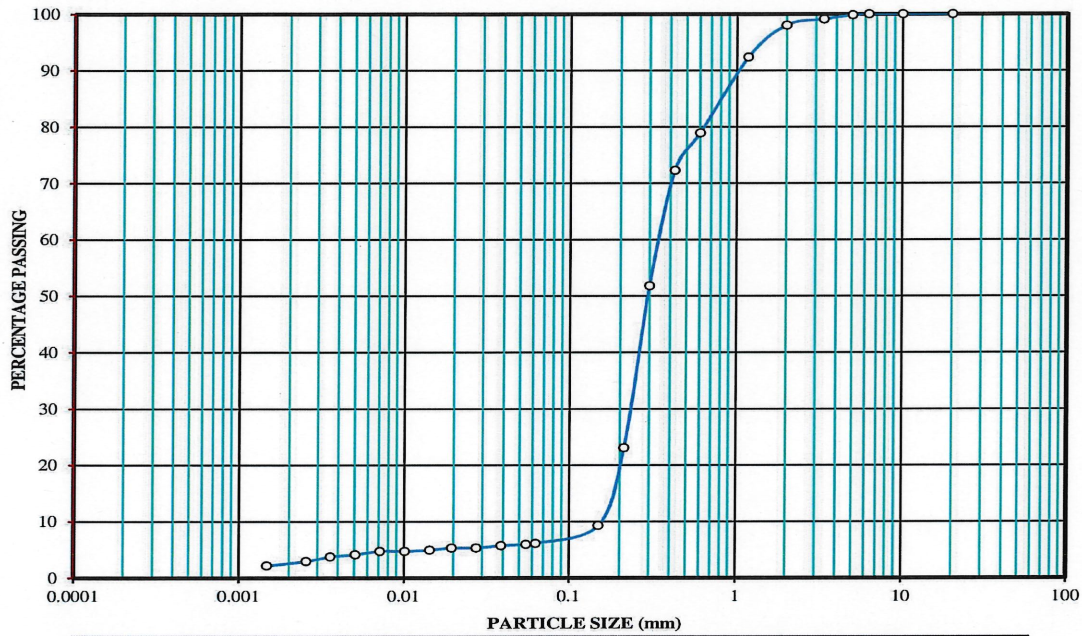
Note:

1. The above test were subcontracted to external lab.

R250 7426/2

RESULTS FOR PARTICLE SIZE DISTRIBUTION

Test Method	:	**BS 1377-2:2022:CL.10**
SN	:	Sample 3
Sample Location/ Description	:	CCGT WSQ3
Sample Depth	:	13.5m
Date (dd/mm/yy)	:	05/08/2025
Time (hrs)		1225 hrs



	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE
CLAY	SILT			SAND			GRAVEL		

SAMPLE NO	DEPTH (m)	GRAVEL %	SAND %	SILT %	CLAY %	SAMPLE DESCRIPTION
"S03"	-	2	92	3	3	Light brownish grey slightly gravelly slightly Silty SAND

Particle Density, SG (Mg/m³) : 2.65 (Assumed)

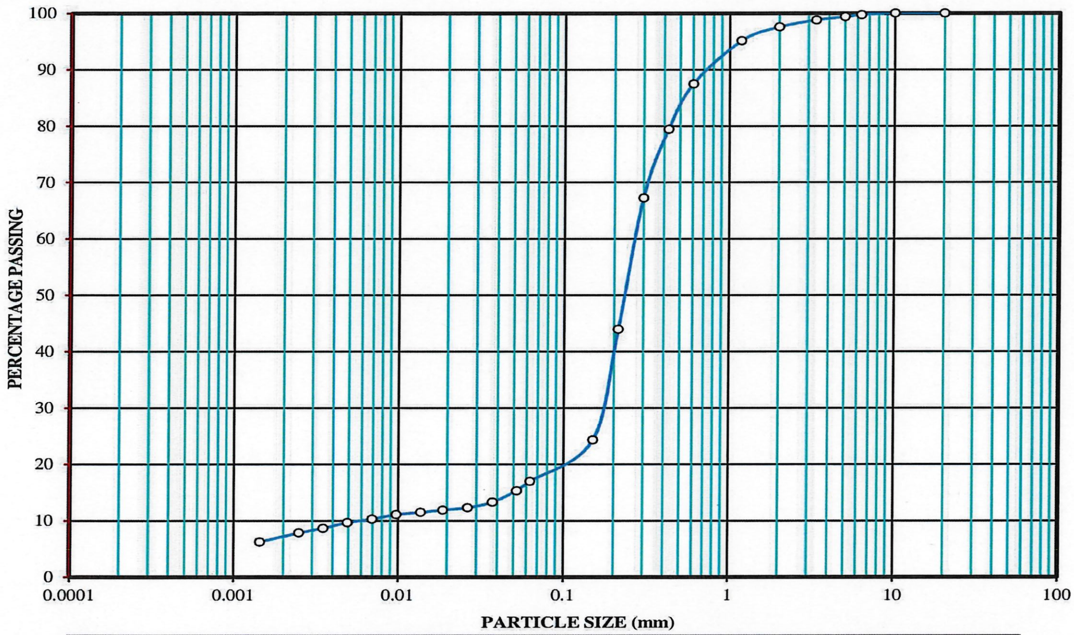
Note:

1. The above test were subcontracted to external lab.

R250 7426/2

RESULTS FOR PARTICLE SIZE DISTRIBUTION

Test Method	**:**	**BS 1377-2:2022:CL.10**
SN	:	Sample 4
Sample Location/ Description	:	CCGT WSQ4
Sample Depth	:	18m
Date (dd/mm/yy)	:	05/08/2025
Time (hrs)		1142 hrs



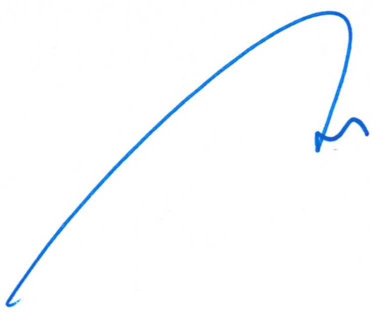
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE
CLAY	**SILT**			**SAND**			**GRAVEL**		

SAMPLE NO	DEPTH (m)	GRAVEL %	SAND %	SILT %	CLAY %	SAMPLE DESCRIPTION
"S04"	-	2	81	10	7	Dark greenish grey slightly gravelly Silty SAND with shell fragments

Particle Density, SG (Mg/m³) : 2.65 (Assumed)

Note:

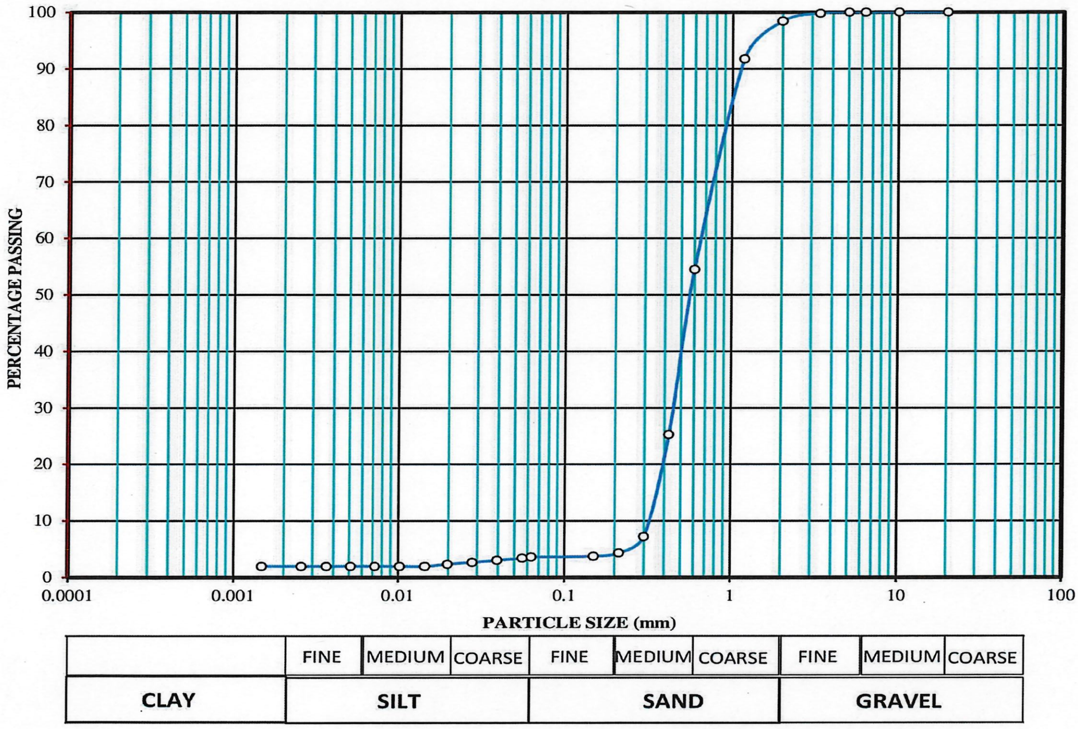
1. The above test were subcontracted to external lab.



R250 7426/2

RESULTS FOR PARTICLE SIZE DISTRIBUTION

Test Method	**:**	**BS 1377-2:2022:CL.10**
SN	:	Sample 5
Sample Location/ Description	:	CCGT WSQ5
Sample Depth	:	22m
Date (dd/mm/yy)	:	05/08/2025
Time (hrs)		1340 hrs



SAMPLE NO	DEPTH (m)	GRAVEL %	SAND %	SILT %	CLAY %	SAMPLE DESCRIPTION
"S05"	-	2	94	2	2	Light brownish grey slightly gravelly slightly Silty SAND

Particle Density, SG (Mg/m³) : 2.65 (Assumed)

Note:

1. The above test were subcontracted to external lab.

APPENDIX E.
IN-SITU WATER QUALITY GRAPHS

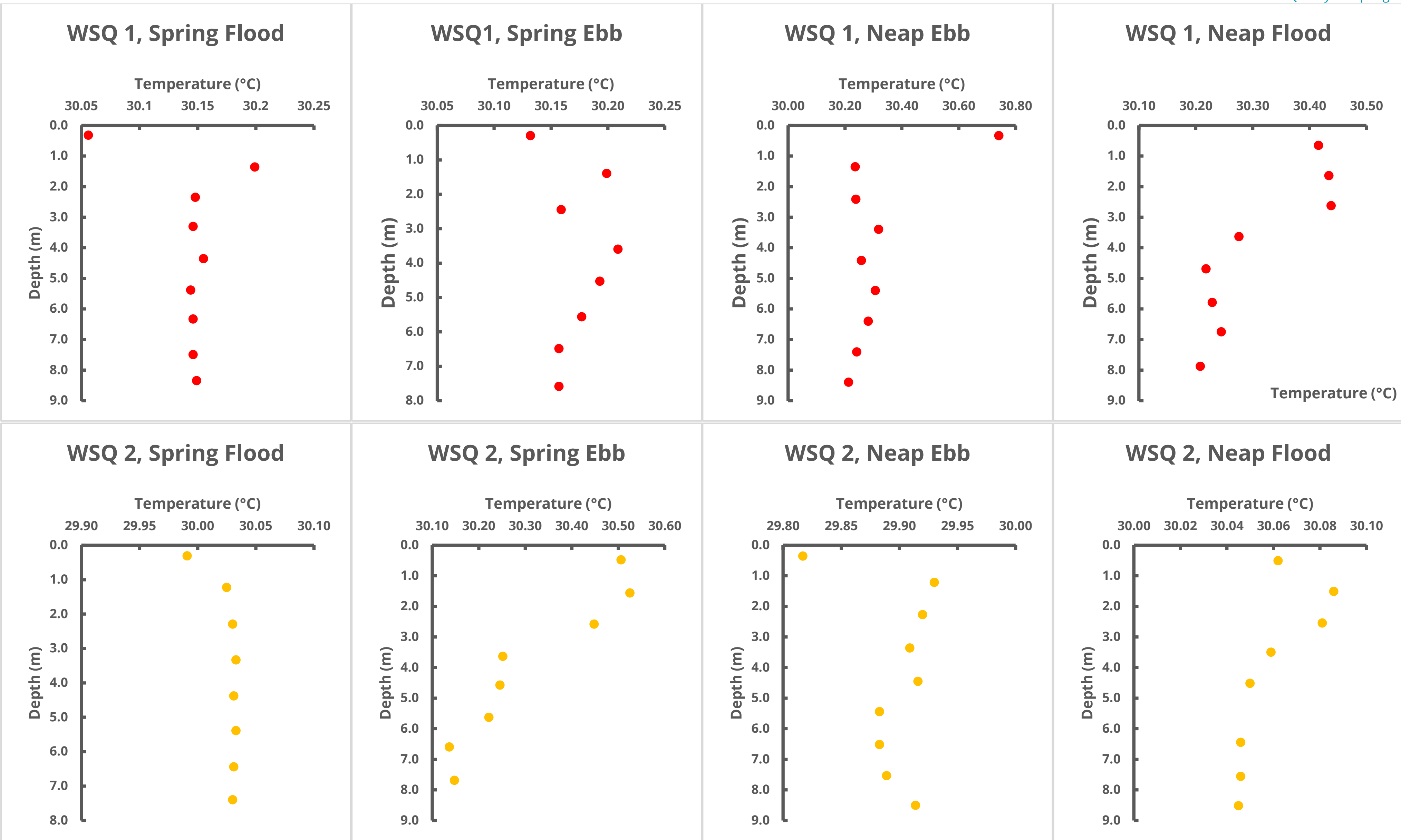


Figure 4-1 WSQ1 and WSQ2 temperature readings for *in-situ* profiling during spring and neap, flood and ebb tides.

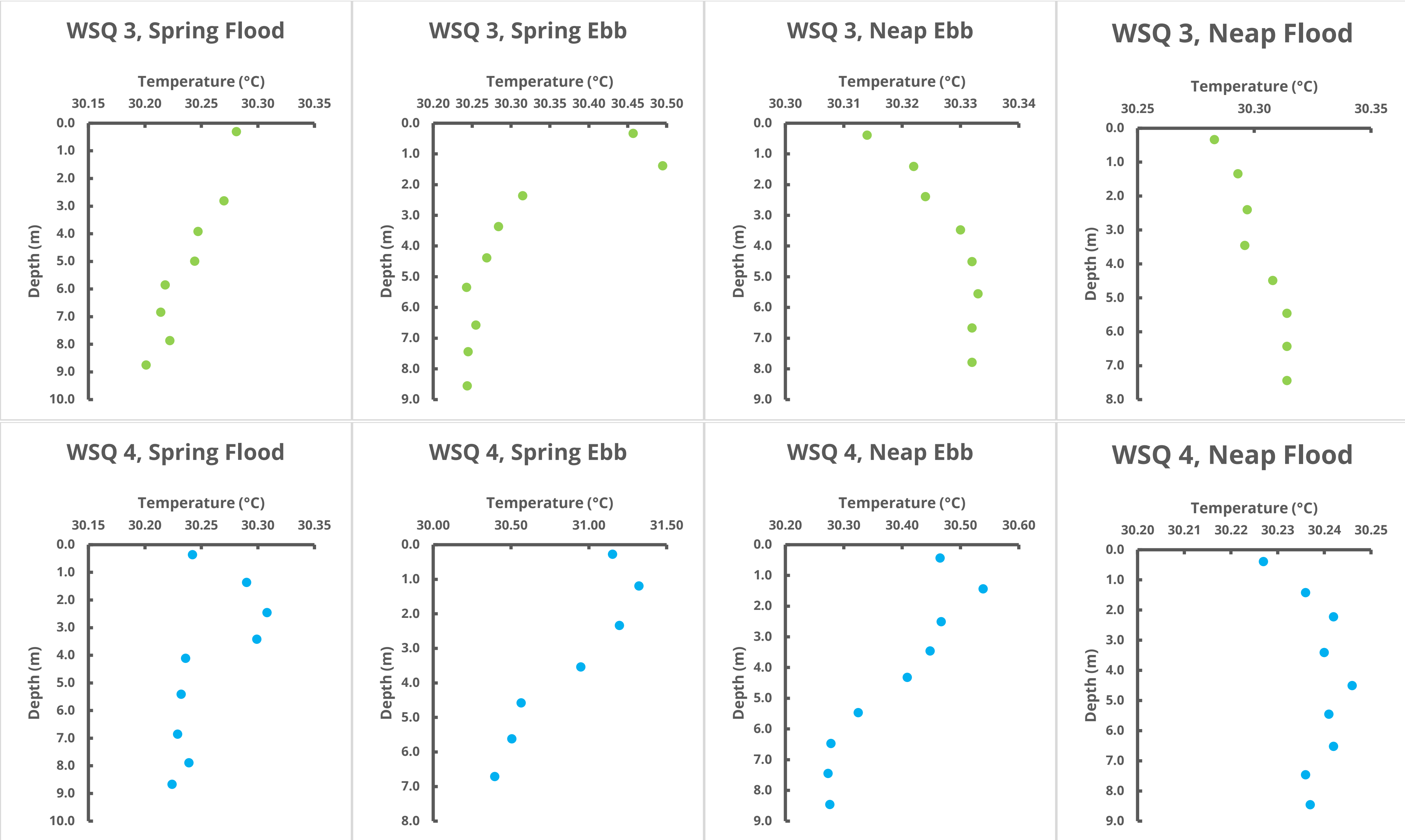


Figure 4-2 WSQ3 and WSQ4 temperature readings for *in-situ* profiling during spring and neap, flood and ebb tides.

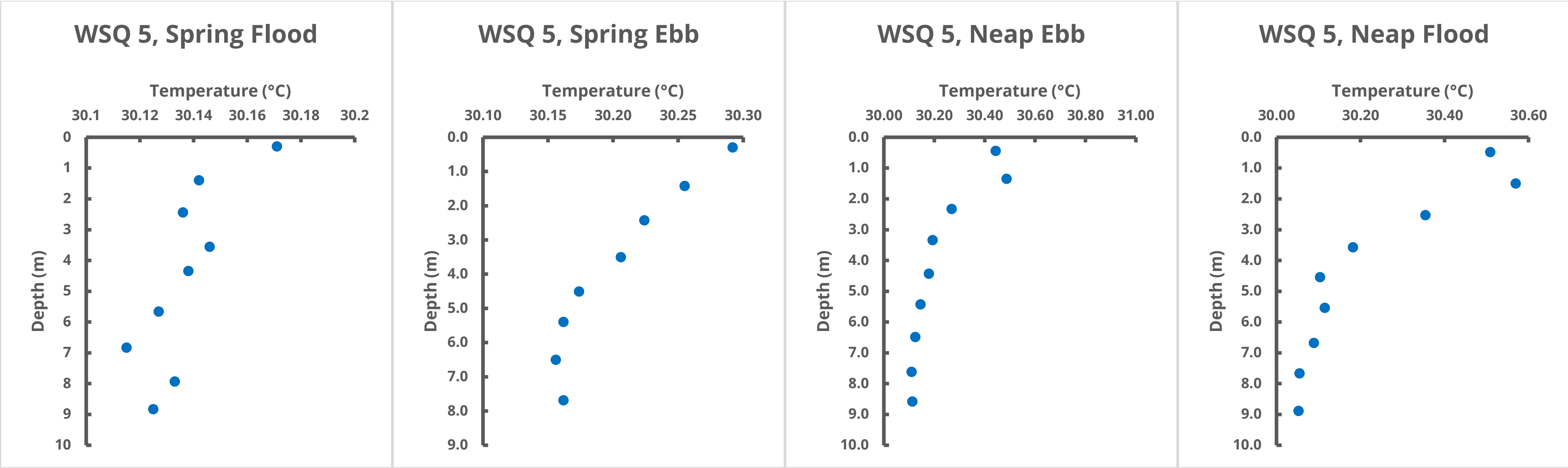


Figure 4-3 WSQ5 temperature readings for *in-situ* profiling during spring and neap, flood and ebb tides.

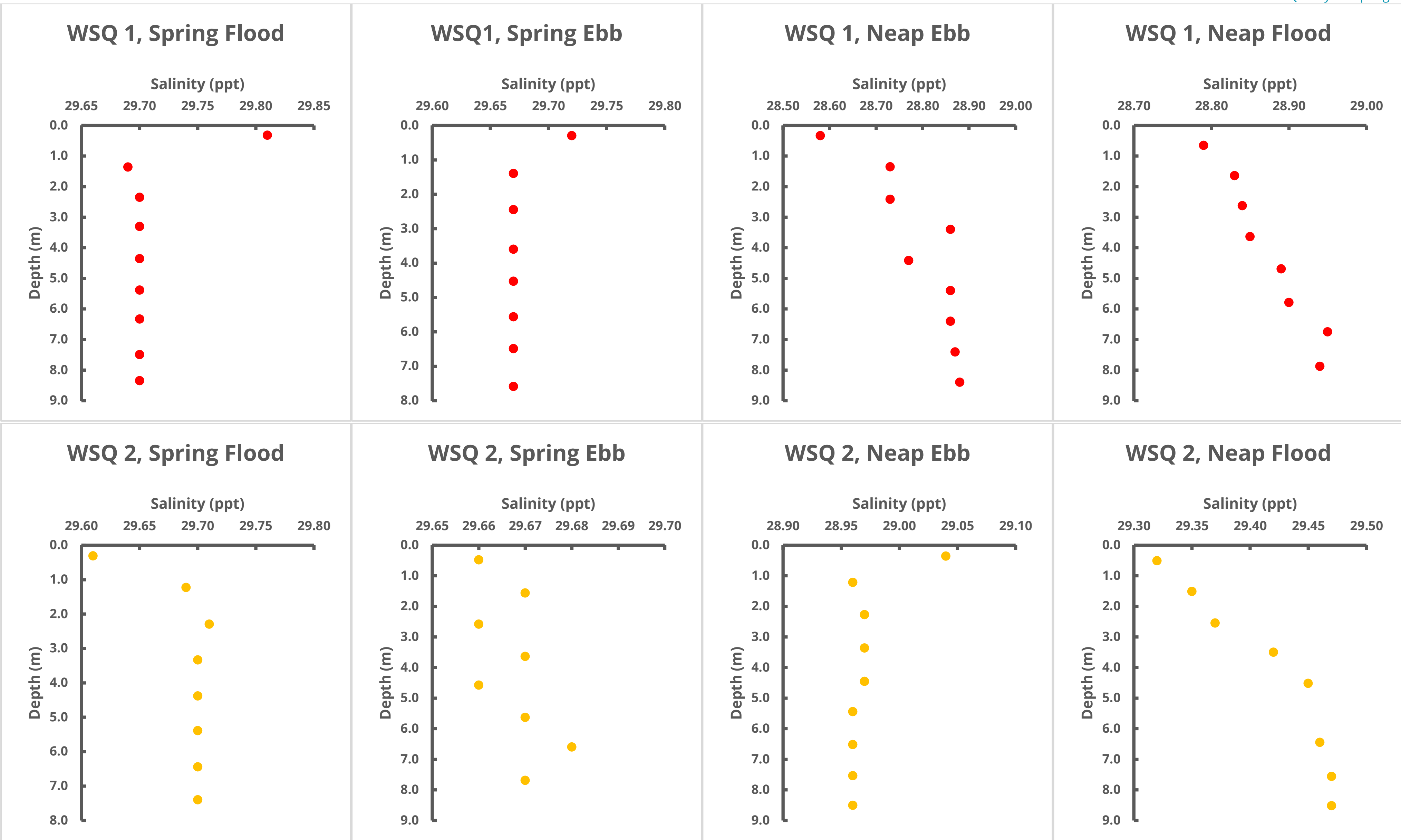


Figure 4-4 WSQ1 and WSQ2 salinity readings for *in-situ* profiling during spring and neap, flood and ebb tides.

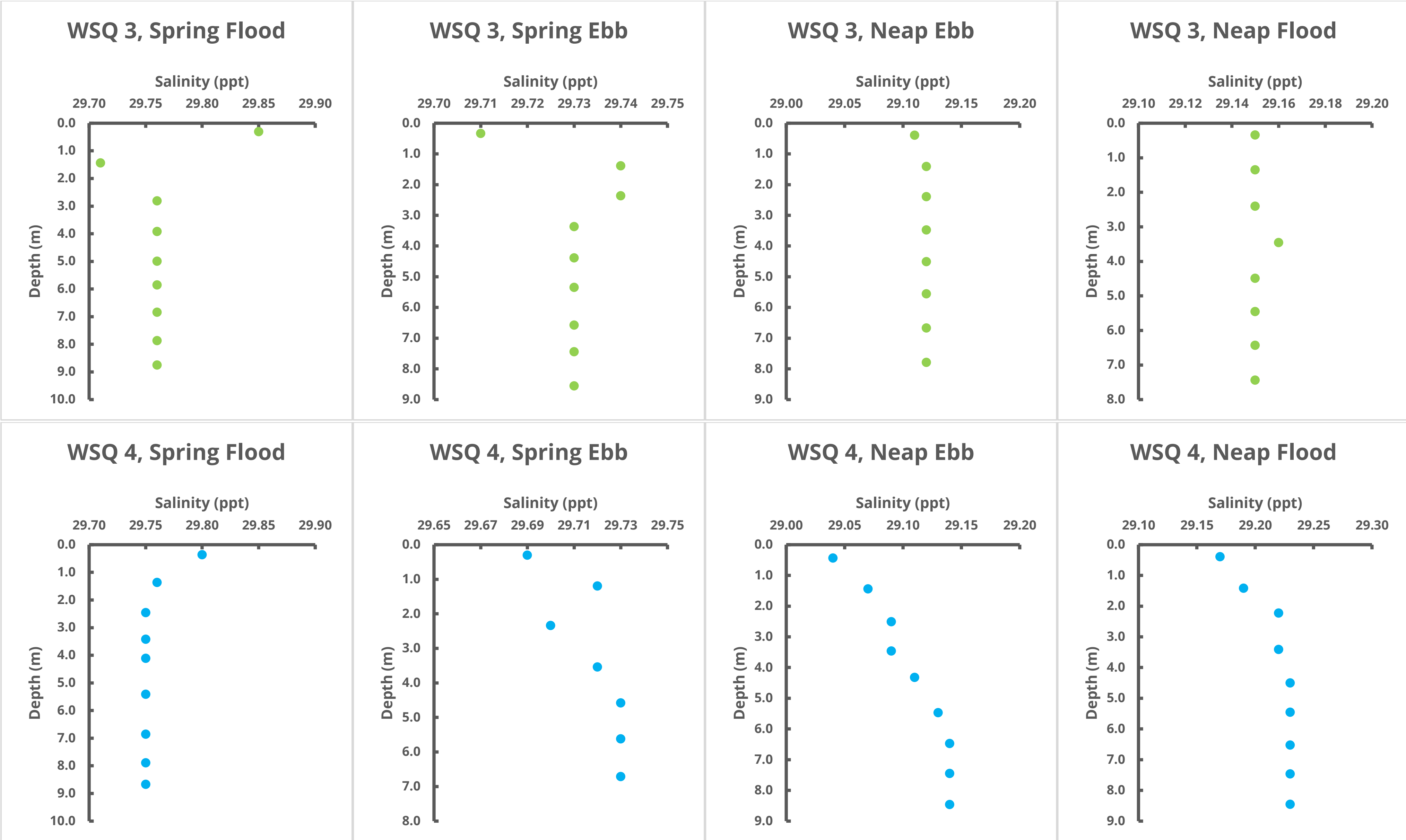


Figure 4-5 WSQ3 and WSQ4 salinity readings for *in-situ* profiling during spring and neap, flood and ebb tides.

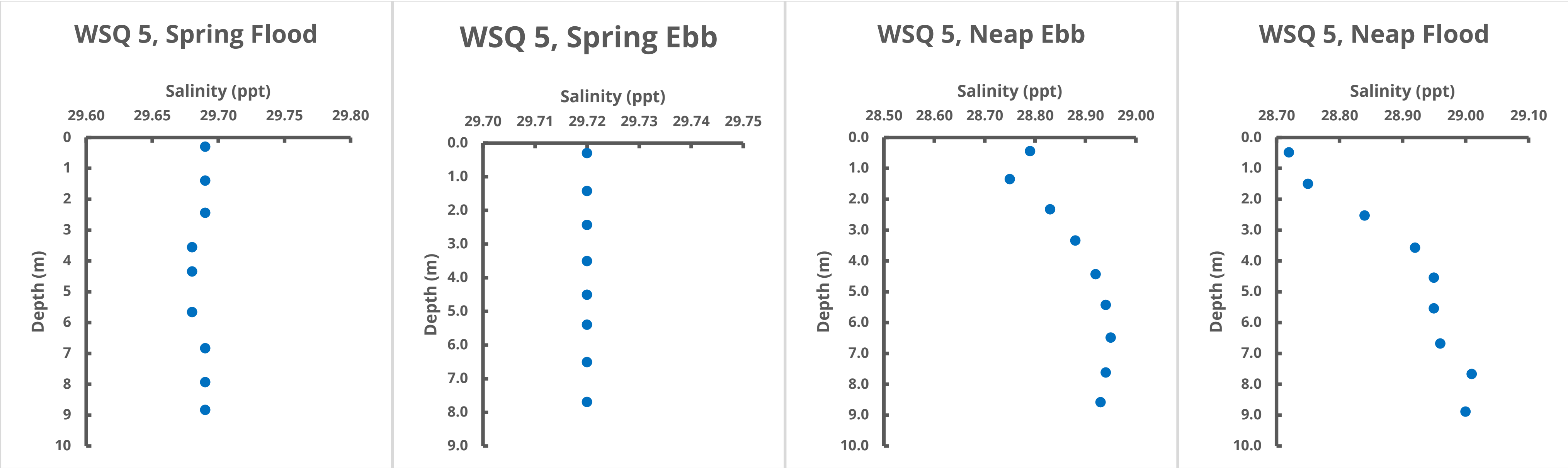


Figure 4-6 WSQ5 salinity readings for *in-situ* profiling during spring and neap, flood and ebb tides.

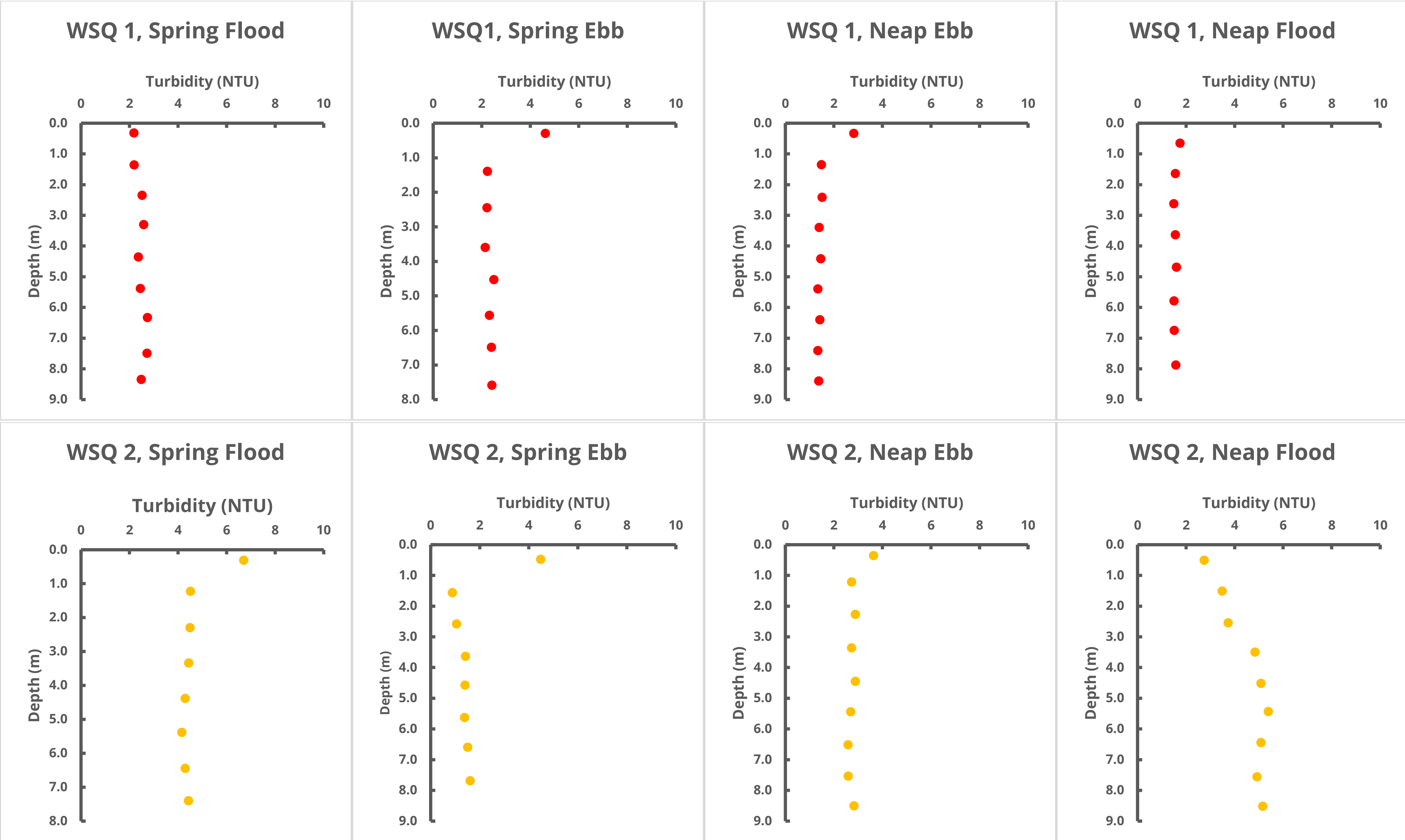


Figure 4-7 WSQ1 and WSQ2 turbidity readings for *in-situ* profiling during spring and neap, flood and ebb tides.

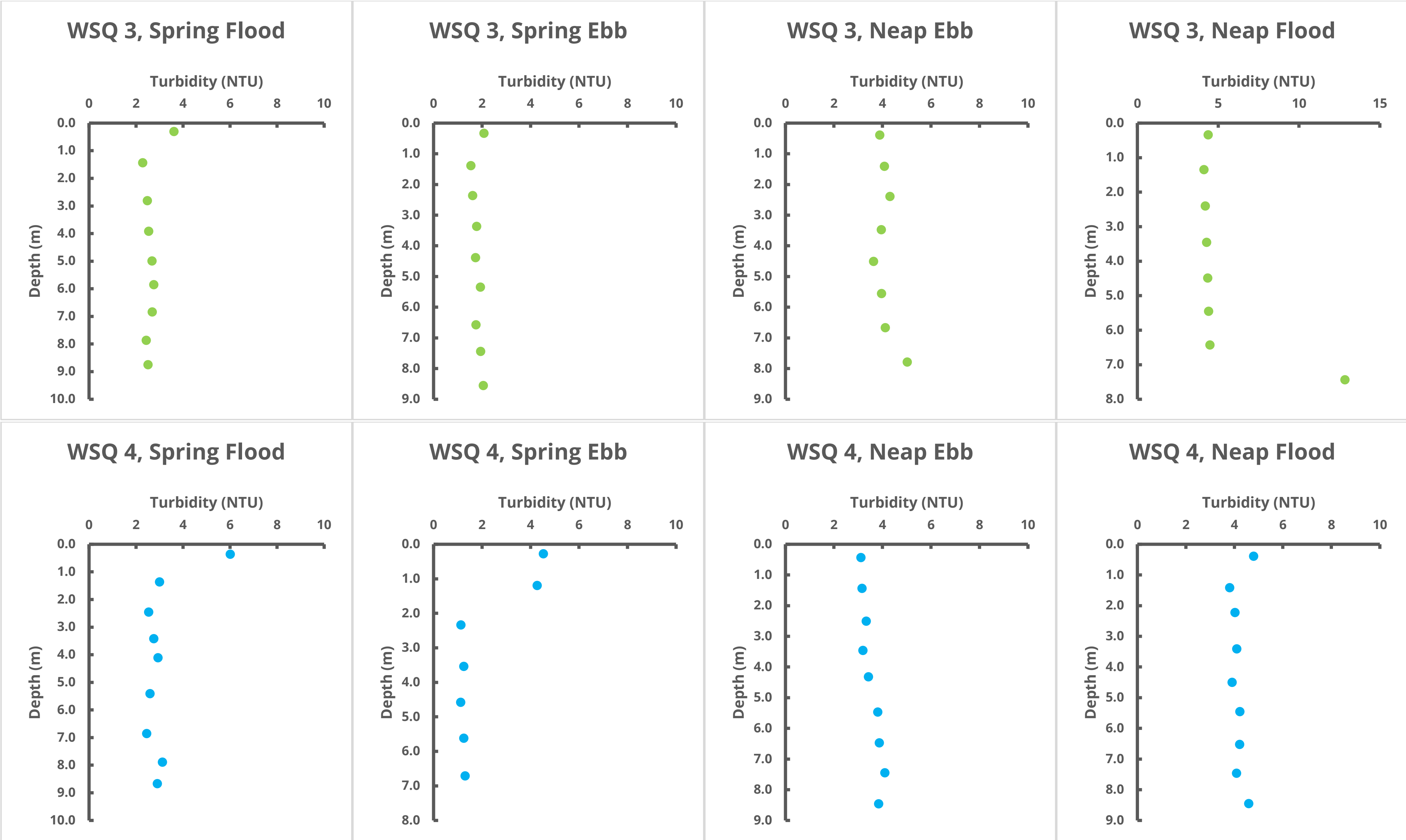


Figure 4-8 WSQ3 and WSQ4 turbidity readings for *in-situ* profiling during spring and neap, flood and ebb tides.

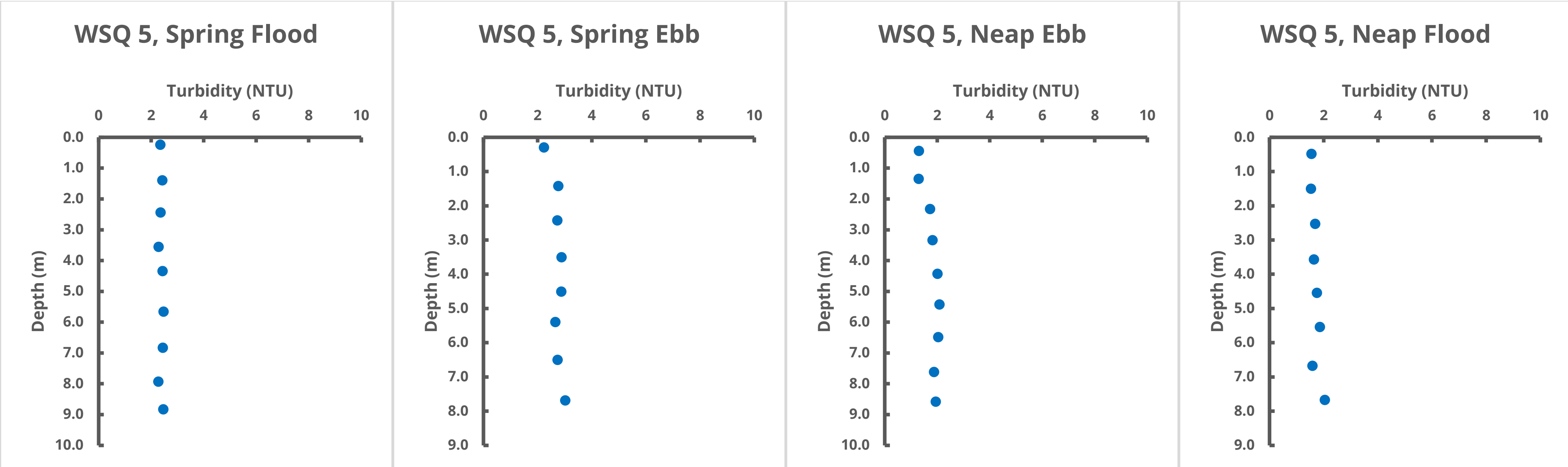


Figure 4-9 WSQ5 turbidity readings for *in-situ* profiling during spring and neap, flood and ebb tides.

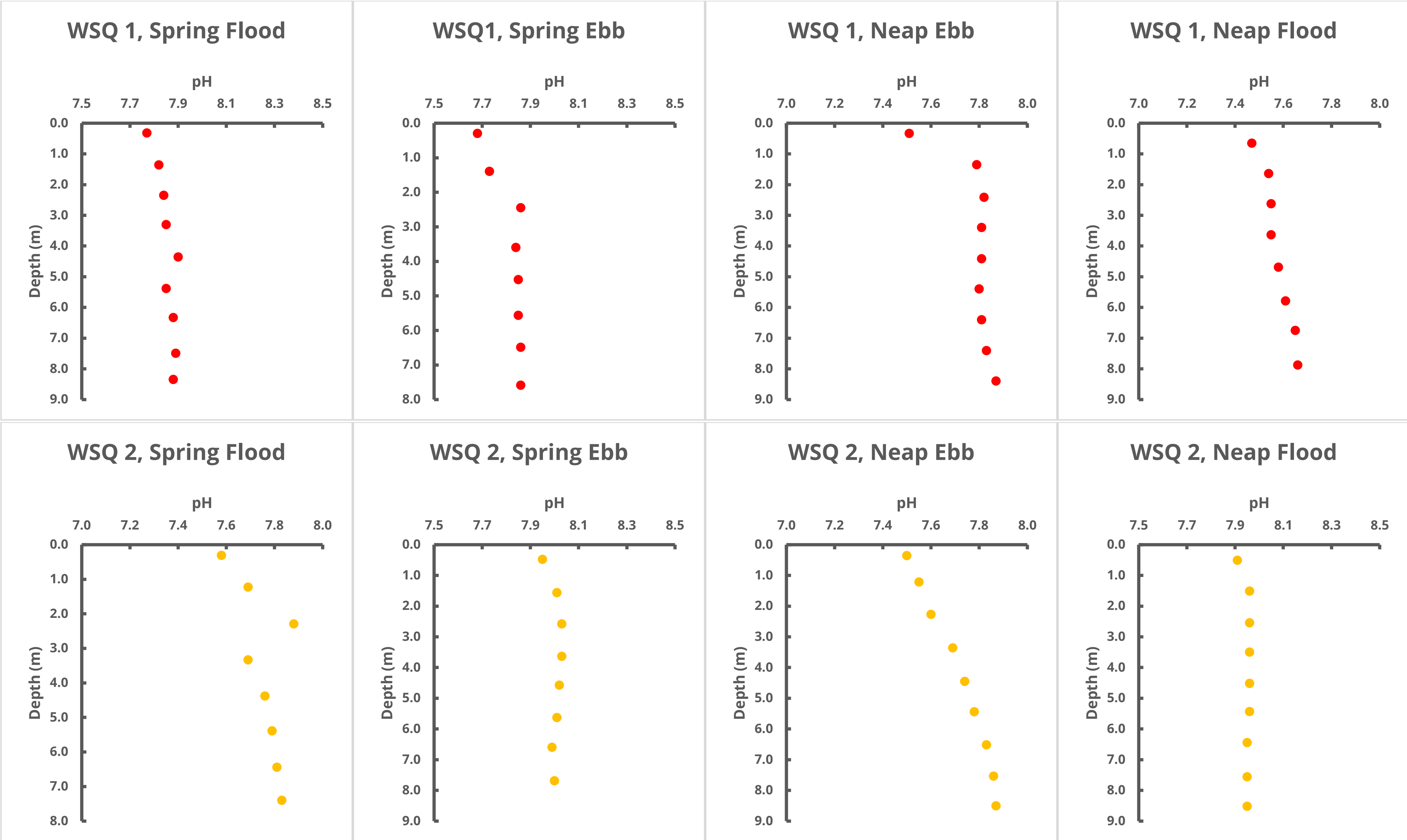


Figure 4-10 WSQ1 and WSQ2 pH readings for *in-situ* profiling during spring and neap, flood and ebb tides.

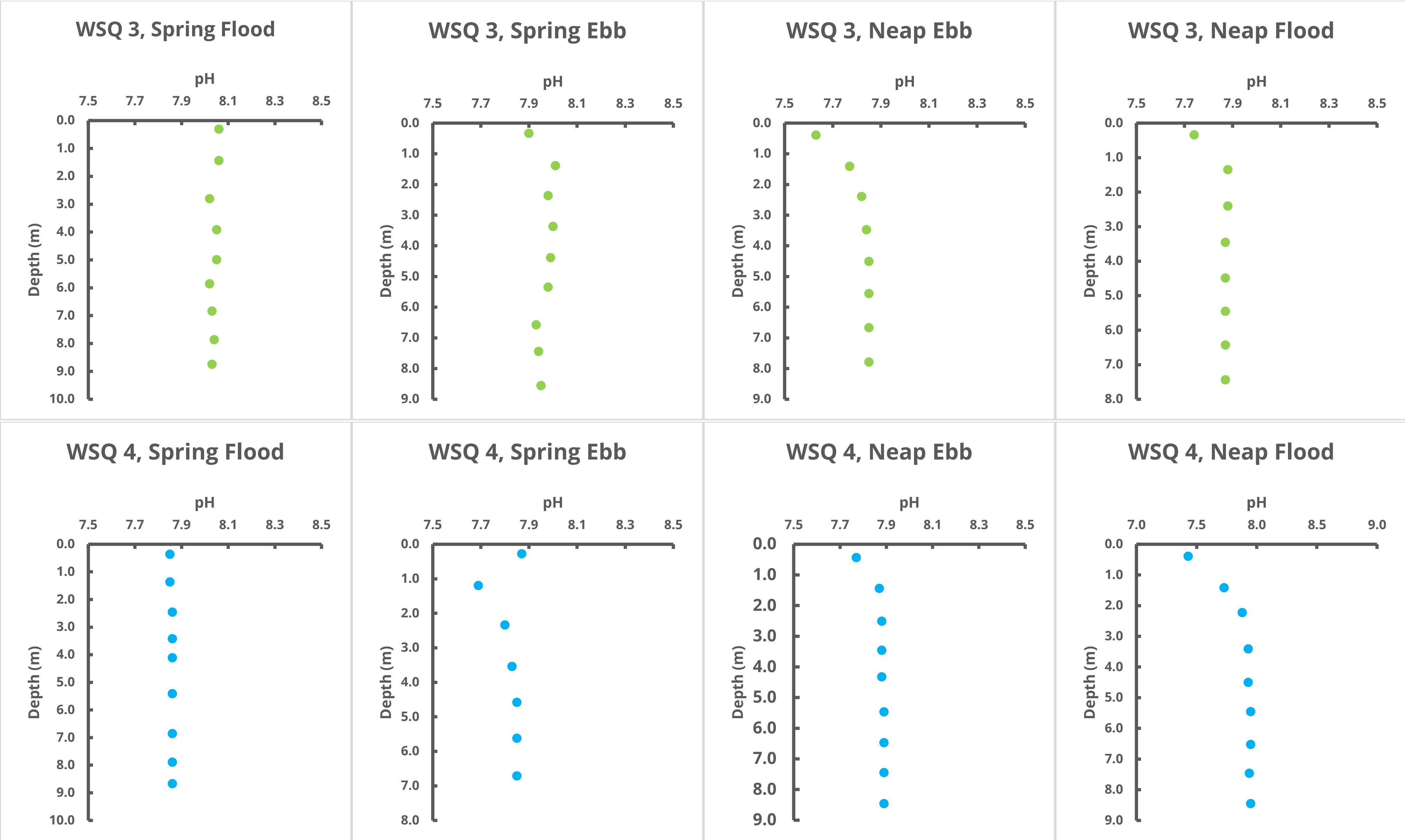


Figure 4-11 WSQ3 and WSQ4 pH readings for *in-situ* profiling during spring and neap, flood and ebb tides.

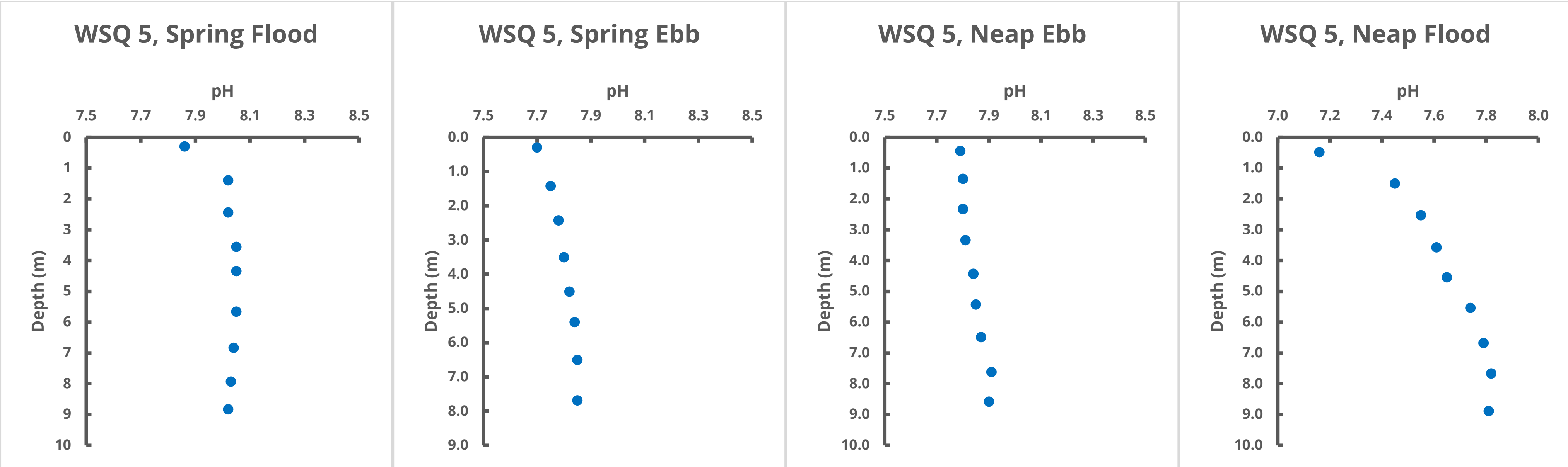


Figure 4-12 WSQ5 pH readings for *in-situ* profiling during spring and neap, flood and ebb tides.

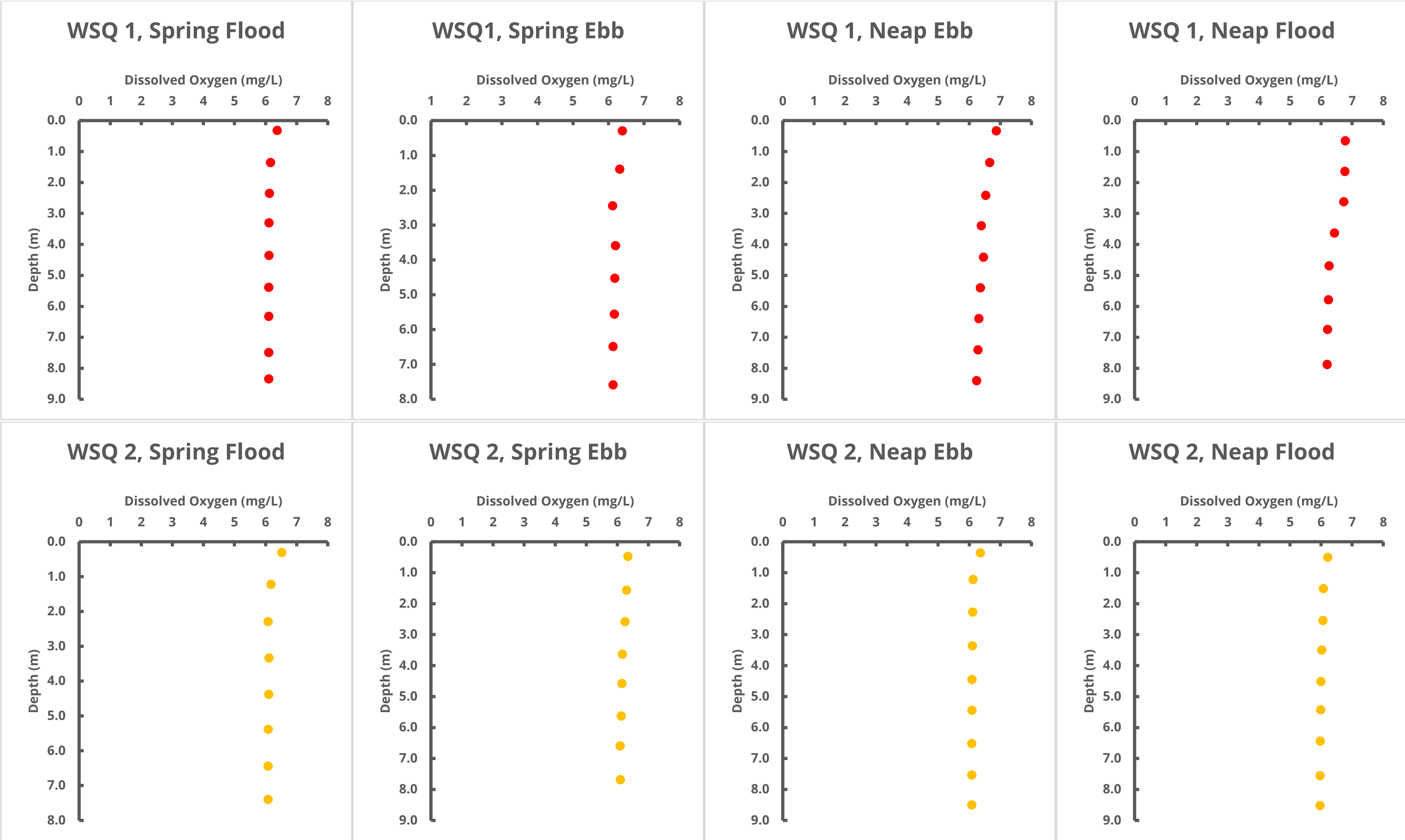


Figure 4-13 WSQ1 and WSQ2 dissolved oxygen readings for *in-situ* profiling during spring and neap, flood and ebb tides.

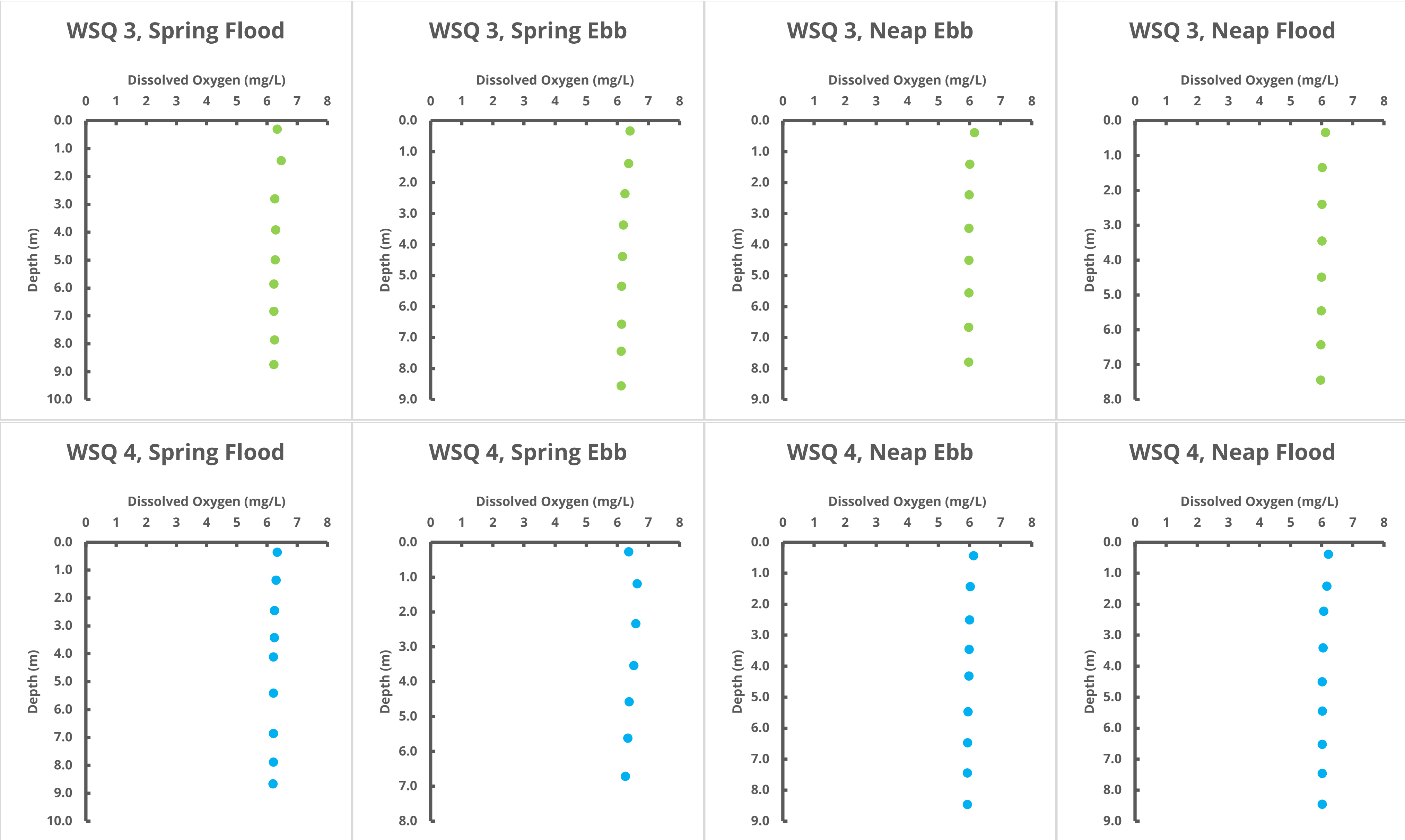


Figure 4-14 WSQ3 and WSQ4 dissolved oxygen readings for *in-situ* profiling during spring and neap, flood and ebb tides.

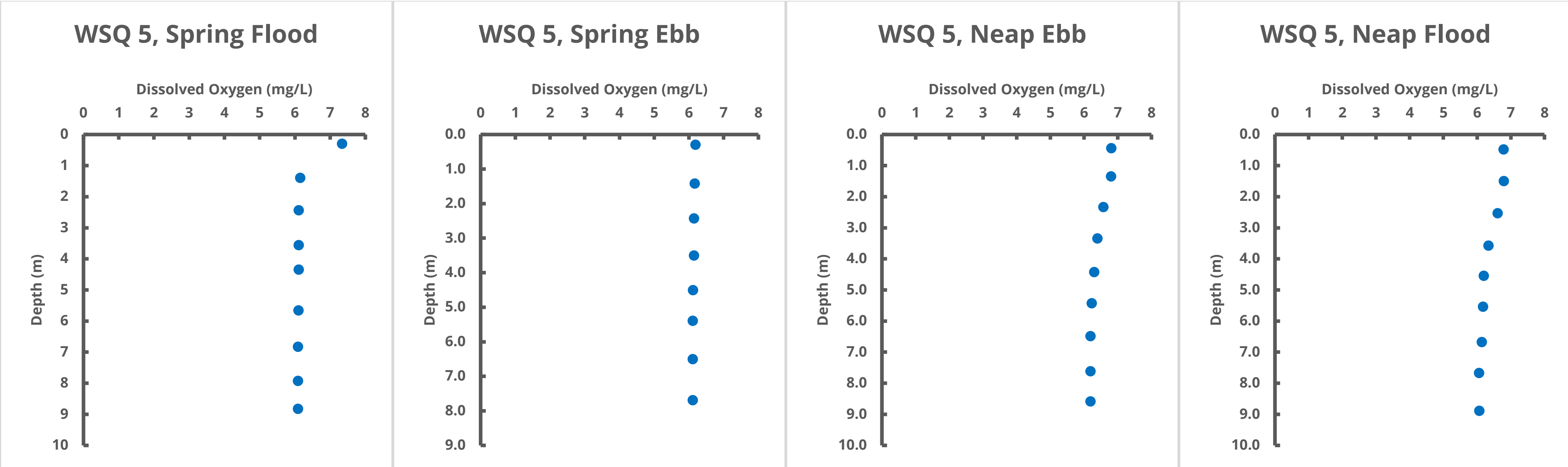


Figure 4-15 WSQ5 dissolved oxygen readings for *in-situ* profiling during spring and neap, flood and ebb tides.

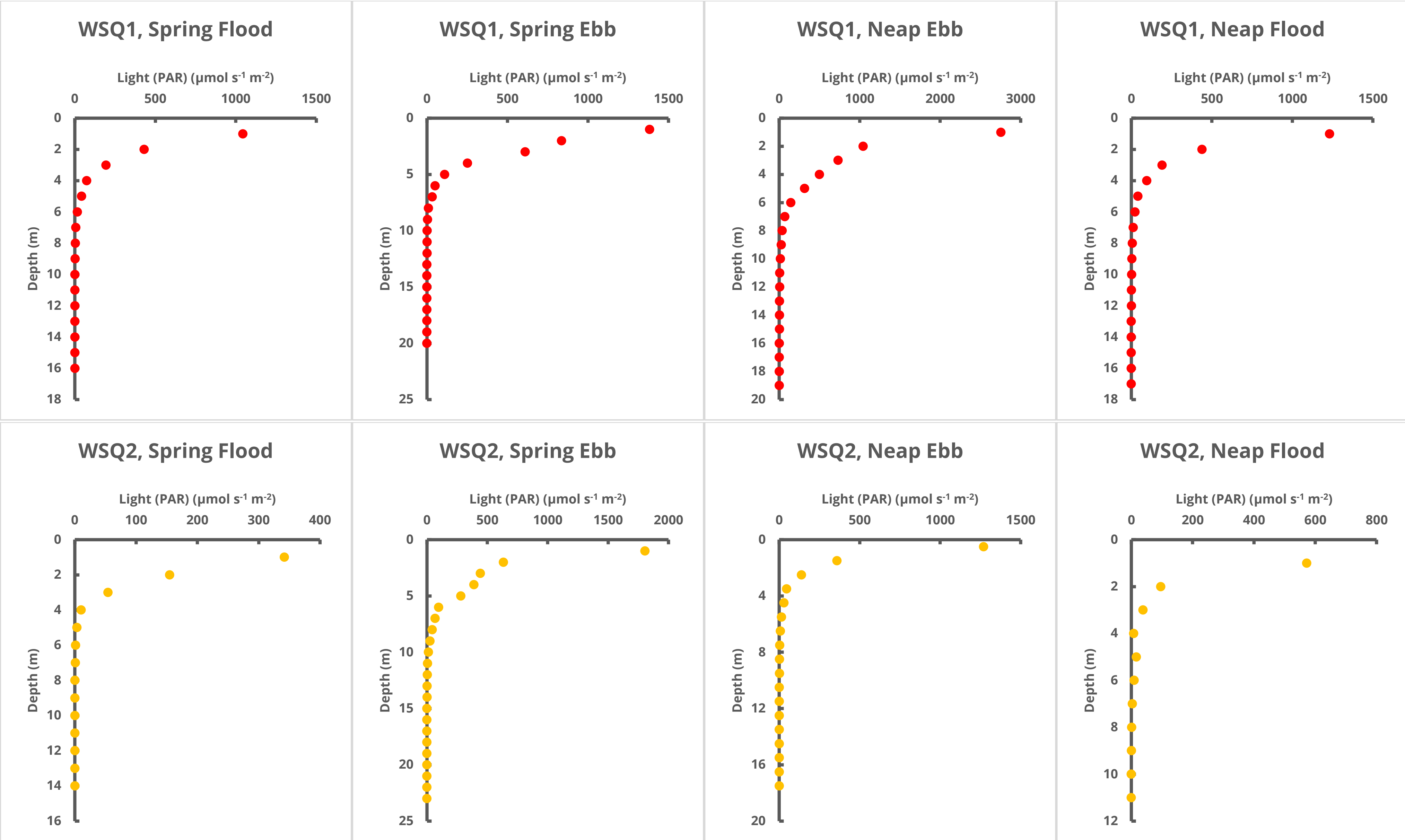


Figure 4-16 WSQ1 and WSQ2 light readings for *in-situ* profiling during spring and neap, flood and ebb tides.

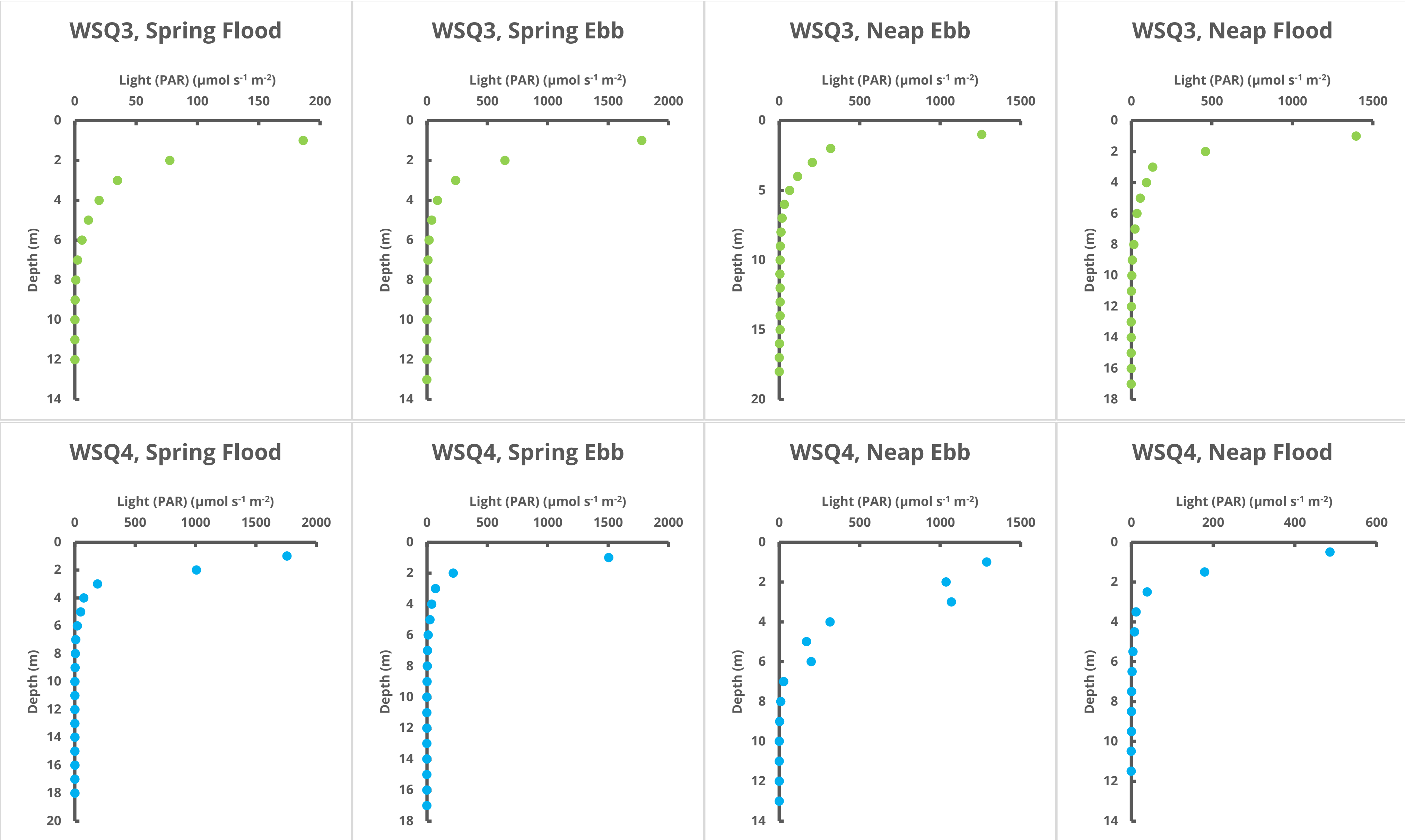


Figure 4-17 WSQ3 and WSQ4 light readings for *in-situ* profiling during spring and neap, flood and ebb tides.

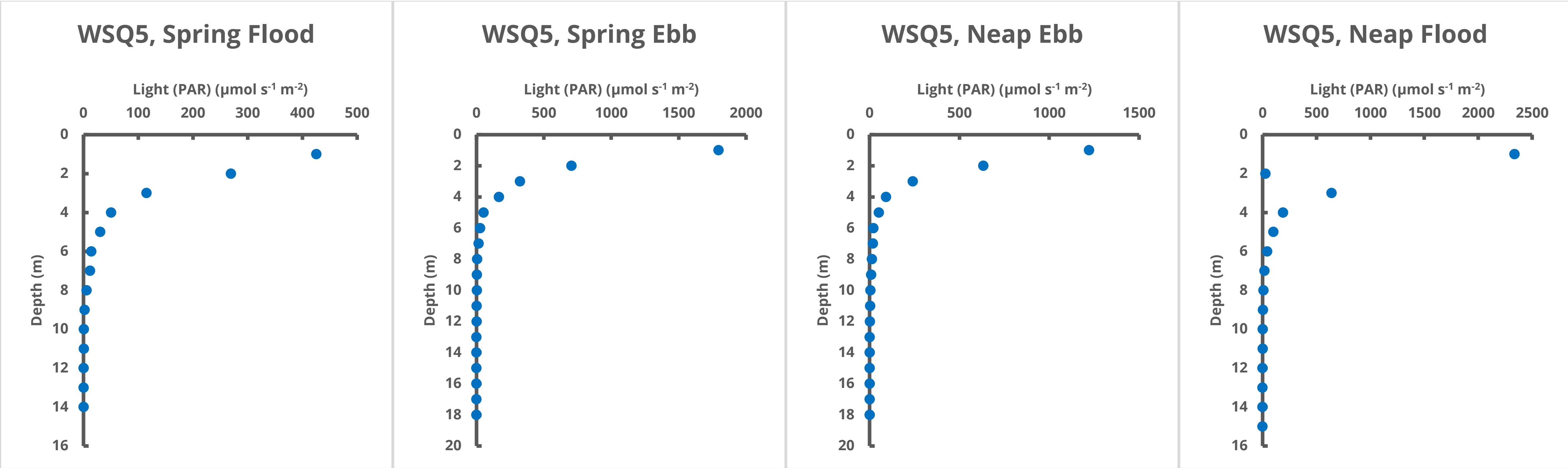


Figure 4-18 WSQ5 light readings for *in-situ* profiling during spring and neap, flood and ebb tides.

Hydrobiology

STREET
Singapore Water Exchange
84 Toh Guan Road East
#04-08/09
Singapore 608501

CONTACT
singapore@hydrobiology.com

www.hydrobiology.com

APPENDIX D WATER QUALITY MODELLING REPORT

REPORT

Assessment of Environmental Impacts from Proposed CCGT at Southern Jurong Island

Environmental Modelling Report

Client: Environmental Resources Management

Reference: SA1859-RHD-XX-XX-RP-X-0001
Status: Final/C07
Date: 9 December 2025

Haskoning
Enhancing Society Together

HASKONING SINGAPORE PTE. LTD.

1 Harbourfront Avenue
Level 13 Keppel Bay Tower
Singapore 098632
Singapore
Water & Maritime
Trade register number: 201012364W

Phone: +65 6779 1502
Email: singapore@rhdhv.com
Website: haskoning.com

Document title:	Assessment of Environmental Impacts from Proposed CCGT at Southern Jurong Island
Subtitle:	Environmental Modelling Report
Reference:	SA1859-RHD-XX-XX-RP-X-0001
Your reference	SG FY26-028
Status:	Final/C07
Date:	9 December 2025
Project name:	CCGT Jurong Modelling
Project number:	SA1859
Author(s):	Andaru Katri Lasrindy, Athaya Qasamah Jauhari, Ryan Liang
Drafted by:	Click here to enter text.
Checked by:	Md Mobassarul Hasan
Date:	09/12/2025
Approved by:	Valen Rangga Gerina
Date:	09/12/2025
Classification:	Project related

Haskoning
Enhancing Society Together

Revision	Date	Description	Prepared	Checked	Approved
C01	29/08/2025	First draft, without the results from CP modelling	Andaru Katri Lasrindy, Athaya Qasamah Jauhari, Ryan Liang	Md Mobassarul Hasan	Valen Rangga Gerina
C02	03/09/2025	Second draft; includes the complete modelling works of HD, thermal plume, and chlorine plume	Andaru Katri Lasrindy, Athaya Qasamah Jauhari, Ryan Liang	Md Mobassarul Hasan	Valen Rangga Gerina
C03	22/09/2025	Third draft: Includes the complete modelling results covering hydrodynamics, thermal plume, chlorine plume, and impacts attributable solely to the CCGT facility.	Andaru Katri Lasrindy, Athaya Qasamah Jauhari, Ryan Liang	Valen, Rangga Gerina, Md Mobassarul Hasan	Daniel Martens
C04	16/10/2025	Fourth draft: Includes the complete modelling results with added outfall discharge channel in the domain mesh	Andaru Katri Lasrindy, Athaya Qasamah Jauhari, Ryan Liang	Md Mobassarul Hasan	Valen Rangga Gerina
C05	23/10/2025	Updated following ERM's comment dated on 22 October 2025: - Revising texts and other editorial comments. - Including more figures for timeseries of temperature and chlorine during SW monsoon. - Removing the mitigation measures due to compliance.	Andaru Katri Lasrindy, Athaya Qasamah Jauhari, Ryan Liang	Md Mobassarul Hasan	Valen Rangga Gerina
C06	13/11/2025	Updated following EPC's request to reduce the discharged temperature from 38°C to 36°C. Other parameters remain the same.	Andaru Katri Lasrindy, Athaya Qasamah Jauhari, Ryan Liang	Md Mobassarul Hasan	Valen Rangga Gerina
C07	24/11/2025	Appendices for sensitivity analysis and additional figures for modelling results are now included.	Andaru Katri Lasrindy, Athaya Qasamah Jauhari, Ryan Liang	Md Mobassarul Hasan	Valen Rangga Gerina
C08	09/12/2025	Updated following ERM's comment dated on 08 December 2025: - Revising texts and other editorial comments. - Adjusted the results and analysis to reflect the +2°C AMWQC threshold for temperature changes only.	Andaru Katri Lasrindy, Athaya Qasamah Jauhari, Ryan Liang	Md Mobassarul Hasan	Valen Rangga Gerina

Appendices

Table of Tables

Table of Figures

Haskoning
Enhancing Society Together

Executive summary

Introduction
The development of a new Combined Cycle Gas Turbine (CCGT) facility at Southern Jurong Island requires environmental modelling to assess its potential impact on the surrounding marine environment, particularly due to seawater intake and discharge operations. This modelling aims to simulate and evaluate changes in current patterns, seawater temperature, and chlorine concentration under both baseline and operational scenarios using the MIKE3 FM modelling suite.

The CCGT is located at the southwestern tip of Jurong Island, with its intake facing Jurong Strait and outfall facing Pandan Strait. Sensitive receptor areas considered in the assessment include Helios Secondary Reef, Pulau Salu, Sakra Terminal, Terumbu Pempang Laut and Tengah, as well as future fish farms near Pulau Bukom.

Assessment criteria
- Hydrodynamic (HD) assessment criteria include changes in current field, mean and maximum current speeds, current speed exceedance limits, and slack water time.
- Thermal plume (TMP) assessment criteria focus on discharge temperature compliance and excess temperature in receiving waters, particularly in relation to sensitive receptors.
- Chlorine plume (CP) assessment criteria are meant to evaluate chlorine concentrations at the discharge point and its dispersion in the receiving waters, referencing both national and international environmental standards.

Data requirements
For this modelling study three categories of data have been utilized:
1. Input data for simulation setup: bathymetry, meteorological data, tidal boundaries, and discharge characteristics from both existing and proposed sources.
2. Calibration data for model validation: observed water levels, current measurements, and temperature monitoring data to ensure model accuracy.
3. Analysis data: receptor locations and environmental criteria used to assess potential impacts on ecological and socio-economic features.

Model approach and assumptions
The model domain was constructed to reflect the current and future coastal configuration, including planned land expansion in Tuas and Tuas Terminal Reclamation (in 4 phases) as outlined in the URA Master Plan 2025. Each scenario was simulated for a period of 30 days to capture two full spring-neap tidal cycles, with February and July selected as representative months for the Northeast (NE) and Southwest (SW) monsoons respectively. Climate change parameters such as sea level rise, temperature increase, and wind speed variation were incorporated based on projections from the Third National Climate Change Study by the Centre for Climate Change Research Singapore (CCRS).

Existing intakes and outfalls were excluded from the model to focus solely on the impacts of the proposed CCGT facility, as their cumulative effects were deemed negligible based on sensitivity analysis. The model includes detailed specifications for the CCGT intake and outfall, with discharge rates of 15.75 m^3/s and temperatures of 36°C (normal), along with chlorine dosing scenarios of 0.25 ppm (normal) and 0.50 ppm (shock). The CCGT outfall channel is included in the model domain for more comprehensive impact.

Wind data from ERA5 and NEA (at Tuas South) were used, converted into U and V components[1] for spatial and temporal input into the model. Precipitation and evaporation data from ERA5 were applied as surface fluxes across the model domain to simulate freshwater input and loss. Heat exchange processes were modelled using ERA5-derived short-wave radiation, long-wave radiation, and atmospheric conditions, applied as spatially and temporally varying fields.

The chlorine decay rate was derived based on initial concentration, temperature, and Total Organic Carbon (TOC) levels, resulting in a final decay rate of 1.185/hr used in the Transport Module of the MIKE modelling suite. Calibrated parameters include reference temperature, eddy viscosity, and bed resistance, selected within recommended ranges to ensure numerical stability. Model limitations include the exclusion of inputs such as ice coverage and vegetation effects, which are not applicable to the study area. Scenarios were developed to represent baseline and operational phase during both NE and SW monsoons, with variations in climate change and chlorine dosing.

Model calibration

Model calibration was carried out based on performance metrics such as bias, RMSE, and correlation coefficient, with targets including ±0.2 m for water level bias and >0.8 for correlation. Hydrodynamic calibration results showed good agreement with observed data, meeting 6 out of 7 performance criteria. Thermal plume calibration results met the “very good” criteria across all monitoring points, assuring the model’s reliability.

Sensitivity analysis

A sensitivity analysis was conducted to validate the exclusion of existing sources and assess the robustness of model assumptions, focusing on hydrodynamic and thermal conditions. Hydrodynamic sensitivity results showed negligible differences, confirming the model is not sensitive to the exclusion of existing sources. Thermal plume sensitivity results also showed minor differences, supporting the decision to exclude cumulative thermal impacts from external sources.

Model results and analysis – general findings

Model results are presented as two-dimensional (2D) maps focusing on surface and bottom layers of the water column, with outputs tagged by attributes such as season, model type, parameter, tidal condition, phase, and layer to facilitate interpretation.

The proposed CCGT facility introduces localised changes in current dynamics near the outfall channel. Maximum current speed variations of up to ±0.20 m/s are observed along the CCGT coastline, while mean current speed changes remain within ±0.05 m/s across the broader study area. These changes are confined to the immediate vicinity of the outfall and do not alter overall current patterns or tidal flow regimes. No exceedance of MPA thresholds (2.0 knots for berthing, 3.5 knots for fairways) is detected, indicating no significant risk to navigation or terminal operations. However, a 25% reduction in slack water duration near the outfall suggests stronger currents that may influence berthing efficiency and localised sediment dynamics.

Thermal dispersion from the CCGT outfall remains largely confined to the surface layer, with minimal influence at depth due to stratification. Model results show that mean excess temperatures generally remain within +2.0°C and are restricted to a 100-m radius from the outfall. However, localised exceedances of the +2.0°C threshold for maximum temperature occur at the surface during both NE and SW monsoons, extending slightly beyond the 100-m mixing zone but remaining within 300 m of the outfall.

[1] The U component of wind is the eastward (zonal) component, and the V component is the northward (meridional) component, representing the horizontal wind's directional breakdown into east-west and north-south directions, respectively. A positive U component indicates wind blowing towards the east, while a positive V component signifies wind blowing towards the north.

At the nearest sensitive receptor, Helios Secondary Reef (located 1.1 km away), surface temperature increases of up to between +1.0°C to +1.5°C during the NE monsoon, but below +1.0°C during the SW monsoon, while bottom-layer changes remain below +0.3°C. These exceedances occur intermittently rather than continuously and persist only for short durations. Maximum surface temperature variations gradually decrease from +1.0°C to +1.5°C at the eastern end of the reef, closest to the outfall, to +0.1 °C toward the western end. These findings indicate that thermal impacts are highly localised and temporary, making it unlikely to cause significant stress to coral communities at the Helios Secondary Reef.

Chlorine concentrations decrease rapidly due to high reactivity and strong tidal mixing, reducing from initial discharge levels of 0.25–0.50 ppm to below 0.02 ppm within 300 m of the outfall. While the discharge complies with Singapore's regulatory limit of 1 ppm, localised exceedances of the more stringent USEPA acute (0.013 ppm) and chronic (0.0075 ppm) thresholds occur within the near-field zone (< 300 m). These exceedances are temporary and confined to the immediate mixing zone, with concentrations falling below both thresholds well before reaching Helios Secondary Reef or other sensitive receptors. No exceedance is observed at depth, and the overall chlorine impact is considered negligible beyond the localised discharge area.

Model results and analysis – specific impact assessment

Hydrodynamic modelling results for the proposed CCGT facility indicate notable hydrodynamic changes in the surrounding area. There is 25% reduction in slack water areas near the outfall mouth where jetties are located, but no exceedances in 2.0 knots for berthing and 3.5 knots for fairways limits. Hence, only slight risk to navigation or terminal operations is expected. The CCGT facility does influence temperature and chlorine concentrations; however, these effects are spatially confined within 300 m of the project site and do not extend to the nearest sensitive receptor, the Helios Secondary Reef. Other environmentally sensitive areas remain unaffected due to their considerable distance from the discharge zone.

Conclusions

The proposed CCGT facility is largely compliant with relevant environmental guidelines; however, localised non-compliance is observed near the outfall for two parameters. Temperature exceeds the +2.0°C AMWQC threshold within the 100 m mixing zone but stay within approximately 300 m of the outfall. Chlorine concentrations also exceed the USEPA acute (0.013 ppm) and chronic (0.0075 ppm) criteria within the near-field zone (< 300 m), although levels fall below these thresholds well before reaching sensitive receptors such as Helios Secondary Reef.

Impact significance was evaluated using the Rapid Impact Assessment Matrix (RIAM). Hydrodynamic changes are assessed as **No Impact**, thermal effects as **Slight Negative Impact**, and chlorine effects as **No Impact**, all of which are temporary, reversible, and localised. Navigation and terminal operations remain compliant with MPA criteria, though localised current acceleration near the outfall may require operational planning considered as **Slight Negative Impact**.

This study focuses solely on the direct impacts of the CCGT facility. Broader external factors, such as climate change, sea level rise, increased wind speeds, and land reclamation, are expected to have a more significant influence on Singapore's marine environment. These factors may alter hydrodynamics and affect the dispersion of discharge; however, they are addressed in separate assessments outside the scope of this report.

1 Introduction

1.1 Background

The development of a new Combined Cycle Gas Turbine (CCGT) facility at Southern Jurong Island represents a significant infrastructure project aimed at enhancing Singapore's energy security and supporting its transition to a more sustain1able energy future. As part of the environmental due diligence and regulatory requirements, it is essential to assess the potential impacts of the project on the surrounding marine environment, particularly those arising from the intake and discharge of seawater used in the cooling system.

The operation of the CCGT involves the abstraction of large volumes of seawater for cooling purposes, followed by the discharge of heated water back into the sea. These activities can alter local hydrodynamic conditions and elevate seawater temperatures, potentially affecting marine biodiversity, water quality, and nearby sensitive receptors such as aquaculture facilities, marine infrastructure, and navigation routes. The impact can be potentially exacerbated when specific chlorine concentration, used to prevent biological growth and to maintain the desired water chemistry, is discharged from the outfall. Therefore, hydrodynamic, thermal plume, and chlorine plume modelling are critical components of the environmental impact assessment (EIA), providing a scientific basis for understanding and mitigating these potential impacts.

This approach is consistent with best practices and regulatory expectations in Singapore, as demonstrated in similar EIA studies such as the Keppel CCGT project at Banyan Basin of Jurong Island, where numerical modelling was used to evaluate changes in current regimes and thermal dispersion patterns.

1.2 Objectives

The primary objective of the hydrodynamic, thermal plume, and chlorine plume modelling is to simulate and evaluate the potential changes in current patterns and seawater temperature, as well as excess chlorine concentration, resulting from the operation of the proposed CCGT facility. Specifically, the modelling aims to:

- Simulate both baseline (pre-construction) and operational (post-construction) scenarios under representative Northeast (NE) and Southwest (SW) monsoon conditions to understand seasonal variations in current, temperature, and chlorine concentration dynamics.
- Quantify the changes in current velocities, temperature and chlorine concentration distributions in the vicinity of the intake and outfall structures, including the influence of future climate conditions based on national climate projections.

The modelling is conducted using the MIKE3 Flexible Mesh (FM) suite developed by DHI, a robust and widely accepted tool for 3D hydrodynamic and thermal simulations in coastal and marine environments. The Transport Module is additionally included to cover chlorine concentration simulations.

1.3 Site definition

1.3.1 Study area

The CCGT is situated at the southwestern tip of Jurong Island. This facility features an intake point facing the west opening of Jurong Strait, and an outfall point facing Pandan Strait which separates Jurong Island from the Southern Islands such as St. John's, Lazarus, Kusu and Sisters' Islands (Figure 1-1). The subsequent sections will detail the hydrodynamic and environmental conditions in the vicinity of the Project.

Figure 1-1 Proposed location of CCGT at Southern Jurong Island; intake point is indicated by yellow "X", and outfalls by red "X"

1.3.2 Sensitive receptors

The changes in temperature and chlorine levels due to the proposed CCGT might affect the environmentally sensitive areas surrounding the facility (see Figure 1-2). Several industrial plants on Jurong Island rely on seawater from Jurong Strait for their cooling systems. Therefore, it is crucial to ensure that the addition of high-temperature water from the CCGT does not disrupt the operations of these existing plants. Currently, Jurong Strait already receives multiple discharges from various sources, including industrial plants, desalination facilities, wastewater treatment plants (WWTP), wastewater reclamation plants (WRP), rivers, and drainage systems.

Regarding living species, several coral reefs exist along Pandan Strait at Helios Secondary Reef, Cyrene Reef and at the Southern Islands, where mangrove also exhibits. Marine mammals are also known to frequent Jurong Strait. The western and eastern parts of Jurong Strait are separated by the Jurong Island Highway, which connects Jurong Island to the mainland. It is a closed structure, hence no transition between the two water bodies. There are small strips of mangroves that grow along the Pandan River, and seagrass habitats are found at West Coast Park. Although these areas are relatively distant from the CCGT, potential impacts will still be assessed in the event that the influence extends into these regions.

Haskoning
Enhancing Society Together

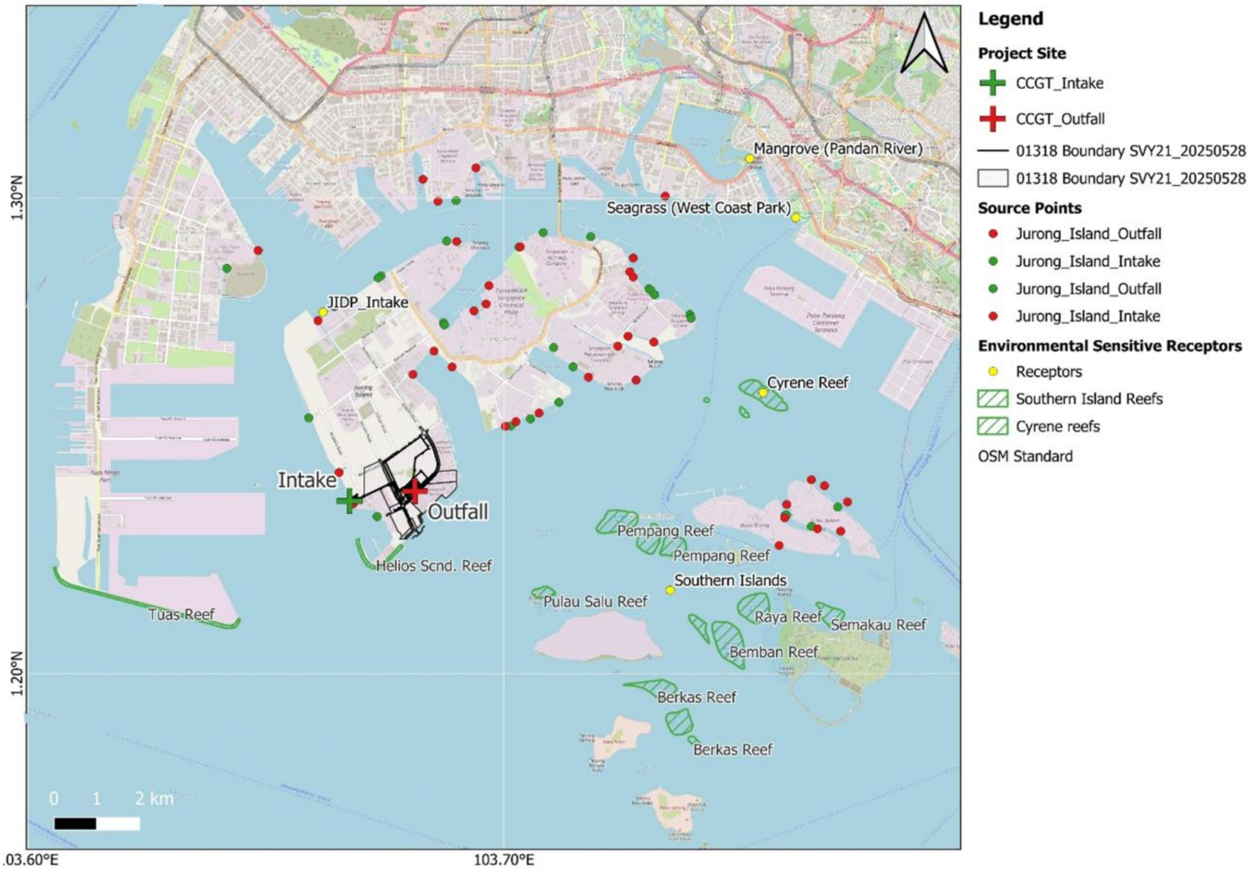


Figure 1-2 Sensitive receptors in the vicinity of CCGT, with inflow and outfalls source points along Jurong and Pandan Straits

Table 1-1 summarizes the selected environmentally sensitive receptors to be assessed in the modelling results based on their proximity to the outfall areas. Their locations are also captured in Figure 1-2 with their corresponding numbers. Terumbu Pempang Laut and Tengah will be combined in the assessment as they are very close to each other.

Table 1-1 Selected environmentally sensitive receptor areas for modelling assessment

No	Environmentally Sensitive Receptor	Distance from Outfall Location
1	Helios Secondary Reef	1.1 km
2	Pulau Salu	3.7 km
3	Coral rubble and Seagrass at Sakra Terminal	4.0 km
4	Terumbu Pempang Laut	4.7 km
5	Terumbu Pempang Tengah	5.7 km

In addition to the 5 selected environmentally sensitive receptor areas that are outlined in Table 1-1, there are also future fish farm developments that have been planned by the Singapore Food Agency (SFA). These developments are proposed on the southeastern side of Pulau Bukom, north of the existing fish farm as depicted in Figure 1-3. This fish farm will be located relatively far from the project area, and the impact of proposed CCGT on this receptor is also assessed in this study.

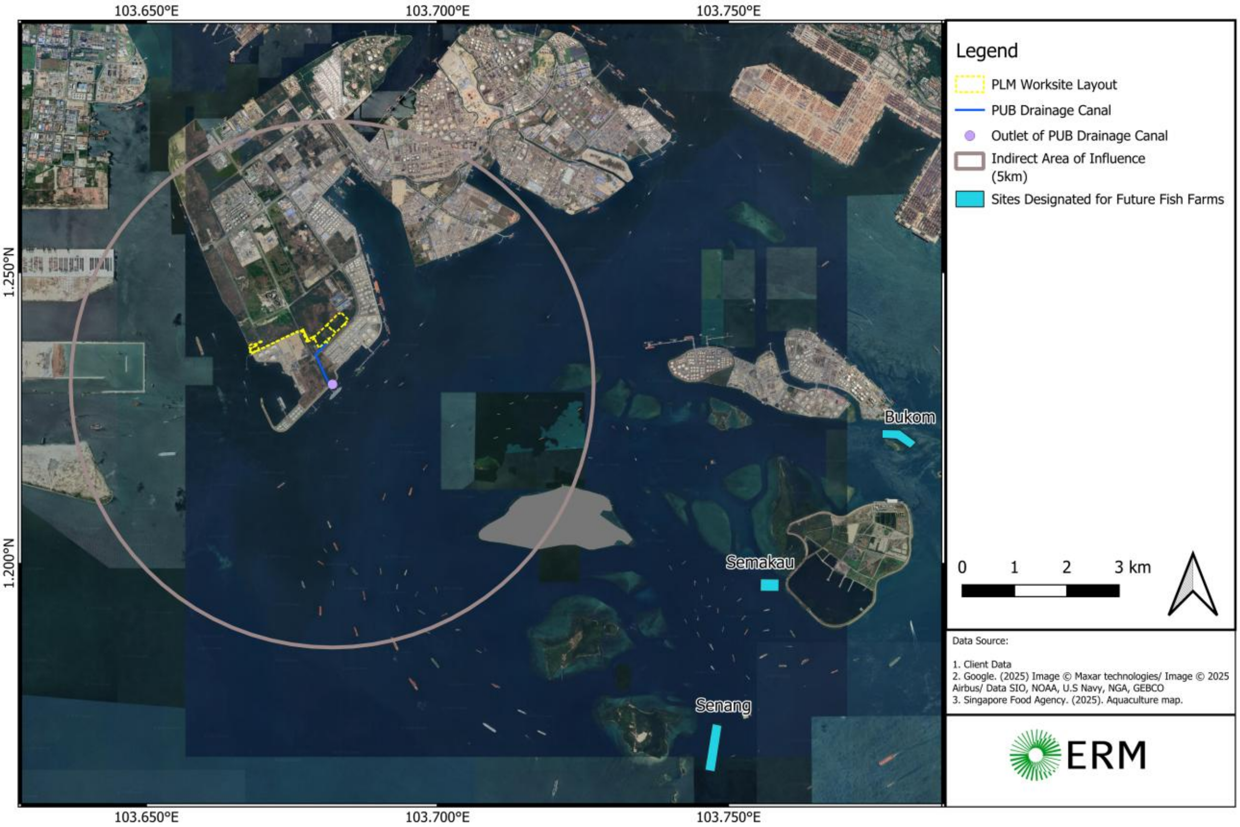


Figure 1-3 Proposed sites designated for future fish farms

2 Environmental impact assessment criteria

To evaluate the potential impacts of the proposed CCGT development at Jurong Island on the surrounding marine environment, a set of impact assessment criteria has been established for hydrodynamic, thermal plume, and chlorine plume modelling. This section outlines the assessment criteria for each of the modelling components.

2.1 Hydrodynamics

The criteria for hydrodynamic are designed to quantify changes in current patterns and flow dynamics between the baseline (pre-construction) and operational (post-construction) phases. The following parameters will be assessed:

1. **Change in current field:**
   The change in current field is a key indicator of how the proposed development may alter local hydrodynamic conditions. This assessment is based on the instantaneous current speeds observed during peak ebb and flood tides across both spring and neap tidal cycles, under NE and SW monsoon conditions. The change is calculated as the difference between current speeds during the operational phase and those in the baseline condition.

   This criterion is particularly important for identifying the formation of shear zones and eddies, which may indicate localised turbulence or stagnation. Such features can have implications for navigational safety and sediment transport and are therefore closely examined in the context of potential negative impacts.

2. **Mean and maximum current speed:**
   Mean and maximum current speed provides a broader temporal perspective on flow conditions. It is calculated as the numerical average of 1-hour interval current speeds at each grid point over a 30-day simulation period, covering two full spring-neap tidal cycles. As with the instantaneous current field, the change in mean and maximum current speed is determined by subtracting baseline values from operational phase values.

   For interpretive purposes, changes in mean current speed of less than 0.05 m/s are typically considered negligible and classified as “No Change.” This threshold helps distinguish between natural variability and project-induced effects. No threshold is defined for maximum current speed, which will be assessed based on the spatial variability.

3. **Current speed exceedance limits:**
   This criterion evaluates the frequency with which current speeds exceed defined thresholds relevant to marine operations. Specifically, the limits of 2.0 knots and 3.5 knots are used, corresponding to the Maritime and Port Authority of Singapore (MPA) berthing and fairway guidelines, respectively, as recommended by the Port Designer’s Handbook (Thoresen, 2018).

   Exceedance is defined as the percentage of time over the 30-day simulation period during which the instantaneous current speed exceeds these thresholds. The impact is assessed by calculating the difference in exceedance percentages between the operational and baseline scenarios. This metric is particularly relevant for assessing potential implications on vessel manoeuvrability and port operations.

4. **Change in slack water time:**

Slack water refers to the brief period during tidal transitions when current speeds drop below 0.25 m/s (0.49 knots). During these intervals, water movement is minimal, and mixing is reduced, which can lead to localised accumulation of pollutants or reduced water quality.

The change in slack water time is assessed by comparing the total duration percentages of slack conditions between the operational and baseline phases. From an ecological perspective, an increase in slack water duration may reduce mixing and water exchange, leading to localised stagnation and possible water quality deterioration near sensitive receptors. Conversely, from a navigational safety and operational planning perspective, slack water is generally considered beneficial, as it provides calmer conditions for vessel manoeuvring and berthing.

2.2 Temperature

The temperature-related criteria are based on both national regulatory requirements and regional environmental protection standards. The assessment focuses on ensuring compliance at the point of discharge and evaluating the extent of thermal influence on nearby sensitive receptors.

1. **Temperature at the discharge point:**
   The first criterion pertains to the temperature of the effluent at the point where it enters the receiving water body. According to Section 8.2 of the Singapore Environmental Protection and Management (Trade Effluent) Regulations 2008, the temperature of trade effluent must not exceed 45°C at the point of discharge into any watercourse or land. For the proposed CCGT at Jurong Island, the design discharged temperature is 36°C and 40°C for normal and emergency operation respectively, which is within the regulatory limit.

2. **Temperature in the receiving water:**
   The second criterion addresses the thermal impact on the ambient marine environment, particularly in areas where sensitive ecological or socio-economic receptors are located. The ASEAN Marine Water Quality Criteria (AMWQC) (ASEAN, 2008) stipulate that the temperature of the receiving water should not increase by more than 2°C above the maximum ambient temperature.

   This assessment focuses on the spatial extent and intensity of the thermal plume, especially in the vicinity of identified environmental receptors such as coral reefs, seagrass beds, and fish farms. Model outputs will be analysed to determine whether the excess temperature remains within the 2°C threshold in these critical areas. Exceedance of this limit may indicate a risk of thermal stress to marine organisms.

2.3 Chlorine

The chlorine-related criteria are based on both national regulatory requirements and global environmental protection standards. Similar with thermal, the assessment focuses on ensuring compliance at the point of discharge and evaluating the extent of chlorine concentration on nearby sensitive receptors.

1. **Chlorine concentration at the discharge point:**
   The first criterion is related to the chlorine concentration at point of discharge. Based on Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008, concentration of free chlorine shall not exceed 1 mg/L (1 ppm) at point of entry to watercourse. For the proposed CCGT at Jurong Island, the latest design discharged chlorine concentrations are 0.25 ppm and 0.5

ppm for normal and shock dosing operation respectively, which is below the regulatory threshold. Same chlorine concentrations were being considered also in the Keppel CCGT EIA study.

2. **Chlorine concentration in the receiving water:**
The second criterion is related to the limit of chlorine concentration at receiving marine environments. To assess the potential ecological effects of chlorine discharge, the acute level of concern recommended for estuarine organisms has been adopted as the assessment criterion. Based on (USEPA-b, 1999), the value is 0.013 mg/L (13 µg/L) and is widely recognised as protective for marine and estuarine species in coastal environments. Because chlorine is a fast-acting and rapidly decaying substance, its risk to aquatic life depends mainly on short-term peak exposure.

In another USEPA guideline (USEPA-a, 1991), aquatic life criteria for both individual toxicants and whole effluent toxicity are defined using two key thresholds:
- Criterion Maximum Concentration (CMC): a 1-hour average acute concentration limit of 0.013 mg/L (0.013 ppm), designed to identify and control short-term exceedances in chlorine levels that could pose immediate risks to marine life.
- Criterion Chronic Concentration (CCC): a 4-day average chronic concentration limit of 0.0075 mg/L (0.0075 ppm), intended to assess and manage long-term exposure effects on aquatic ecosystems.

These two criteria are adopted in this study to establish chlorine concentration limits, enabling differentiation between the temporary and long-term environmental impacts of CCGT operations.

2.4 Summary of assessment criteria

The assessment criteria outlined in Sections 2.1 to 2.3 are summarised in Table 2-1 below.

Table 2-1 Summary of assessment criteria for hydrodynamics, temperature and chlorine concentrations relevant to CCGT

Modelling component	Parameter	Criterion	Source
Hydrodynamics	Change in current field	N/A	N/A
	Mean and max current speed	< 0.05 m/s = No Change	N/A
	Current speed exceedance limits	≤ 2.0 knots (berthing) ≤ 3.5 knots (fairways)	(Thoresen, 2018)
	Change in slack water time	N/A	N/A
Temperature	Temperature at discharge point	< 45°C at the point of discharge	Environmental Protection and Management (Trade Effluent) Regulations 2008
	Temperature in receiving water	ΔT < 2°C above ambient	(ASEAN, 2008)
Chlorine	Concentration at discharge point	< 1 mg/L (1 ppm) at point of entry to water	Environmental Protection and Management (Trade Effluent) Regulations 2008
	Concentration in receiving water and allowable duration	< 0.013 mg/L (13 µg/L) (1-hr average, acute - CMC)	(USEPA-b, 1999) (USEPA-a, 1991)
	Concentration in receiving water and allowable duration	< 0.0075 mg/L (7.5 µg/L) (4-days average, chronic - CCC)	(USEPA-a, 1991)

2.5 Rapid Impact Assessment Matrix (RIAM)

While the afore-mentioned criteria are used to assess compliance or non-compliance against the existing guideline, the significance of environmental impacts arising from the proposed CCGT development shall be still evaluated by adopting the Rapid Impact Assessment Matrix (RIAM) evaluation framework in this study. RIAM provides a transparent, rapid, and reproducible method to translate complex environmental data, such as modelling outputs, into a quantified Environmental Score (ES) that reflects the overall significance of each impact.

RIAM is particularly valuable when non-compliance against environmental criteria or guidelines is observed, as it enables a more nuanced interpretation of the impact beyond binary compliance/non-compliance outcomes. Instead of treating all exceedances as equally significant, RIAM incorporates five weighted evaluation criteria based on this following formula:

$$ES = I \times M \times (P + R + C)$$

where:

- Importance (I) – importance or relevance level of the receptor,
- Magnitude (M) – degree of change or stress imposed,
- Permanence (P) – duration of the impact,
- Reversibility (R) – potential for recovery or mitigation,
- Cumulative Impact (C) – likelihood of cascading or secondary effects.

By combining these criteria, RIAM allows the assessment to contextualize exceedances. For example, a minor exceedance in a low-importance area may result in a low ES and be classified as a slight or minor impact, whereas the same exceedance in a highly sensitive receptor zone may be classified as moderate or major.

This approach ensures that impact significance is not overstated where guideline breaches are localised, temporary, or reversible, and conversely, that critical impacts are not understated due to rigid threshold-based assessments.
The standard (generic) definitions of each evaluation criteria, and the associated ordinal scores used to calculate the environmental score, are shown in Table 2-2. The calculated ES scores will be then translated into the impact significance following the ranged values summarised in Table 2-3.

Table 2-2 Evaluation criteria and the associated standard definitions and ordinal scores used in the calculation of ES

Evaluation Criteria	Standard Definitions	Ordinal Score
Importance	Important to national/international interests	5
	Important to regional/national interests	4
	Important to areas immediately outside the local condition	3
	Important to the local conditions (within a large direct impact area)	2
	Important only to the local conditions (within a small direct impact area)	1
	No Importance	0
Magnitude	Major positive benefit or change	+4
	Moderate positive benefit or change	+3

Evaluation Criteria	Standard Definitions	Ordinal Score
	Minor positive benefits or change	+2
	Slight positive benefit or change	+1
	No change/status quo	0
	Slight negative disadvantages or change	-1
	Minor negative disadvantages or change	-2
	Moderate negative disadvantages or change	-3
	Major negative disadvantages or change	-4
Permanence	No change or not applicable	1
	Temporary or short-term change	2
	Permanent change or long-term; value and/or function unlikely to return	3
Reversibility	No change or not applicable	1
	Recoverable or controllable through EMMP	2
	Irrecoverable	3
Cumulatively	No change or not applicable	1
	Impact can be defined as non-cumulative/single (not interaction with other impacts)	2
	Presence of obvious cumulative/cascading effect that will affect other Developments or activities or trigger secondary impacts	3

Table 2-3 Range bands used in RIAM

RIAM Environmental Score (ES)	Range Value (alphabetical)	Range Value (numeric)	Description of Range Value
116 to 180	D	4	Major positive impact
81 to 115	C	3	Moderate positive impact
37 to 80	B	2	Minor positive impact
7 to 36	A	1	Slight positive impact
-6 to 6	N	0	No change/ no impact
-7 to -36	-A	-1	Slight negative impact
-37 to -80	-B	-2	Minor negative impact
-81 to -115	-C	-3	Moderate negative impact
-116 to -180	-D	-4	Major negative impact

3 Data requirements

The required datasets for this study can be broadly categorized into three functional groups based on their purpose in the modelling workflow: model inputs, calibration data, and analysis data.

- Model Inputs:
  These are the foundational datasets required to construct and run the numerical models. They represent the physical and operational characteristics of the study area and are essential for simulating real-world conditions.

- Calibration Data:
  Calibration data are observed measurements used to validate and fine-tune the model's performance. These datasets are not used to drive the model but to compare against model outputs to ensure the model behaves realistically.

- Analysis Data:
  This category includes contextual and supporting information that is not directly used in the model simulations but is essential for interpreting results and informing decision-making.

Further elaboration about these datasets, including examples and how each datasets plays a distinct role in ensuring the accuracy, reliability, and relevance of the modelling outcomes, are presented in the next sections.

3.1 Model inputs

Required datasets for modelling inputs include:
- Bathymetry,
- Meteorological data,
- Tidal boundary conditions,
- Discharge and inflow from existing outfalls and intakes, rivers, or other sources in Singapore; and
- Discharge and inflow from new outfalls and intakes of CCGT.

These inputs define the model domain, boundary conditions, and forcing mechanisms. Without accurate and complete input data, the model cannot reliably simulate hydrodynamic or water quality processes. More detailed information on these datasets is presented in Table 3-1. Some of the requested datasets are already in Haskoning's possession, however permission from the relevant agencies is required to re-use the data in this or any subsequent study.

In order to ensure all relevant data can be implemented in the models, the data ought to be converted to model-compatible formats. For DHI MIKE, this includes point coordinate files (.xyz) for bathymetry, temporally and spatially varying data (.dfs2) for meteorological data, or timeseries data (.dfs0) for discharge data.

Table 3-1 Summary of datasets for modelling inputs

Parameter	Source	Status*	Location	Period	Data Format
Bathymetry data is used to construct the model grid for hydrodynamics model. The data must be interpolated onto the model mesh, referenced to a consistent vertical datum (e.g., Chart Datum or MSL), and checked for anomalies or gaps. Smoothing may be applied to avoid numerical instability.					
Bathymetry	CMAP	Secured	Singapore	N/A	Points (.xyz)

Parameter	Source	Status*	Location	Period	Data Format
Meteorological data is used to simulate the air-sea interaction and heat exchange processes. Data must be quality-checked, converted to the required units (e.g. m/s), and interpolated spatially or temporally if needed. Wind vectors may need to be decomposed into U and V components for model input.					
Meteorological data (including wind, evaporation & precipitation, and heat exchange)	ERA5	Secured	Singapore	Jan 2018 – Dec 2018	.dfs2
Wind measurements	NEA	Provided	S115 (Tuas South)	Mar 2010 – Dec 2021	Information in .xlsx/.txt
Tidal boundaries are used as forcing mechanism to simulate water level fluctuations and current patterns at the model boundaries. Constituents or water level in time series must be extracted from SIM Model at boundary locations and formatted for the model's boundary condition input. Datum consistency must be ensured.					
Tidal components from Haskoning's Singapore Island Model (SIM)	Haskoning	Secured	Singapore	N/A	.dfs0
Discharge outfall information is used as the primary project-related inputs to simulate the operational phase of CCGT outfall. No specific data preparation would be required, which the data can be used directly as inputs.					
Discharge location and depth	EPC	Provided	CCGT	Specific value on the coordinate. Assumed depth at near surface.	Points (.xyz)
Discharge rate	EPC	Provided	CCGT	Specific value on the rate. Continuous and direct discharge.	Information in text
Discharge temperature	EPC	Provided	CCGT	Specific value on the temperature. Excess salinity is considered negligible.	Information in text
Discharge chlorine concentration	EPC	Provided	CCGT	Specific value on the concentration, Continuous chlorine dosing.	Information in text
Detailed layout plan of the outfall channel	EPC	Provided	CCGT	Details on channel's geometry and its vertical levels.	Information in drawing (.pdf)
Intake information is used as the primary project-related inputs to simulate the operational phase of CCGT intake. No specific data preparation would be required, which the data can be used directly as inputs.					
Intake location and depth	EPC	Provided	CCGT	Specific value on the coordinate. Assumed depth at near surface.	Points (.xyz)
Inflow rate	EPC	Provided	CCGT	Specific value on the rate. Continuous and direct inflow.	Information in text

**Secured: data is available already within Haskoning database. Provided: data is obtained or requested from external sources.*

3.2 Calibration data

Required datasets for calibration include:

- Observed water levels,
- Current measurements, and
- Temperature and salinity monitoring data.

These datasets are critical for assessing the model's accuracy. A well-calibrated model increases confidence in the predictions made for future or hypothetical scenarios. More detailed information about this data is presented in Table 3-2, with corresponding monitoring locations indicated in Figure 3-1.

Since these datasets are do not serve as direct input to the model setup, no formatting of this data is required. Data have been thoroughly quality-checked and ensured that they are relevant and sufficient for the calibration and validation process.

Table 3-2 Summary of datasets for calibration

Parameter	Source	Status	Location	Period
Observed water level is used as reference points for water level calibration. It helps ensuring that the model accurately replicates tidal amplitudes, phases, and water level fluctuations at key locations.				
Observed Water level	MPA	Provided	West Coast (1° 17.4'N, 103° 45.6'E)	Jan 2018 – Dec 2018
Current measurement is used as reference points for current speed calibration. It helps validating the model's ability to simulate tidal currents and flow patterns.				
Current measurement	MPA	Provided	Gusong (1° 11.4'N, 103° 47.4'E)	Jul 2018 – Dec 2018
Water quality monitoring data are used as reference points for temperature calibration. It helps to accurately represent the temperature stratification in the model area. TOC is used for chlorine decay rate analysis.				
Temperature and Total Organic Carbon (TOC)	ERM	Provided	Jurong Island (WSQ1-WSQ5) – locations refer to Figure 3-1	28-Jul-2025 (spring tides) 05-Aug-2025 (neap tides)

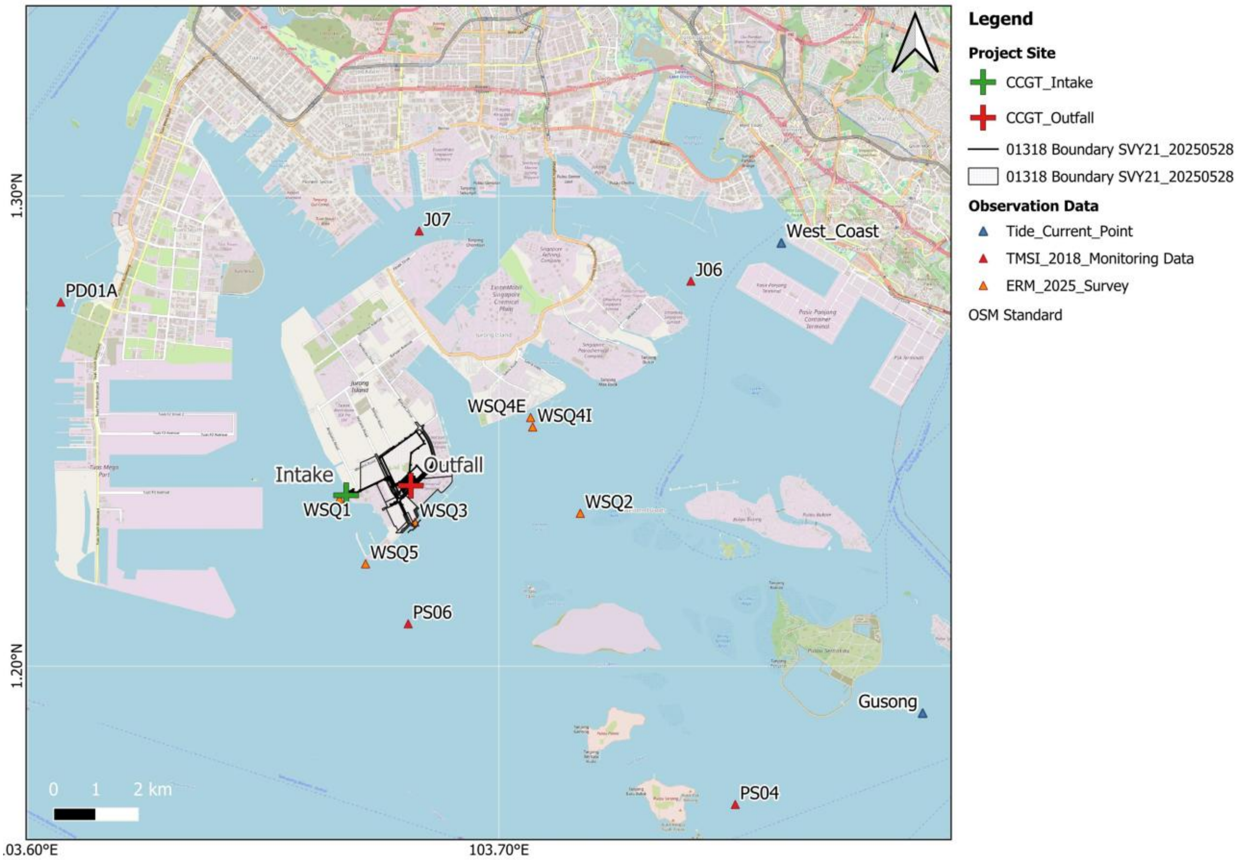


Figure 3-1 Map with locations of calibration data near Jurong Island, comprising both hydrodynamics and temperature model data

3.3 Analysis data

Required datasets for analysis include:

- Environmentally sensitive receptors (i.e., aquaculture / fish farm, coral, seagrass, mangrove, socio-economic such as recreational, navigational etc.), referring to Section 1.3.2 in this report.
- Environmental criteria (i.e., current speed change and exceedance, excess temperature, allowable chlorine concentration etc.), referring to Section 2 in this report.

These datasets help assess the potential impacts of the project on ecological and socio-economic receptors. They are especially important for environmental impact assessments and stakeholder consultations.

Similarly to the datasets used for calibration, the datasets used for analyses do not serve as direct input to the model setup; thus, no formatting of this data is required. The data can be used directly for analysis purposes, to support the assessment of model results against relevant environmental criteria.

4 Model approach and assumptions

To ensure accurate and representative simulation of hydrodynamic and thermal conditions in the vicinity of the proposed CCGT at Jurong Island, the model setup has been carefully designed to reflect both present-day and future environmental conditions. This section outlines the approach taken in setting up the model, the input parameters applied, as well as the scenarios defined for the impact assessment.

4.1 Model setup

4.1.1 Model domain and boundary conditions

Model domain incorporates future land developments as outlined in the URA Master Plan 2025[2], specifically accounting for planned land expansion in the northern part of Tuas and the Tuas Port Finger 1 – 4 area (see Figure 4-1). These developments are included to ensure the model reflects the anticipated coastal configuration during the operational phase of the CCGT.

Other known developments which are not part of the URA Master Plan 2025 are excluded from the mesh to maintain alignment with officially endorsed planning documents.

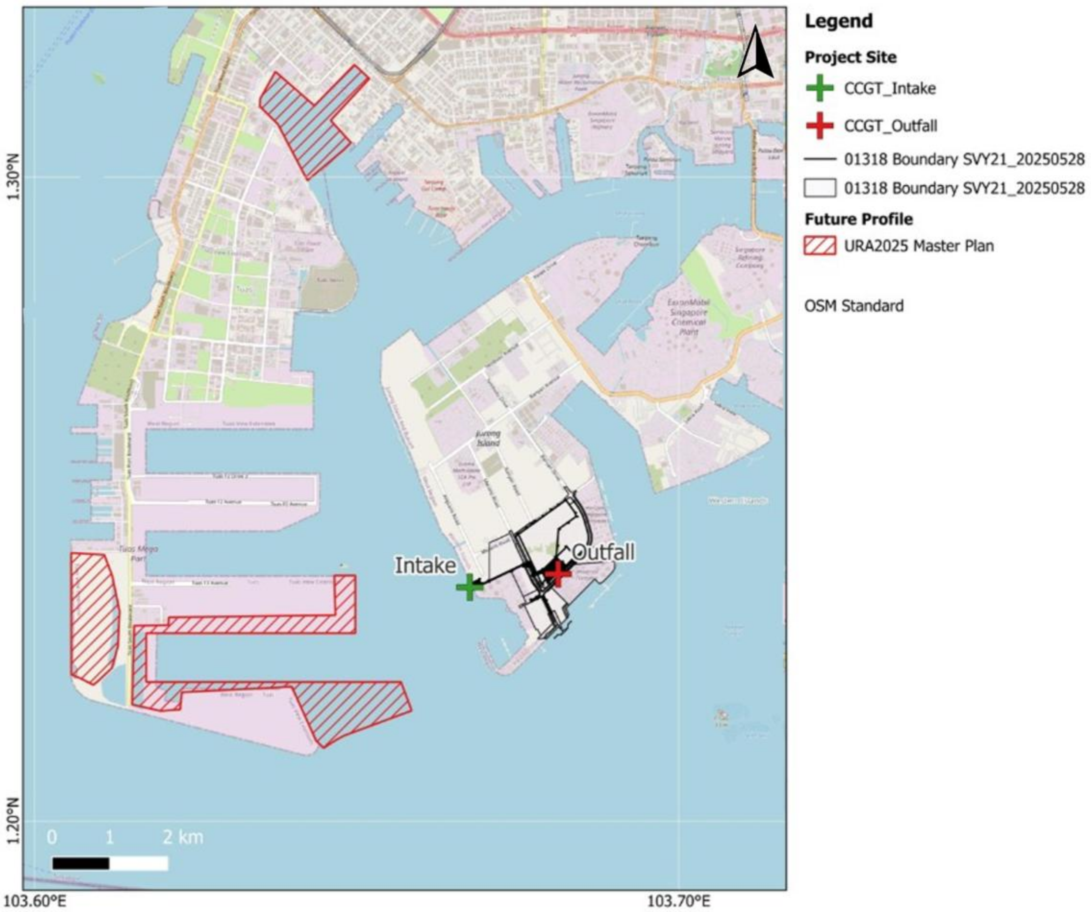


Figure 4-1 Future development in the project area

[2] https://www.uradraftmasterplan.gov.sg/

The model domain and boundary conditions are based on the calibrated Singapore Island Model (SIM) developed by Haskoning, which includes 9 boundaries (see Figure 4-2). These boundaries are defined as time-varying water levels along the open boundary lines.

A nesting model approach is applied, with high-resolution triangular grids (approximately 60 m) implemented in the vicinity of the intake and outfall structures (Figure 4-2). This allows for enhanced accuracy in the area of interest while maintaining hydrodynamic connectivity with the broader Singapore coastal system and optimising computational efficiency.

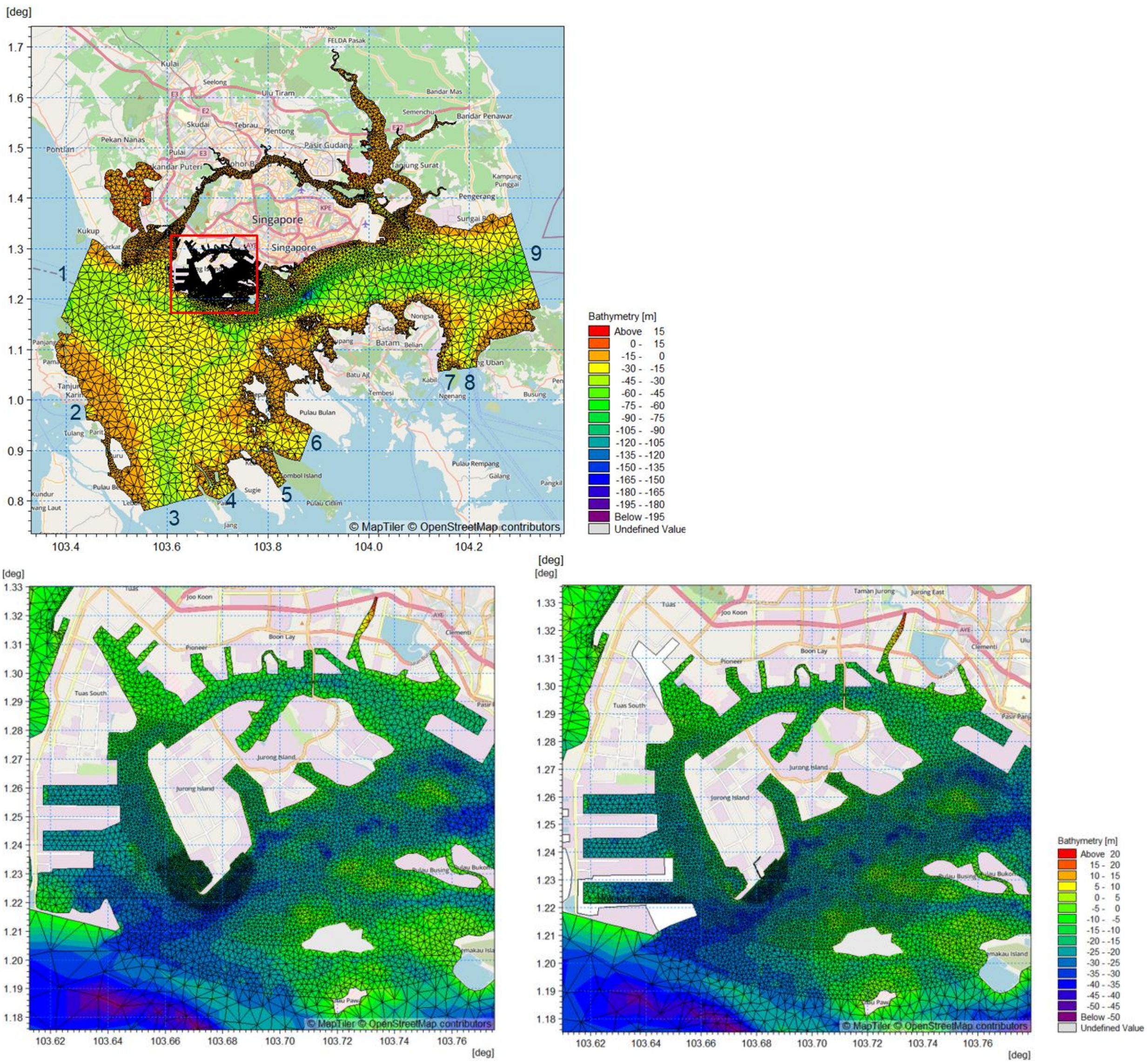


Figure 4-2 Top: full model domain, indicating boundaries and nested model. Bottom left: Current Profile in nested model. Bottom right: Future Profile with outfall channel in nested model

The invert levels of the channel were obtained from the provided engineering drawings (No. 040086C006C and 040086C007E) from the EPC. These drawings indicate that the channel has a sloped invert, ranging from -1.2 mMSL at the outfall location to -2.4 mMSL at the seaside end (see Figure 4-3). This gradient reflects a deepening of the channel toward the sea. The channel has a width of 34 m, which is represented in the model using two computational grids, each measuring 15 min width (see Figure 4-4).

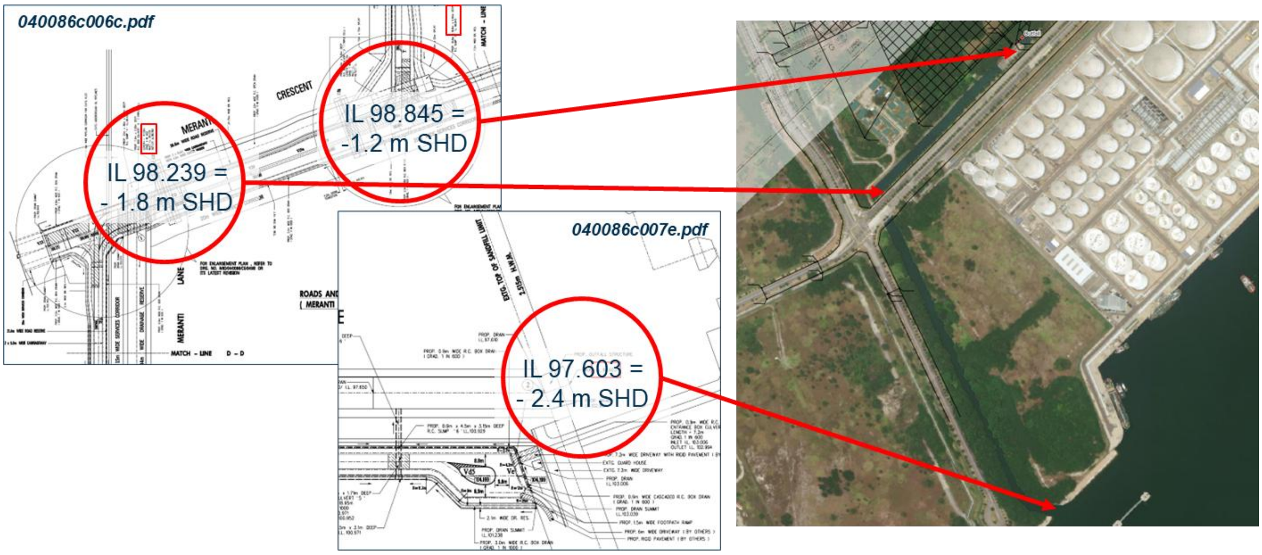


Figure 4-3 Details of the channel depths incorporated into the model

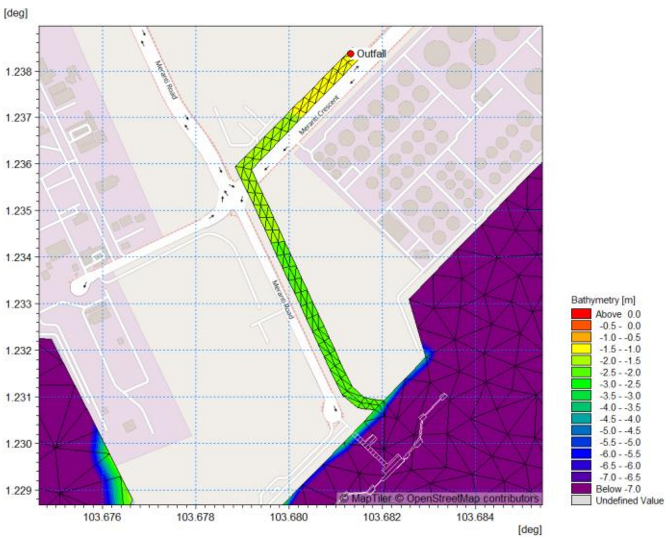


Figure 4-4 Outfall channel configuration in the computational mesh

4.1.2 Simulation period and monsoon representation

Each simulation is carried out for a period of approximately 30 days to capture two full spring-neap tidal cycles, representing both the NE and SW monsoon conditions. An additional one-month buffer is included at the start of each simulation to allow the model to stabilize and eliminate initial transients.

Representative months are selected based on historical data analysis, prioritizing periods with the highest wind speeds (Figure 4-5), tidal ranges, and current velocities (Figure 4-6) to ensure that seasonal variability is well captured. February and July have been selected as representative months for the NE and SW monsoons, respectively.

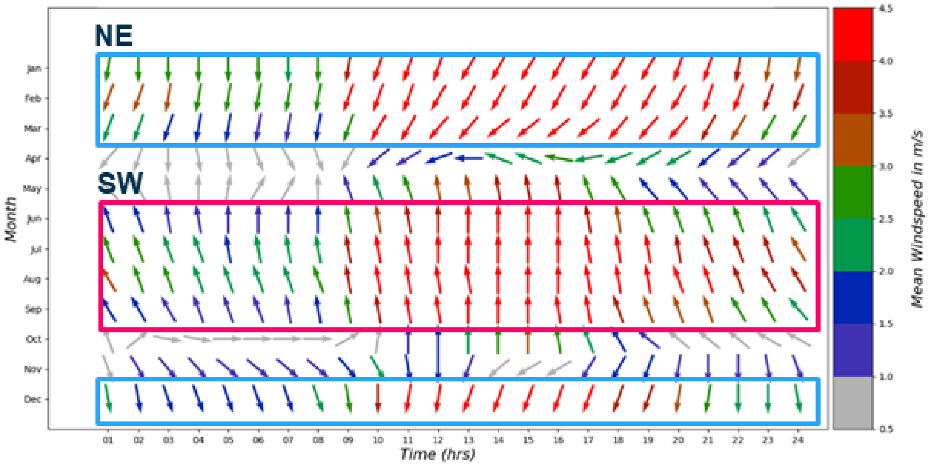


Figure 4-5 Hourly variation of surface wind speed (m/s) and direction for each month (1991-2020 average) (MSS, n.d.)

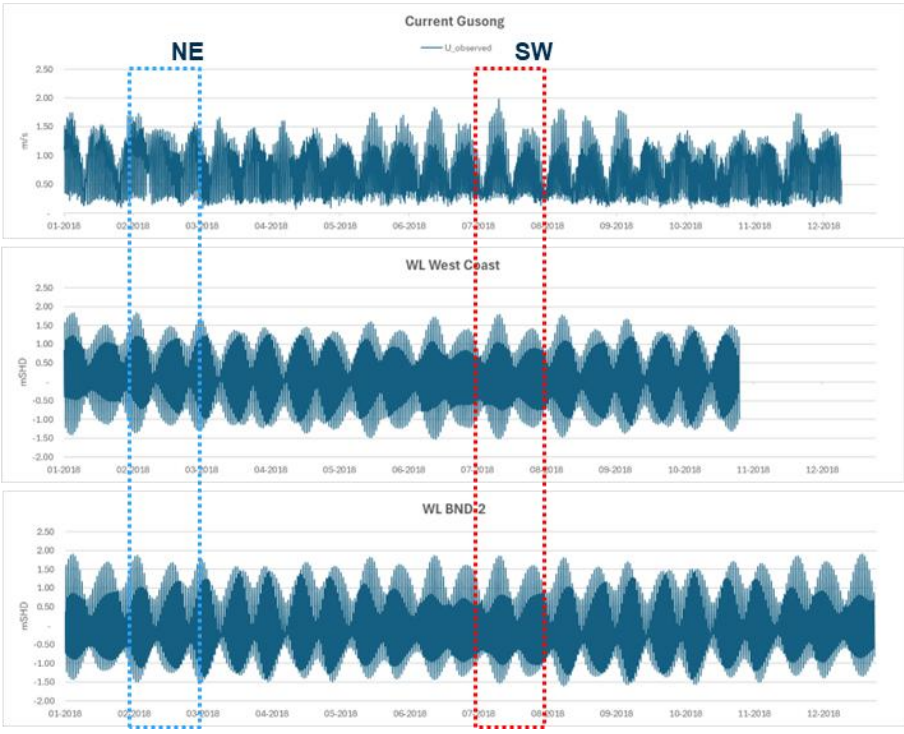


Figure 4-6 Time series of measured currents and water levels considered for determining the selected months, i.e., Feb-2018 for NE and Jul-2018 for SW

4.2 Input parameters

4.2.1 Point Sources

The model includes proposed CCGT intake and outfall as source inputs within the study area, while excluding the existing intakes and outfalls for the actual runs, as explained in Section 4.4 and in Appendix A1. This is based on the consideration that the impact assessment only considers changes in hydrodynamics, temperature (including excess heat), and chlorine from the proposed outfall. Furthermore, cumulative impacts of the existing intakes and outfalls are not required to be assessed since the intake assessment is not part of the modelling scope but will be part of the design study instead (this approach is consistent with the Keppel CCGT EIA).

The exclusion of existing intakes and outfalls was agreed on with the Client, based on the sensitivity analysis which concluded that impacts on the hydrodynamic conditions (i.e., water levels and current speeds) within the vicinity of proposed intake and outfall are negligible when existing intakes and outfalls are excluded. Differences in temperatures are expected to occur, but they are considered relatively minor (less than 1ºC). Details on the sensitivity results are provided in Appendix A1 in this report.

4.2.1.1 Proposed CCGT intake and outfalls

The proposed CCGT intake and outfall are included (see the detailed locations in Figure 4-8), with both inflow and discharge rates assumed at 56,700 m^3/hour or approx. 15.75 m^3/s, based on information provided by the EPC contractor (see a summary in Table 4-1). Note that negative discharge is included in the model input at the intake to ensure a water balance with the outfall in the model area. Furthermore, an additional 2 m^3/s of stormwater discharge from the outfall is not considered in the model since storm events is not within the scope of our modelling scenario, in addition that it may not happen continuously.

The invert levels of both the intake and outfall are also specified in Table 4-1. The outfall is located further inland, where it discharges into an outfall channel that conveys the flow toward the sea. Based on the latest drawings provided on 06 October 2025, the end point's invert level of the outfall, just before entering the sea, is noted at -2.4 m SHD. The intake location is shifted toward the seaside based on the latest drawing to match with the seabed level.

The discharge temperature is set at 36°C for normal operation of the CCGT and 40°C during emergency operation, which complies with regulatory limits (below 45°C) and it is lower than what was applied at Keppel CCGT (approx. 37°C) as reference. For the purpose of this EIA, the model simulation will only account for a discharge temperature applicable to normal operational phase. A continuous duration and constant value assumption are applied for the temperature discharge.

The temperature at the intake will follow the ambient temperature of approximately 30°C from the baseline with no excess temperature since existing intakes and outfalls are excluded as sources. The intake maximum temperature of 32°C based on the EPC Contractor is noted for our information only, but not to be included in the model setup since the intake assessment will not be done as agreed above.

Chlorine concentrations are defined as a combination of normal dosing at 0.25 ppm and shock dosing at 0.50 ppm was applied, as informed by ERM in the email dated 12 September 2025. The dosing schedule consists of 30 minutes of continuous shock dosing and followed by normal dosing per shift (once every 8 hours), totalling three doses per day. This pattern is illustrated in Figure 4-7 for a 1.5-day period and is maintained consistently throughout the 30-day simulation.

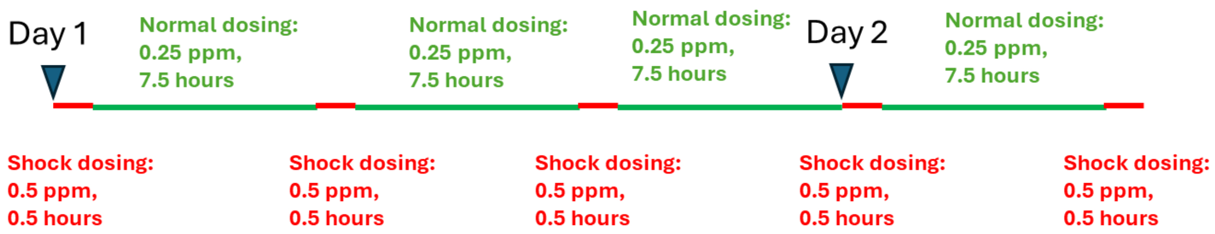


Figure 4-7 Chlorine dosing scenario

Figure 4-8 Locations of CCGT intake and outfall

4.2.1.2 Intake and outfall parameters included in the model

The assumptions regarding the discharge location, flow rate, and concentration used in the model are summarised in the table below. These assumptions were reviewed and agreed by ERM upon prior to the commencement of the modelling work and later updated to reflect the EPC request in reducing the discharged temperature.

Table 4-1 Summary of key assumptions for CGGT intake and outfall (Source: EPC Contractor Specification, based on information on 21 July 2025, 12 September 2025, and 06 October 2025)

Source		Intake	Outfall
Locations (UTM Zone 48N)	Easting [mE]	351534	353281
	Northing [mN]	136676	136913
Level [m CD]	-	-8.1 (-9.84 m SHD)	-0.66 (-2.4 m SHD)
Temperature	Flow Rate [m³/s]	-15.75	15.75
	Temperature [°C]	Ambient Temperature	36 (normal) 40 (emergency)
	Duration [hr per day]	24 (continuous)	24 (continuous)
Chlorine	Flow Rate [m³/s]	-	15.75
	Residual Chlorine Concentration [ppm]	-	0.25 (normal) 0.50 (shock dosing)
	Duration [hr per day]	-	30 minutes of continuous shock dosing, followed by normal dosing per shift (once every 8 hours), totalling three doses per day (see Figure 4-7)

4.2.2 Meteorological forcings

4.2.2.1 Wind forcing

Wind is a critical driver of surface currents and mixing processes. In this model, wind forcing is applied as spatially and temporally varying wind speed and direction fields. The primary dataset is the ERA5 reanalysis from the European Centre for Medium-Range Weather Forecasts (ECMWF). To validate the quality of the ERA5 wind dataset, the data were compared with the hourly wind measurements obtained from the National Environment Agency (NEA) at Tuas South, ensuring alignment with observed conditions in Singapore (see Figure 4-9). The spatial ERA5 wind data is included in the model as timeseries tiles U and V wind components, provided at a resolution of 0.25° × 0.25°.

Figure 4-9 shows that Tuas South Station falls within the same ERA5 grid cell of Latitude 1.25° and Longitude 103.0°. As illustrated in Figure 4-10, the wind speeds recorded at Tuas South are approximately half those of the ERA5 data. This discrepancy is expected, as Tuas South is located inland where wind speeds are generally lower due to land surface friction and urban shielding. In contrast, the ERA5 dataset incorporates offshore wind conditions, which typically exhibit higher velocities ranging from 2 to 5 m/s. Despite this variation, the Tuas South dataset remains relevant for ERA5 data wind check, as the predominant wind direction across all datasets consistently coming from the northeast for February 2018 and from the south for July 2018, as illustrated in the wind rose plots in Figure 4-11. This pattern corresponds to the data monsoon period, where February falls within the Northeast Monsoon season, and July within the Southwest monsoon.

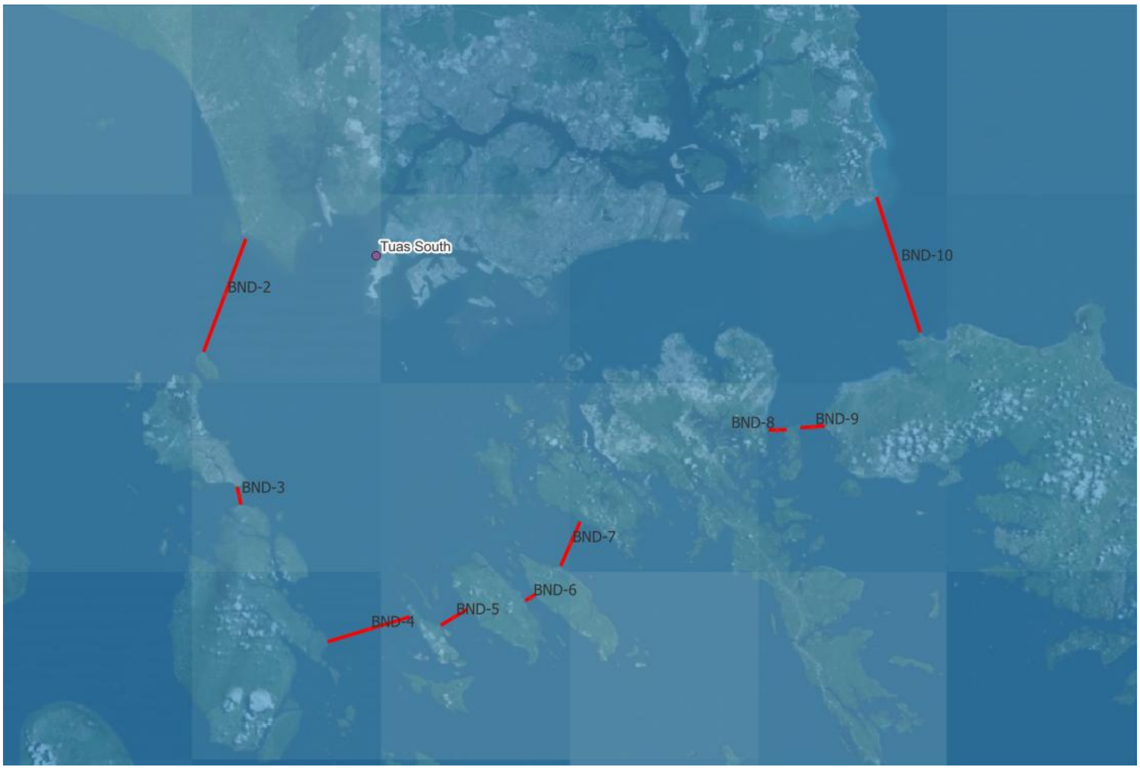


Figure 4-9 ERA5 wind data overlayed across regional model, along with NEA Tuas South Station

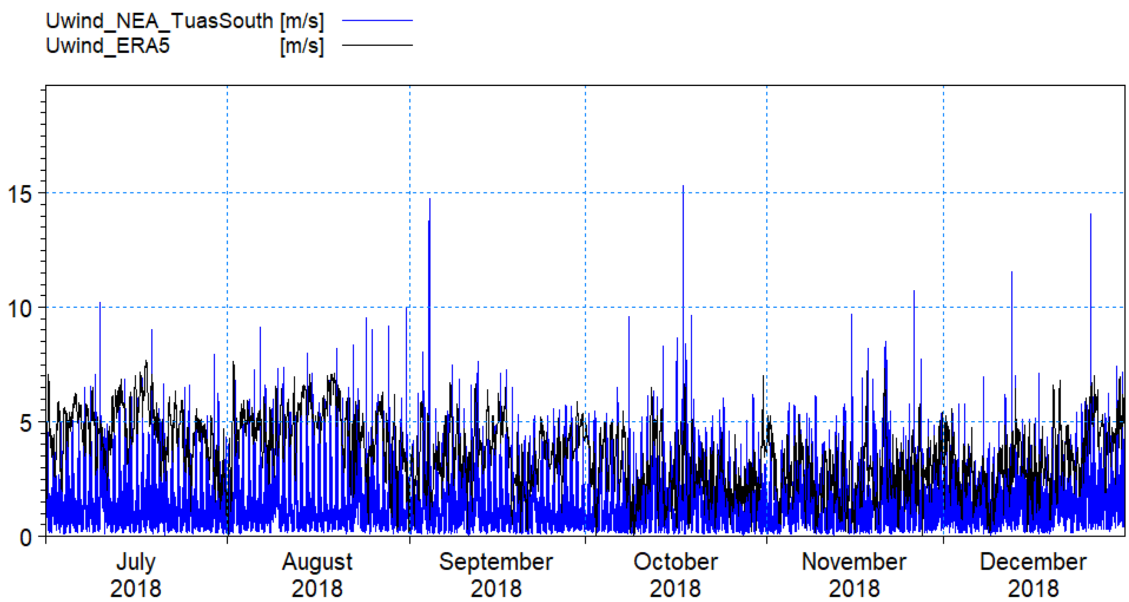


Figure 4-10 Timeseries comparison of NEA Tuas South vs ERA5

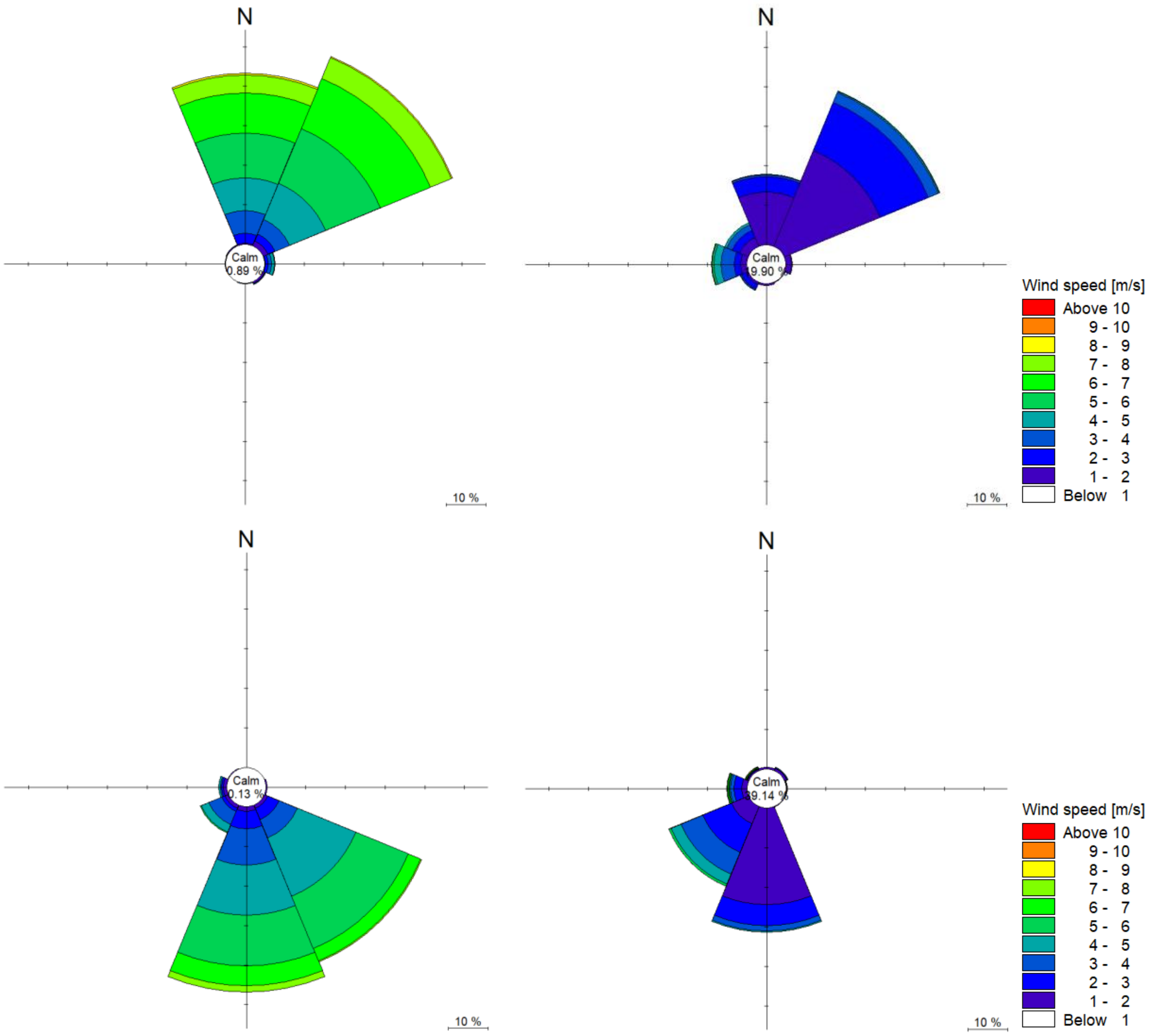


Figure 4-11 Wind rose plot of ERA5 Latitude 1.25°, Longitude 103.00° (left) and NEA Tuas South (right) during Feb-18 (top) and Jul-18 (bottom)

4.2.2.2 Precipitation and evaporation

Precipitation is included as surface fluxes that vary in time and space across the model domain. These inputs are also sourced from the ERA5 dataset and are essential for capturing freshwater inputs, which can influence surface salinity and stratification. Examples of dataset are shown in Figure 4-12 as gridded timeseries data covering the whole Singapore and neighbouring areas.

Evaporation is included as a constant input in the model setup, as this approach yields better results in the calibration compared to using a variable value. The constant is derived from the average evaporation data obtained by ERA5.

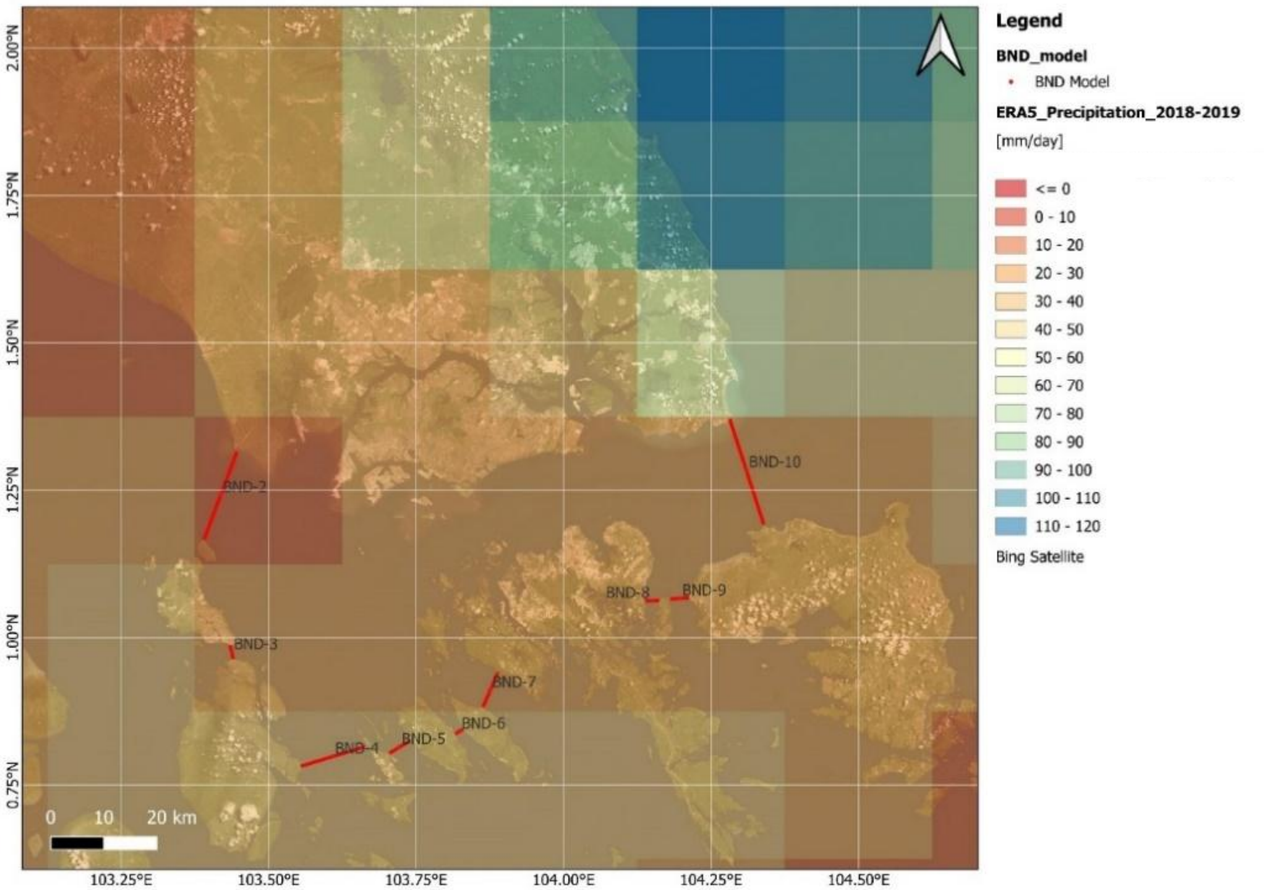


Figure 4-12 Example of precipitation data at specific timestamp across model domain from ERA5

4.2.2.3 Atmospheric heat exchange

Heat exchange processes are modelled using three key components: shortwave (solar) radiation, longwave (thermal) radiation, and atmospheric conditions (e.g., air temperature, humidity). These inputs are also derived from ERA5 and are applied as spatially and temporally varying fields. They are critical for simulating surface heat fluxes and temperature dynamics in the water column. These parameters are incorporated into the model with variations over time (hourly) and space (at a resolution of 0.25° × 0.25°). An example is illustrated in Figure 4-13.

All meteorological inputs—wind, precipitation, evaporation, and heat exchange—are adjusted to reflect future climate conditions based on the aforementioned climate change projections.

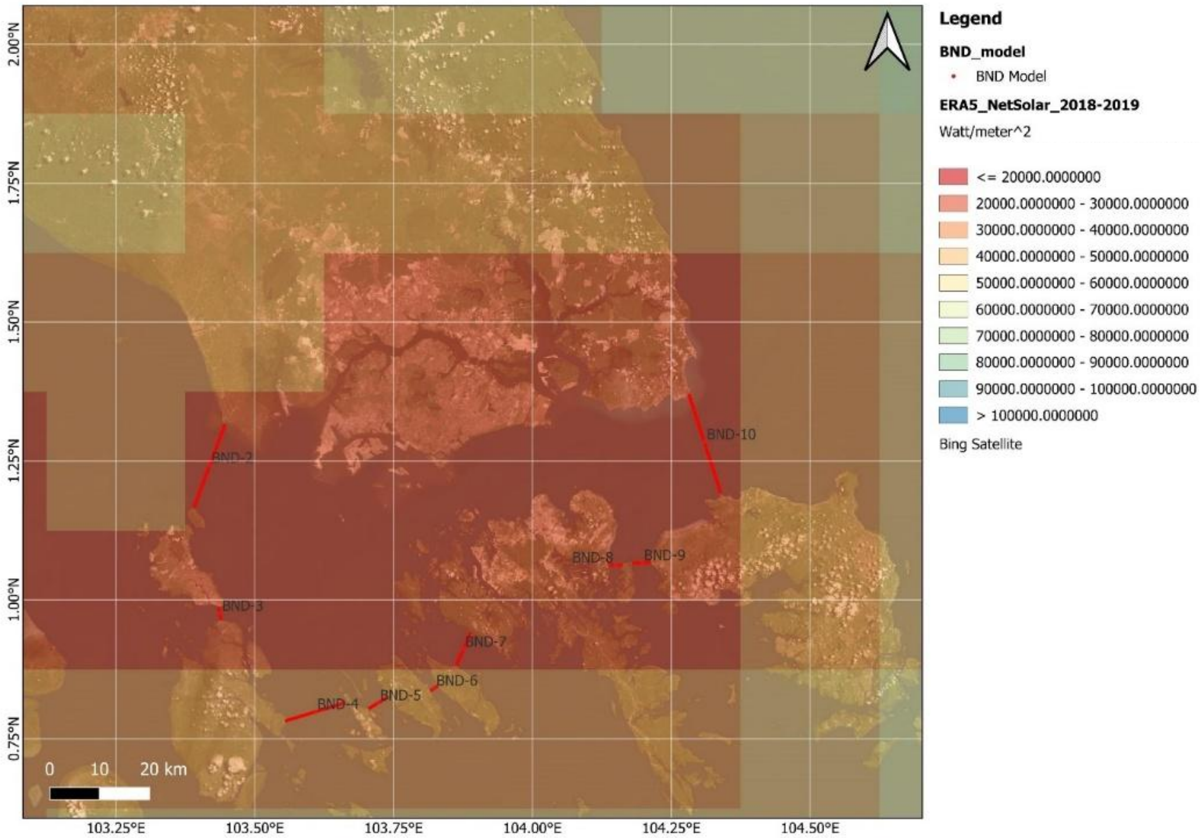


Figure 4-13 Example of solar radiation data at specific timestamp across model domain from ERA5

4.2.3 Chlorine decay rate

Initial decay rates from CCGT, corresponding to 0.25 mg/L and 0.50 mg/L of chlorine, are relatively low. Since it is assumed working in a seawater environment, it is generally more difficult to find open-source materials, such as journals or reports, that provide detailed datasets for decay rate versus initial chlorine concentration. However, it has been identified from a published study in which experiments were conducted in seawater, establishing a dataset that shows a straight-line relationship between decay rate and initial chlorine concentration. While the commonly expected trend, especially in freshwater, is non-linear due to the slower decay process, seawater conditions differ significantly. In seawater, chlorine reacts almost instantly with bromide, leading to the rapid formation of brominated oxidants and a faster initial decay (Eppley, Renger, & Williams, 1976).

Therefore, a straight-line relationship between decay rate and initial chlorine concentration is reasonable in our case, particularly given that we are operating at relatively low concentrations. This further supports the validity of the assumption in our context.

Yi, et. al., (2020) investigated chlorine decay rates as a function of initial chlorine dose at a TOC (Total Organic Carbon) concentration of 1.3 mg/L, with results presented in Table 4-2. Based on our previous project experience, the TOC concentration observed at Jurong Island is approximately 1.26 mg/L, which is very close to the 1.3 mg/L used in Yi's study, thereby supporting the relevance of their findings to our site conditions. However, our study considers lower initial chlorine doses of 0.25 mg/L and 0.50 mg/L, which are not directly covered in Table 4-2. To estimate the corresponding decay rates, a linear trendline equation was developed based on the data in Table 4-2 (see Figure 4-14), yielding decay rates of 1.039/hr and 1.038/hr for 0.25mg/L and 0.50mg/L, respectively.

Table 4-2 Estimated kinetics parameters depending on total organic (TOC) and initial chlorine dose

Sample	TOC [mg/L]	Initial Chlorine Dose [mg/L]	Estimated Constants			R^2	RMSE
			ks [h^{-1}]	kf [h^{-1}]	z		
Sea Water	1.3	1.2	1.036	80.49	0.353	0.885	0.109
		1.8	1.034	80.43	0.369	0.941	0.194
		2.4	1.032	80.38	0.381	0.905	0.143

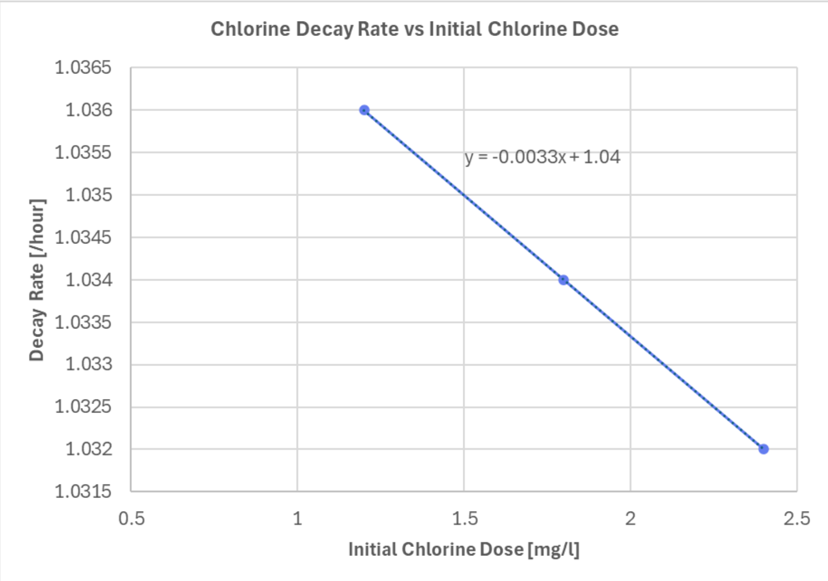


Figure 4-14 Chlorine decay vs initial chlorine dose

From the measurements in this study, summarised in Table 4-3, the average TOC concentrations were found to be 2.1mg/L during neap tide and 2.2mg/L during spring tide, giving an average value of 2.15mg/L. This is considerably higher than the reference value of 1.3mg/L, so the decay rate needs to be adjusted for the higher TOC concentration.

Table 4-3 Lab results of TOC measurements

WQ Point	Ebb or Flood	Time [hrs]	TOC [mg/L]
Spring Tides (28 July 2025)			
WSQ1	Flood	13:23	2.29
	Ebb	15:05	2.15
WSQ2	Flood	09:55	2.24
	Ebb	16:55	2.19
WSQ3	Flood	11:58	2.09
	Ebb	15:47	2.38
WSQ4	Flood	10:52	2.12
	Ebb	16:25	2.36
WSQ5	Flood	12:53	2.19
	Ebb	15:30	2.29

WQ Point	Ebb or Flood	Time [hrs]	TOC [mg/L]
Neap Tides (05 August 2025)			
WSQ1	Flood	14:52	2.16
	Ebb	13:48	2.27
WSQ2	Flood	17:15	2.02
	Ebb	10:25	2.13
WSQ3	Flood	15:50	2.02
	Ebb	12:05	2.23
WSQ4	Flood	16:40	2.10
	Ebb	11:22	2.15
WSQ5	Flood	15:25	2.20
	Ebb	13:20	2.15

Two research studies, Saidan et. al., (2017) and Powell et. al., (2000), explored the relationship between TOC concentration and decay rate. Saidan et. al., (2017) developed two correlations: one using modelled data and another using observed data. Since modelled data may contain uncertainties, the correlation based on observed data was chosen (Figure 4-15).

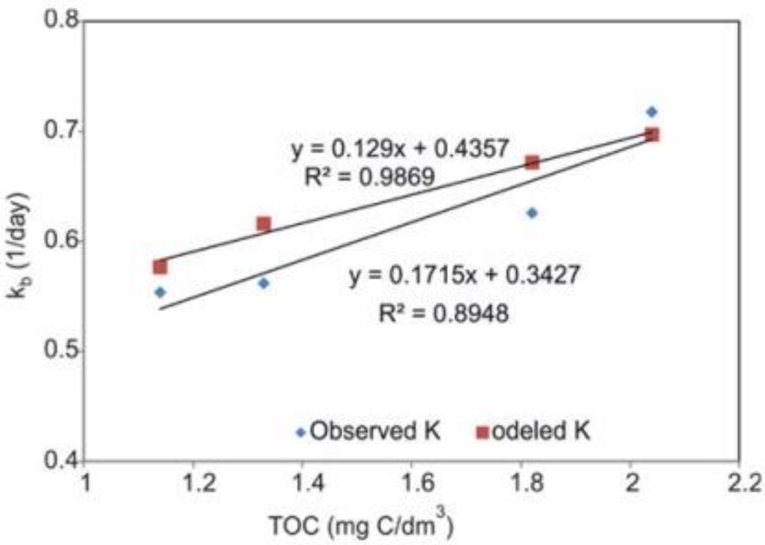


Figure 4-15 Correlation between chlorine decay rate and TOC concentration (Saidan, Rawajfeh, Nasrallah, Meric, & Mashal, 2017)

Similarly, Powell et. al., (2000), developed correlations for both Pre-GAC and Post-GAC conditions [GAC: Granular Activated Carbon] (Figure 4-16). The Post-GAC correlation covers the TOC range from 1.3 to 2.2 mg/L, which matches the conditions in this study. In contrast, the Pre-GAC correlation involves much higher TOC concentrations and extrapolating it to our range would produce unrealistic (negative) decay rates. Therefore, the Post-GAC correlation was adopted for further analysis.

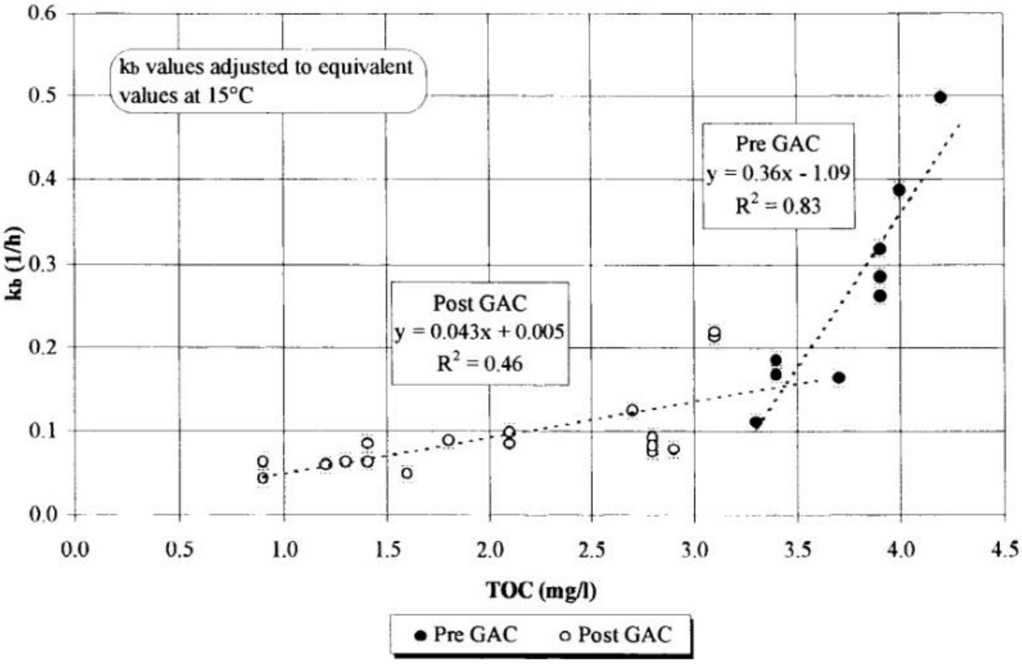


Figure 4-16 Correlation between chlorine decay rate and TOC concentration (Powell, Hallam, West, Forster, & Simms, 2000)

Using both studies, the increase in decay rate for a TOC concentration of 2.215 mg/L was calculated and summarized in Table 4-4. It was found that Saidan et. al., (2017) provided smaller values, and for a conservative approach, these smaller values were selected for subsequent calculations as an adjustment.

Table 4-4 Decay rate difference for different TOC based on several literatures

TOC	Decay rate [h^{-1}]	
	Saidan et at, 2017	Powell et al, 1999
1.3	0.027	0.061
2.15	0.034	0.097
Difference	**0.006**	**0.037**

These decay rates were established at a temperature of 19.0°C, whereas the average site temperature at our site is 29.3°C. This value was derived from annual average sea temperature near the outfall, extracted from ERA5 reanalysis data provided by ECMWF, which is also aligned with the measured temperature from Keppel CCGT EIA study. To account for the effect of temperature, correction factors were derived from a separate study by Wang (Wang, et al., 2008), who examined TRO (Total Residual Oxidant) decay rates in both distilled and seawater across various temperatures (see Table 4-5). TRO typically comprises both free chlorine (e.g., HOCl, OCl^-) and combined chlorine species such as chloramines. Therefore, it is reasonable to assume that the temperature-dependent characteristics of TRO can serve as a suitable proxy for correcting chlorine decay rates.

Using their data, a temperature-based trend line was developed (Figure 4-7) to calculate the expected change in decay rate between 19.0°C and 29.4°C. The calculation showed that the rate increased by 0.14 /hr. This increment was then applied to our previously estimated decay rates at 19.0°C to obtain the decay rate at 29.3°C. The final corrected decay rates for 0.25 mg/L and 0.5 mg/L chlorine doses are 1.185/hr (including TOC adjustment) to be considered in the model inputs for Transport Module. Note that the initial concentrations for both cases are relatively small, which the decay rate difference is only 0.001, hence it is suggested to use the same value of decay rate in the model for all scenarios.

Table 4-5 The rate of TRO decay in distilled water (DW) and sea water (SW) at a giver temperature

Temperature [K]	Temperature [°C]	Half-life DW [hr]	Half-life SW [hr]	Decay Rate DW [1/hr]	Decay Rate SW [1/hr]
298	25	10.02	1.93	0.07	0.36
303	30	8.00	1.63	0.09	0.43
313	40	5.68	1.20	0.12	0.58
323	50	3.88	0.77	0.18	0.90

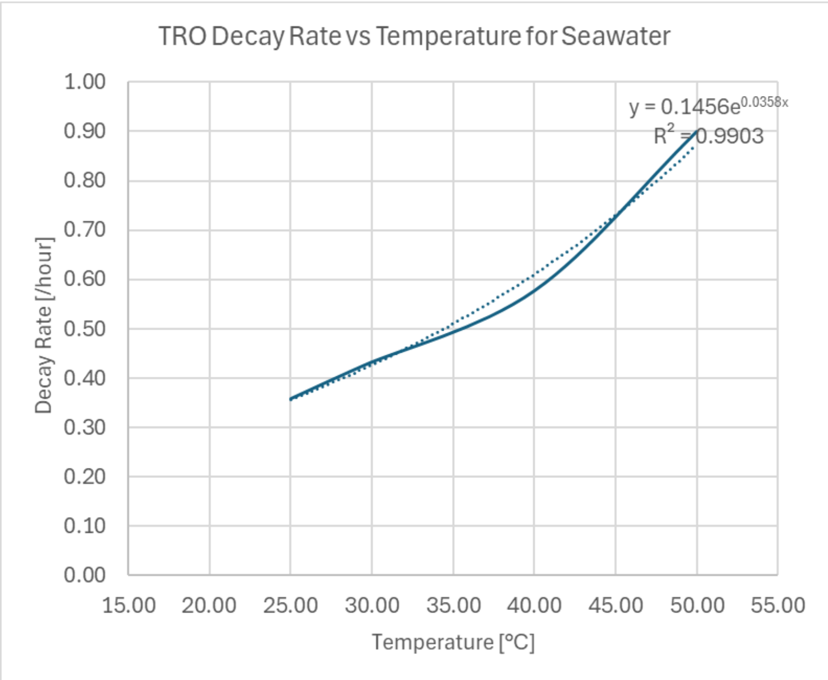


Figure 4-17 TRO decay vs Temperature

4.3 Model limitations and exclusions

Certain model inputs that are not relevant to the study area are excluded. These include parameters such as ice coverage, vegetation effects etc, which are not applicable in the study area.

4.4 Sensitivity analysis

A sensitivity analysis was conducted to assess the robustness of the model setup before applying it for impact assessments (Appendix A1). The analysis examined how the exclusion of existing intake/outfall sources might affect model outputs, focusing on both hydrodynamic and thermal conditions.

Results showed negligible differences in water levels and current speeds, with bias and RMSE values close to zero and correlation coefficients approaching 1.0. This confirms that excluding existing intakes and outfalls does not significantly alter the hydrodynamic baseline, and therefore these existing sources can be reasonably omitted from the analysis. For temperature, a reduction was observed when existing sources were excluded, but this is acceptable for the study purpose, as the objective is to evaluate temperature dispersion from the proposed outfall only, rather than cumulative thermal impacts. The focus is on relative changes between pre- and post-development conditions.

Overall, this confirms that the exclusion of existing sources and the adopted model assumptions do not significantly influence the predicted impacts from the proposed CCGT facility, thereby supporting the validity of the final model setup.

4.5 Model calibration

Model calibration was carried out to ensure that the developed model reliably reproduces site conditions before being applied for impact assessments. The calibration process, described in detail in Section 5, covered key parameters including water levels, current speeds and directions, and temperature. The model performance was evaluated using statistical metrics such as RMSE, bias, correlation coefficient, and PBIAS, with the acceptance criteria defined earlier in Section 2.

4.6 Projected climate considerations

To ensure the model remains relevant under future conditions, potential impacts other than those caused directly from proposed CCGT intake and outfall were also taken into consideration, specifically those arising from climate change projections. Future climate scenarios have been integrated into the operational phase simulations using data from the Third National Climate Change Study by the Centre for Climate Research Singapore (CCRS), published in 2023 (MSS, 2023). The selected scenario is SSP5-8.5, a high-emissions pathway, to assess the potential impact of climate change under worst-case-scenario.

The model reflects mid-century conditions (circa 2060), which aligns with the expected operational timeline of the CCGT (starting between 2028 and 2030) and its estimated design lifetime of 30 years. These projections are used to adjust sea level, temperature, and other relevant parameters to ensure the model remains robust under future climate scenarios. Table 4-6 provides a summary of selected climate change projections for 2060.

Table 4-6 Summary of selected climate change projections under SSP5-8.5 to 2100 (MSS, 2023) and estimated change for 2060

Parameter	Period	Change in 2100 (end-century)	Estimated change in 2060 (mid-century)
Sea Level Rise	-	up to 1.15m	up to 0.45m
Annual avg. daily mean temperature	-	+3.8º (average)	+1.6º (average)
Annual Rainfall	DJ (wet)	2.0%	1.0%
	FM	-18.0%	-9.0%
	AM	18.0%	9.0%
	JJAS (dry)	-14.0%	-7.0%
	ON	14.0%	7.0%
Monsoonal Winds	DJFM (NE)	11.0%	3.3%
	AM (First IM)	8.6%	2.6%
	JJAS (SE)	13.8%	4.1%
	ON (Second IM)	5.8%	1.7%
Annual Humidity	DJ	-1.9%	-0.8%
	FM	-2.6%	-1.3%
	AM	-0.8%	-0.4%
	JJAS	-2.0%	-1.0%
	ON	-2.2%	-1.1%

Haskoning
Enhancing Society Together

Ultimately, climate change projections along with future land development activities (refer to Section 4.1) are external drivers that may significantly influence future hydrodynamic conditions and therefore require careful consideration. To better understand and distinguish the environmental impacts attributable to the proposed CCGT intake and outfall, these effects are addressed separately: Section 6.2 focuses on impacts from the CCGT alone, while the combined effects, including external influences are presented in separate assessment.

4.7 Scenario design and configuration

Considering the above assumptions for the model setups, a series of scenarios were developed for HD, Temperature, and Chlorine modelling. These scenarios are summarised in Table 4-7.

Table 4-7 Summary of selected model scenarios, excluding calibration and sensitivity simulations

ID	Scenario ID	Season	Land Profile*	Simulation Period**	Climate Change*	SLR [+m MSL]	Intake	Outfall		
							Disc. [m³/s]	Disc. [m³/s]	Temp. [°C]	Chlo. [ppm]
1	Baseline_HD_T_NE	NE	CP	Jan – Feb	-	+0.00	-	-	-	-
2	Baseline_HD_T_SW	SW	CP	Jun – Jul	-	+0.00	-	-	-	-
3	Future_Baseline_HD_T_NE	NE	FP	Jan – Feb	CC	+0.45				
4	Future_Baseline_HD_T_SW	SW	FP	Jun – Jul	CC	+0.45				
5	Operation_HD_T_NE	NE	FP with outfall channel	Jan – Feb	CC	+0.45	-15.75	+15.75	36.0	-
6	Operation_HD_T_SW	SW	FP with outfall channel	Jun – Jul	CC	+0.45	-15.75	+15.75	36.0	-
7	Operation_Chl_NE	NE	FP with outfall channel	Jan – Feb	CC	+0.45	-15.75	+15.75	36.0	normal (0.25) & shock dosing (0.50)
8	Operation_Chl_SW	SW	FP with outfall channel	Jun – Jul	CC	+0.45	-15.75	+15.75	36.0	normal (0.25) & shock dosing (0.50))

Note:

** CP = Current Profile, FP = Future Profile, CC = Climate Change projection being considered.*

*** Simulation periods include 1-month additional buffer time to allow for initial instability during the model run.*

The purpose of each scenario is outlined below:

- Scenarios 1 & 2 provide an overview of the existing hydrodynamic conditions. These scenarios do not incorporate climate change projections, sea level rise, or future land reclamation activities.
- Scenarios 3 & 4 represent future hydrodynamic conditions, including climate change projections, sea level rise, and planned reclamation developments.
- Scenarios 5 & 6 reflect the operational phase of the proposed CCGT facility, building upon the future conditions in Scenarios 3 & 4, but with the CCGT system in operation.
- Scenarios 7 & 8 assess chlorine concentration, using the hydrodynamic conditions from Scenarios 5 & 6, which already incorporate the CCGT operational system.

By comparing different scenarios:

- Scenarios 1 & 2 vs. Scenarios 5 & 6 allow assessment of changes in hydrodynamics and temperature resulting from the CCGT operation, in combination with climate change and land reclamation.

- Scenarios 3 & 4 vs. Scenarios 5 & 6 isolate the impacts of the CCGT operation alone, under future environmental conditions.
- Scenarios 7 & 8 focus specifically on the chlorine plume resulting solely from the operation of the CCGT facility.

5 Model calibration

Model calibration was conducted to ensure that the base model accurately reflects existing conditions before being applied to assess scenarios related to CCGT implementation. This section outlines the calibration approach, criteria used, and results obtained. The outcomes demonstrate a strong agreement between model predictions and measured data, confirming that the model is sufficiently reliable for use in this study.

5.1 Approach

Model calibration is initially done to confirm the model performance by comparing it with the existing current, water level, and temperature data (see the data summary in Table 5-1 and their locations in Figure 5-1). Calibration is done covering both Northeast and Southwest monsoons from July to December 2018 (6 months), using the current land profile (see Figure 5-1), and without considering climate change in the meteorological inputs.

Table 5-1 Summary of data used for calibration

Parameter	Source	Location	Period
Observed Water level	MPA	West Coast (1° 17.4'N, 103° 45.6'E)	01-Jan 2018 to 31-Dec-18
Current measurement	MPA	Gusong (1° 11.4'N, 103° 47.4'E)	01-Jul-18 to 31-Dec-18
Temperature from ERM 2025 baseline survey*	ERM	WSQ1 to WSQ5	28-Jul-25 (spring tide) 05-Aug-25 (neap tide)
**) The ERM 2025 survey was conducted on 28-Jul-2025 during spring tide conditions and on 05-Aug-2025 during neap tide conditions. As this survey period falls within the Southwest Monsoon season, the corresponding period from the 2018 simulation was selected for model calibration to ensure consistency in seasonal hydrodynamic conditions when comparing against the measured data.*			

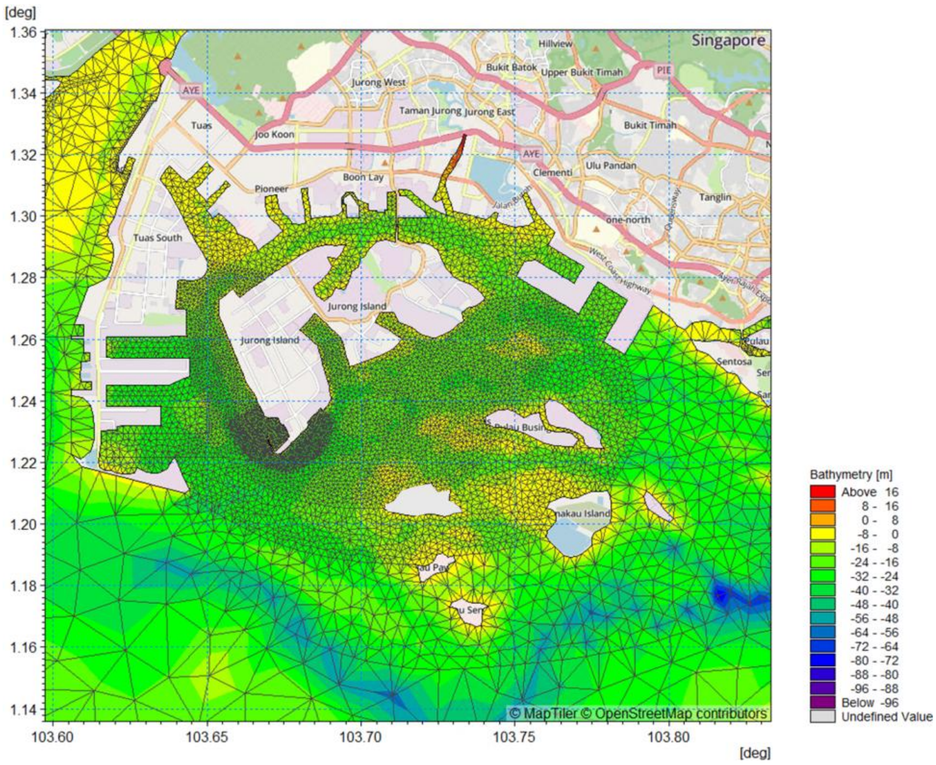


Figure 5-1 Current land profile considered in the mesh for calibration

The calibration process is an iterative process whereby model parameters are adjusted until the model outputs, water level and currents, match with measurements to be within some tolerance level that may be described as the goodness-of-fit. Goodness-of-fit is then translated into performance criteria, which can be determined using several methods. The Foundation for Water Research (Report No FR0374) is used as main reference, i.e., Percent Bias (PBIAS) and Root Mean Square Error (RMSE) (Evans, 1993) for water level and current performance in the model. The criteria are complemented by criteria which are described in ABPmer: i.e., correlation coefficient (ABPmer, 2013). For the temperature, the PBIAS value is used to determine the model performance (Moriasi, Gitau, Pai, & Daggupati, 2015)

Table 5-2 presents the model performance criteria and adopted calibration/validation targets.

Table 5-2 Summary of modelling performance criteria

Items	Criteria	Calibration/Validation target
Water levels	Bias (Mean error)	± 0.2m
	Root Mean Square Error (RMSE)	< 0.2m
	Correlation coefficient (R)	> 0.8 (very good fit)
Currents	Bias (Mean error)	± 0.2m/s or ± 10–20%
	Root Mean Square Error (RMSE)	< 0.2m/s
	Correlation coefficient (R)	> 0.8 (very good fit)
	Direction	±20°
Temperature	Percentage bias (PBIAS)	< 15% (very good fit) 15% - 20% (good) 20% - 30% (satisfactory) >30% (not satisfactory)

5.2 Current speed and direction

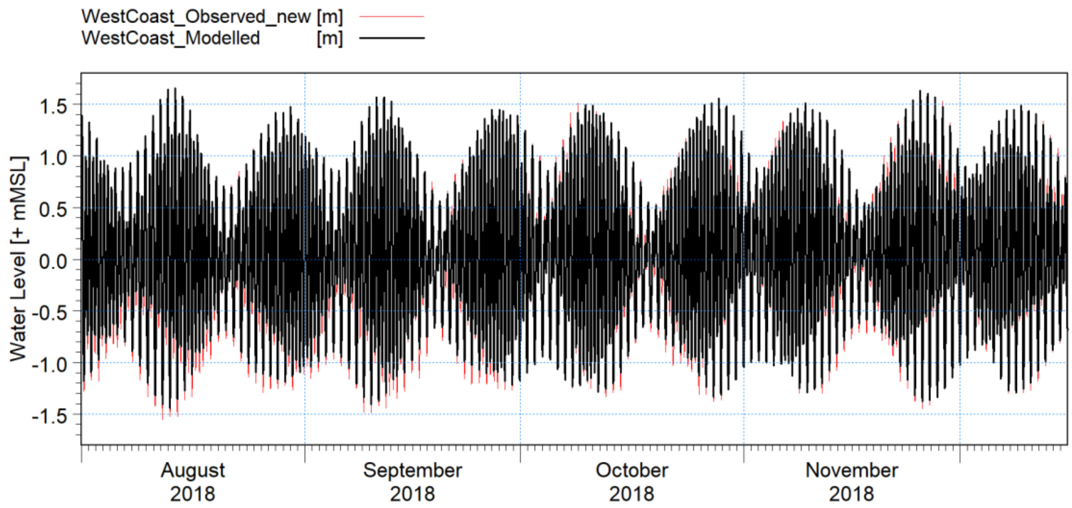
Hydrodynamic model result was checked against the measurement data in August – December 2018 for current speed and August – October 2018 for water level. Different periods in the modelling performance assessment are due to the overlapping data limitations as summarised earlier in Table 5-1. While the calibration for current speeds is preferably covering both monsoon period, it is not necessarily required for water level calibration because it is not subject to seasonal variation, and typically 1-month period of calibration is considered sufficient already.

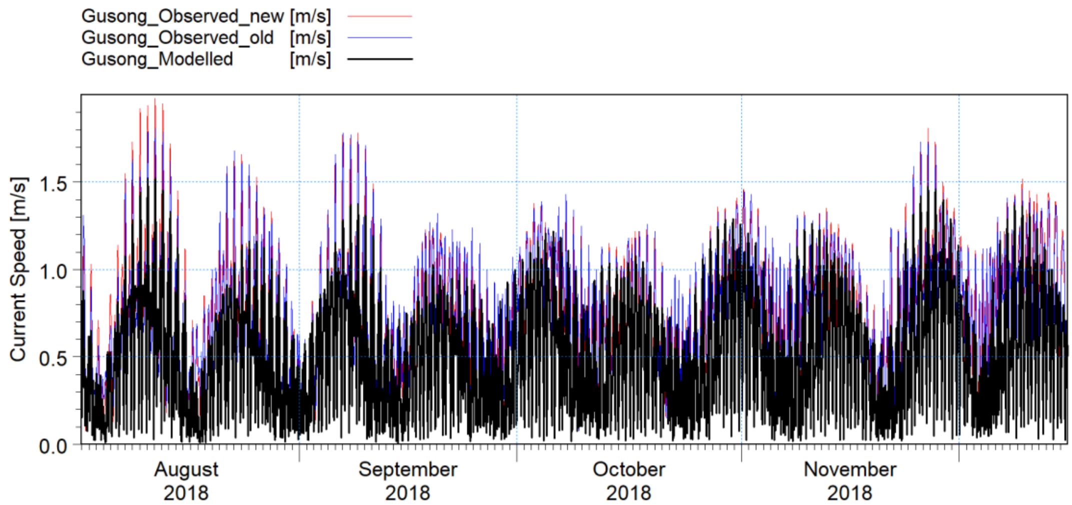
Calibration result is captured in Figure 5-2. From visual inspection, calibration result seems to be aligned with the measurement data quite well. Quantitatively, 6 out of 7 criteria are met, which we can conclude that the model performance is good, and this model setup (especially for calibrated parameters, explained in the next section) is suitable for the scenario runs.

Note that it is generally less feasible to meet all criteria due to the limitation of recommended ranges of calibrated parameter values specified in the MIKE manuals. In addition, adjusting the parameters to achieve a specific criterion will also impact the other criteria, hence the calibration is typically focus on meeting the criteria as many as possible rather than trying to meet all of them.

Table 5-3 Summary of model calibration performance statistics

Project	WL – West Coast			Current - Gusong			
	Bias [m]	RMSE [m]	R [-]	Bias [m/s]	RMSE [m/s]	R [-]	Dir [°]
Criteria	(±0.2m)	(<0.2m)	(>0.8)	±0.2m/s or ±10–20%	< 0.2m/s	>0.8 (very good fit)	(±20°)
Magnitude	0.07	0.12	0.99	-0.17	0.26	0.83	1.58
Criteria Met	Yes	Yes	Yes	Yes	No	Yes	Yes





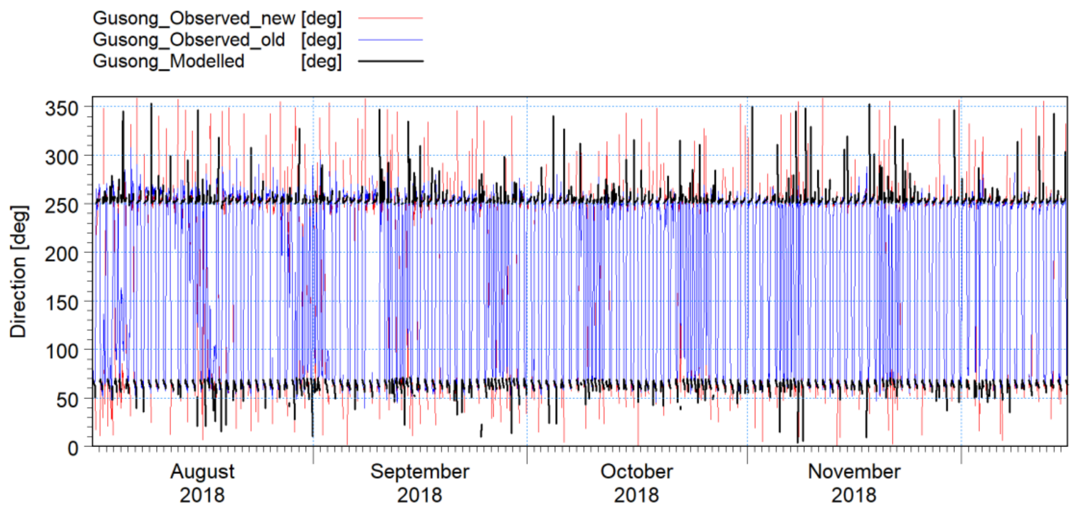


Figure 5-2 Time series comparison between observed and modelled water level, current speed, and current direction

5.3 Temperature

The acquired ERM baseline survey data which was conducted in July and August 2025 was used for model calibration. The new survey locations are shown in Figure 3-1 for locations.

Model adjustments were implemented in version Calib_v1.3, following the evaluation of results from Calib_v1.1. The updated configuration in Calib_v1.3 produced temperature outputs approximately 0.5°C higher, resulting in improved alignment with the mean values of field measurements across all five WSQ monitoring points (see Figure 5-2). The comparison was limited to depths up to -10 m SHD, as this represents the maximum depth reached by the survey instrument during data collection.

The average of model result is compared against the average of measurement data to calculate the model performance (PBIAS value), results are as summarised in Table 5-4. The model meets the ‘very good’ calibration criteria across all data points, indicating that it is well-calibrated and suitable for use in further simulations.

Table 5-4 Summary of model calibration performance statistics

Monitoring Point	PBIAS [%]	Model Performance for Temperature Results (Moriasi, Gitau, Pai, & Daggupati, 2015)
WSQ1	0.78	Very Good
WSQ2	0.08	Very Good
WSQ3	0.74	Very Good
WSQ4	-0.17	Very Good
WSQ5	0.06	Very Good

Figure 5-3 Calibration result for temperature with ERM 2025 survey

6 Model results and analysis

This section presents the results of the impacts attributed solely to the proposed CCGT intake and outfall, including a discussion on whether these impacts remain within acceptable limits for nearby sensitive receptors, navigation routes, and terminal operations. The combined impact of the CCGT facility and external drivers such as climate change and land reclamations, has been assessed to evaluate potential cumulative changes expected by 2060, when the CCGT is scheduled to be operational. The results of this assessment, including potential effects on relevant sensitive receptors, are discussed in a separate assessment note.

6.1 Presentation of model results

Although the simulations in this study were conducted using a three-dimensional (3D) modelling framework, the results are primarily presented as two-dimensional (2D) maps, focusing on the surface and bottom layers of the water column. These layers are selected because they represent the most ecological and operationally relevant zones in the marine environment. Together, these layers provide a comprehensive view of vertical variability while maintaining clarity and interpretability in spatial analysis:

- The surface layer is critical for assessing convective processes with the atmosphere, such as heat exchange, and the potential exposure of marine organisms to elevated temperatures and chlorine concentrations.
- The bottom layer, on the other hand, is essential for evaluating impacts on benthic habitats, sediment transport, and the dispersion of discharges from outfall structures, which are typically located closer to the seabed.

In addition to layer-specific outputs, depth-averaged hydrodynamic results are also presented. Depth-averaging is a standard practice in coastal modelling to capture the overall flow regime and to simplify complex 3D current structures into a single representative metric. This approach is particularly useful for evaluating changes in mean and maximum current speed, slack water duration, and current exceedance percentages. Depth-averaged results are sufficient for impact assessment purposes, especially in areas where vertical stratification is minimal or where regulatory criteria are defined based on integrated flow conditions.

Model outputs are generated for both NE and SW monsoon seasons, each representing distinct hydrodynamic and meteorological regimes. For each season, results are presented for both the baseline and operational phases, along with difference maps that highlight the changes attributable to the proposed CCGT development.

The 2D maps include statistical representations of mean and maximum conditions for key parameters, calculated over the full 30-day simulation period. These statistics provide insight into both typical and extreme conditions, supporting a robust assessment of potential environmental impacts. For hydrodynamic modelling specifically, additional maps are provided to illustrate instantaneous current speed and direction during peak flood and peak ebb tide conditions. These snapshots are critical for identifying transient features such as shear zones, eddies, and slack water areas, which may not be captured in time-averaged results but are important for understanding short-term risks to navigation and water quality.

To facilitate cross-referencing and interpretation, each map is tagged with a unique figure code that reflects the following attributes:

- Season: NE or SW monsoon
- Model type: HD (Hydrodynamic), TMP (Thermal Plume), or CP (Chlorine Plume)
- Parameter: Specific variable assessed (e.g., current speed, temperature, chlorine concentration)
- Tidal condition: Either specific (peak flood/ebb) or general (30-day average)

- Phase: baseline / future baseline (pre-construction), operational (post-construction), or difference
- Layer: surface, bottom, or depth-averaged

All result plots are presented in Appendix A2, Appendix A3 and Appendix A4 while corresponding key analyses are presented in the subsequent sections of this report.

6.2 Impact of CCGT

In this section we present the model results and discuss the potential impacts of proposed CCGT development on hydrodynamics, temperature, and chlorine plume in the area of interest. All plots and analyses are presented for the area of interest, in the vicinity of the CCGT. Observations indicate that the influence of the CCGT operation is spatially limited, with measurable effects extending up to approximately 2 km from the project site.

6.2.1 Hydrodynamics

6.2.1.1 Change in current field

The assessment of changes in current field begins with a description of the baseline hydrodynamic conditions at the project site. As is standard practice in hydrodynamic modelling, the analysis is based on depth-averaged current speeds, which provide a representative view of the overall flow regime and are suitable for evaluating potential impacts on navigation, sediment transport, and water quality.

Baseline conditions

Figure 6-1 and Figure 6-2 illustrate the depth-averaged current fields for NE and SW monsoon conditions for the future baseline, respectively.

During peak flood tide for NE monsoon conditions, the dominant current flows south-westward along the coastline where the outfall is situated (Figure 6-1). Near the outfall, current speeds are approximately 0.4 m/s, increasing to around 1.0 m/s further offshore. In contrast, the intake area, which faces the Jurong Strait, experiences relatively weak currents below 0.1 m/s, flowing inward into the strait.

During peak ebb tide, the current reverses direction, flowing north-eastward along the same coastline. Current speeds during this phase are typically stronger, reaching about 0.3 m/s near the outfall and increasing further seaward. At the intake location, currents are slightly stronger than during the flood tide, with speeds up to 0.1 m/s, flowing outward from the Jurong Strait.

During the SW monsoon, a similar flow pattern is observed as during the NE monsoon scenario. However, current speeds near the proposed CCGT outfall during peak flood are slightly higher, by approximately 0.1 m/s, while during peak ebb, they are marginally lower. These variations are attributed to the influence of prevailing monsoonal winds. Despite these differences, the overall trend remains consistent across both monsoon seasons, with flood currents near the proposed CCGT outfall being generally stronger than ebb currents.

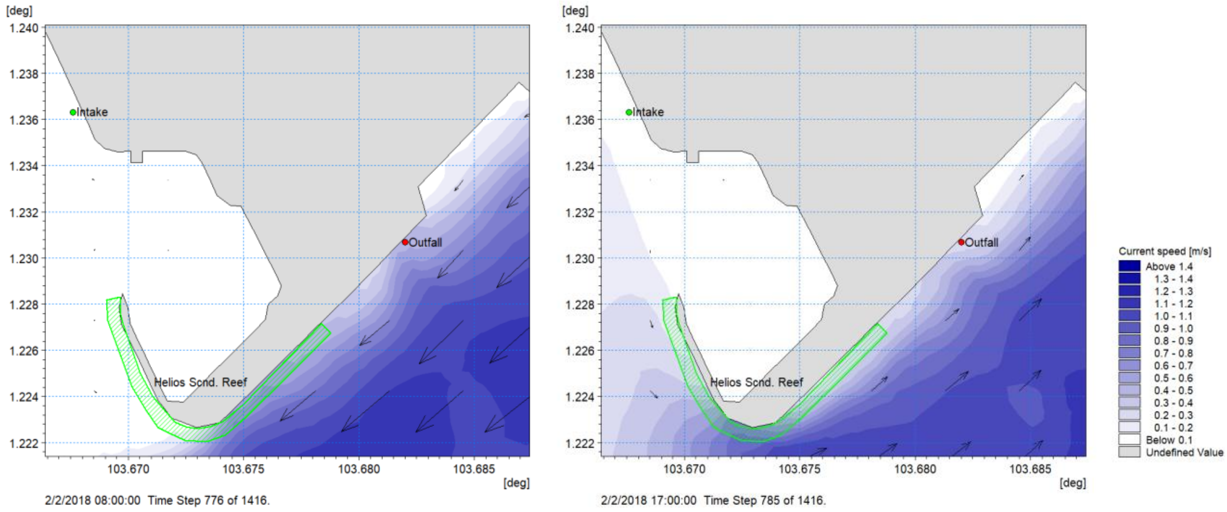


*Figure 6-1 Depth averaged current field during peak flood (left) and peak ebb (right) for **future baseline conditions** during NE monsoon*

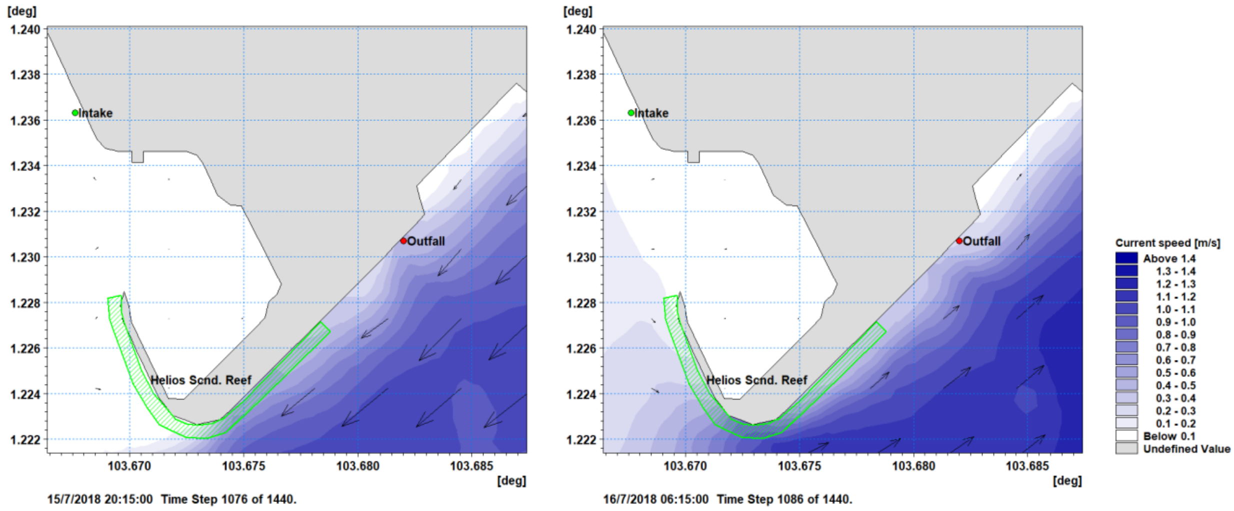


*Figure 6-2 Depth averaged current field during peak flood (left) and peak ebb (right) for **future baseline conditions** during SW monsoon*

Changes between future baseline and operational phase conditions

Figure 6-3 and Figure 6-4 present the depth-averaged current fields for NE and SW monsoon conditions during the operational phase. Both figures reveal that the current pattern during peak flood and ebb tides remain consistent with those of baseline condition, indicating minimal variation between the two scenarios.

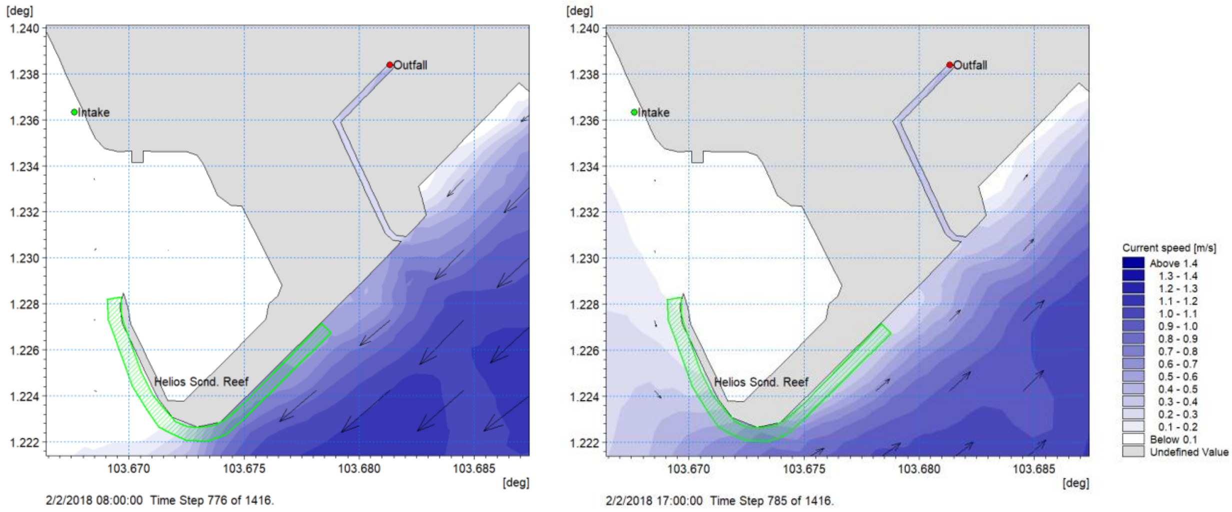


*Figure 6-3 Depth averaged current field during peak flood (left) and peak ebb (right) for **operational phase** during NE monsoon*

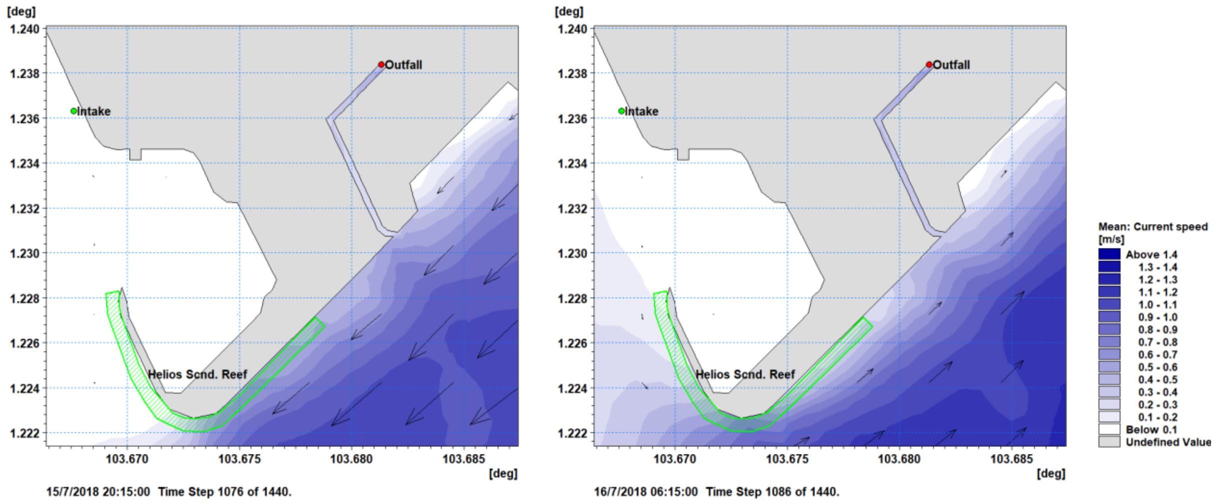


*Figure 6-4 Depth averaged current field during peak flood (left) and peak ebb (right) for **operational phase** during SW monsoon*

Figure 6-5 and Figure 6-6 compare the depth-averaged current fields between the future baseline and the operational phase with the CCGT facility in operation during both monsoon seasons. A noticeable change in current speed is observed during flood tide conditions along the CCGT coastline, where the additional 15.75 m^3/s outfall discharge results in increased flow velocities up to 0.25 m/s. During ebb tide, the impact is more pronounced near the bend of the Helios Secondary Reef in the south, extending toward the intake location in the western part of Jurong Strait. In this area, maximum current speeds are reduced by 0.20 m/s compared to the future baseline scenario without the outfall discharge.

This reduction is attributed to the natural ebb flow, which typically transports water from Jurong Strait toward Pandan Strait. The outfall discharge disrupts this flow pattern, as water from the channel flows freely into the sea during ebb conditions, more prominently than during flood conditions, thereby altering the local hydrodynamics.

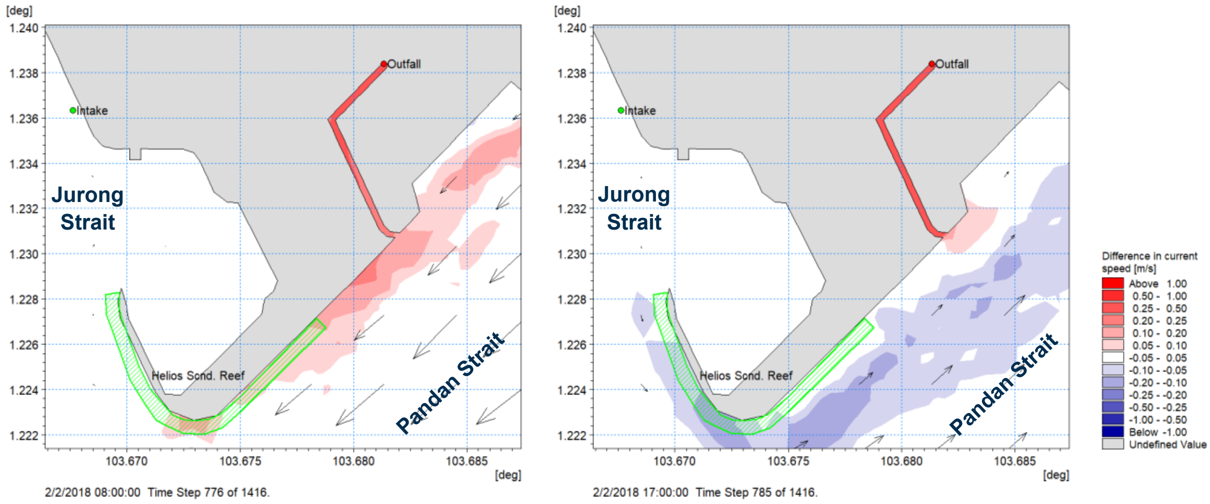


Figure 6-5 Depth averaged current field difference during peak flood (left) and peak ebb (right) between ***operational phase - future baseline*** *during NE monsoon; an increase in current speed is indicated in red with positive values, while a decrease is shown in blue with negative values*

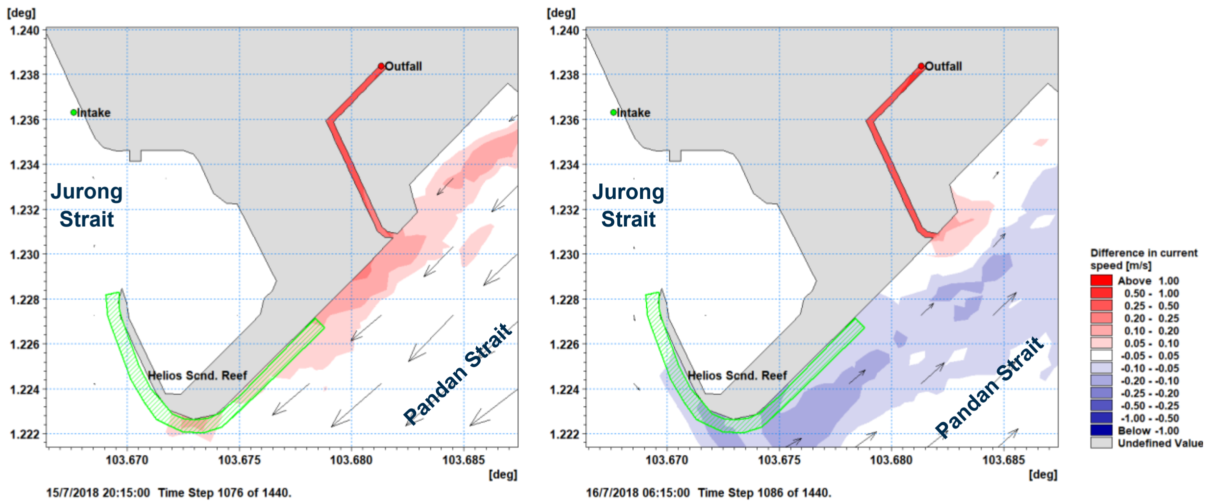


Figure 6-6 Depth averaged current field difference during peak flood (left) and peak ebb (right) between ***operational phase - future baseline*** *during SW monsoon; an increase in current speed is indicated in red with positive values, while a decrease is shown in blue with negative values*

6.2.1.2 Changes in mean and maximum current speed

The assessment of mean and maximum current speeds was carried out to evaluate any potential changes in the overall flow regime resulting from the operation of the proposed CCGT facility.

Figure 6-7 and Figure 6-8 show the mean and maximum current speeds for the NE and SW monsoons respectively under **future baseline conditions**. It is evident from the figures that the mean current speed during both monsoons at the outfall ranges between 0.10 m/s and 0.20 m/s, while the maximum current speed ranges between 0.40 m/s and 0.50 m/s, gradually increases towards deeper water.

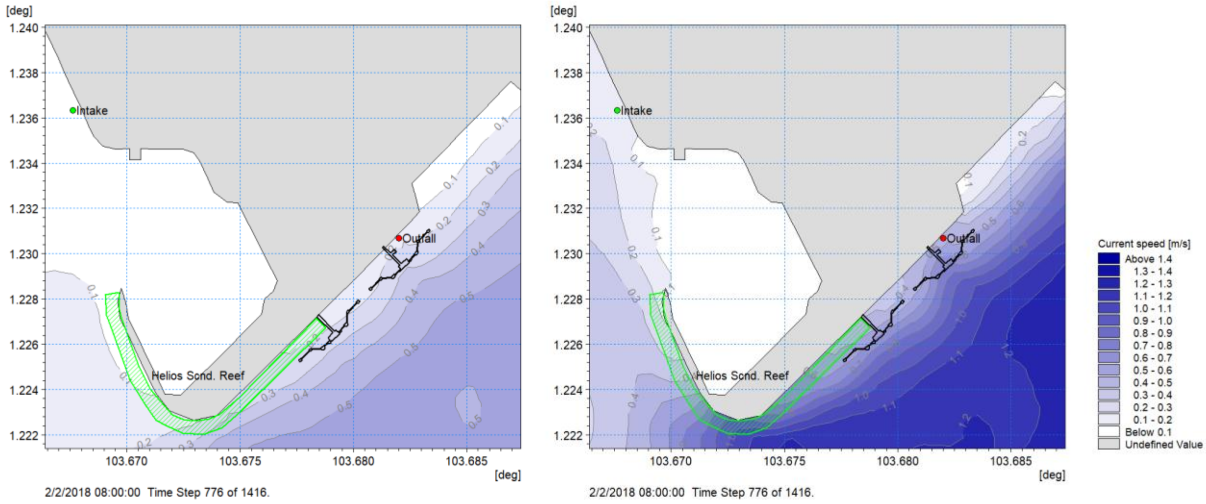


*Figure 6-7 Mean (left) and maximum (right) depth averaged current speeds for **future baseline conditions** during NE monsoon*

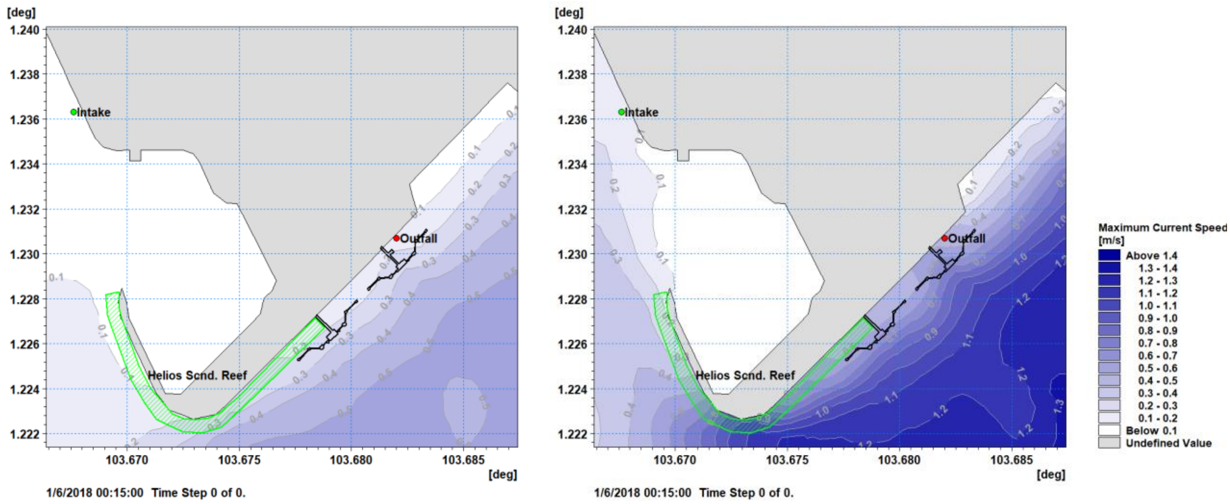


*Figure 6-8 Mean (left) and maximum (right) depth averaged current speeds for **future baseline conditions** during SW monsoon*

Figure 6-9 and Figure 6-10 illustrate the mean and maximum current speeds during the northeast (NE) and southwest (SW) monsoon seasons under **operational phase**. The figures show that the additional discharge of 15.75 m³/s from the CCGT outfall leads to increased current speeds, particularly around 300 meters from the discharge point, as indicated by the darker contour patterns.

A reduction in current speed near the intake location in western Jurong Strait is also evident, consistent with earlier observations in Figure 6-5 and Figure 6-6. This suggests that the outfall discharge influences local hydrodynamics, enhancing flow near the outfall while dampening currents in adjacent areas.

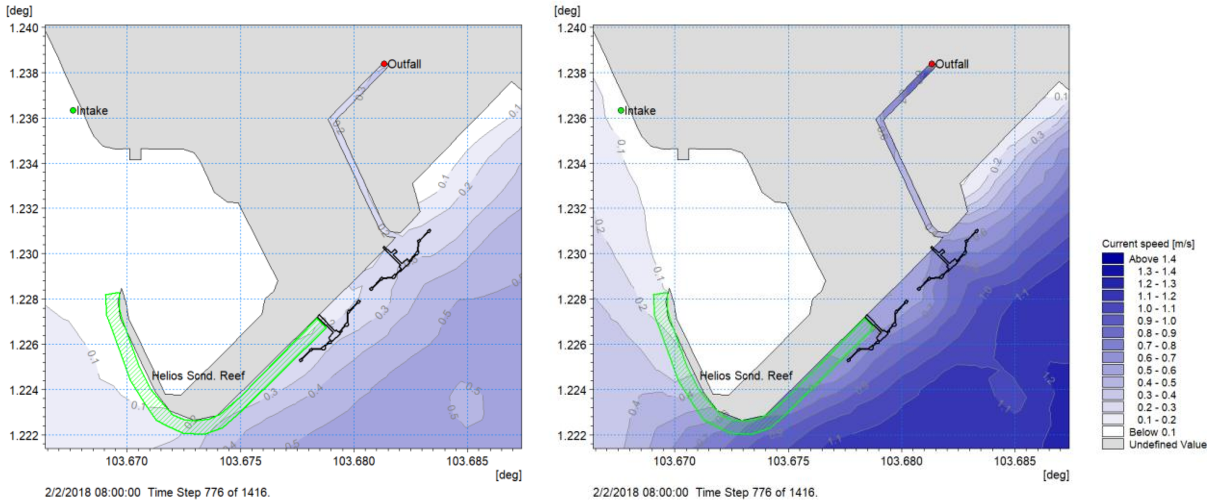


*Figure 6-9 Mean (left) and maximum (right) depth averaged current speeds for **operational phase** during NE monsoon*

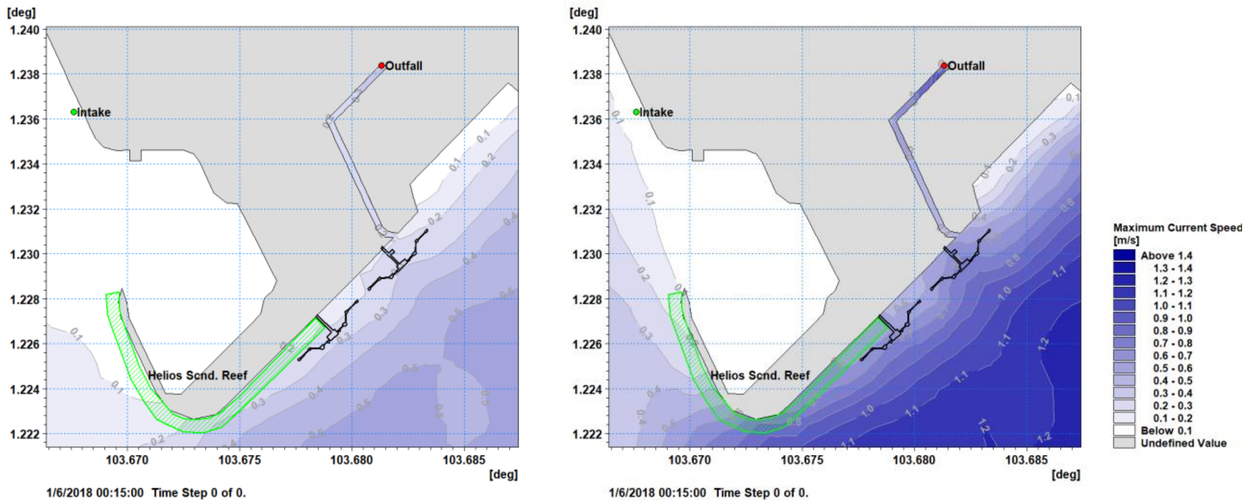


*Figure 6-10 Mean (left) and maximum (right) depth averaged current speeds for **operational phase** during SW monsoon*

In line with Figure 6-5 and Figure 6-6, the difference plot of mean and maximum values for the NE and SW are presented in Figure 6-11 and Figure 6-12. The results show a consistent pattern, with increased current speeds, up to a maximum of 0.20 m/s, observed near the discharge mouth and along the CCGT coastline during both monsoon seasons. Conversely, a reduction in maximum current speed of approximately 0.20 m/s is observed near the intake location in the western part of Jurong Strait, extending toward the bend of the Helios Secondary Reef and into Pandan Strait.

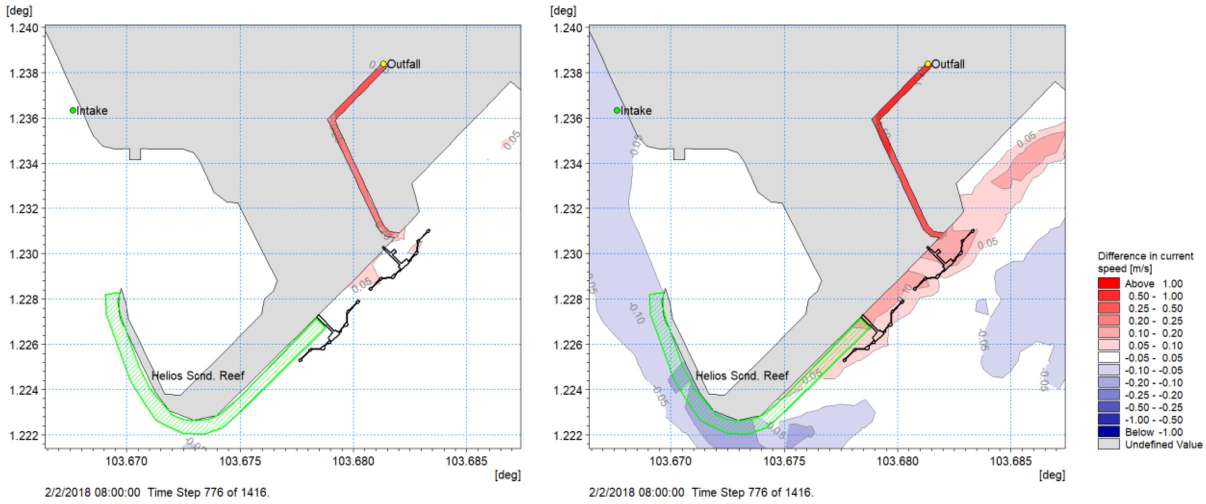


*Figure 6-11 Difference in Mean (left) and maximum (right) depth averaged current between **operational phase - future baseline** during NE monsoon*

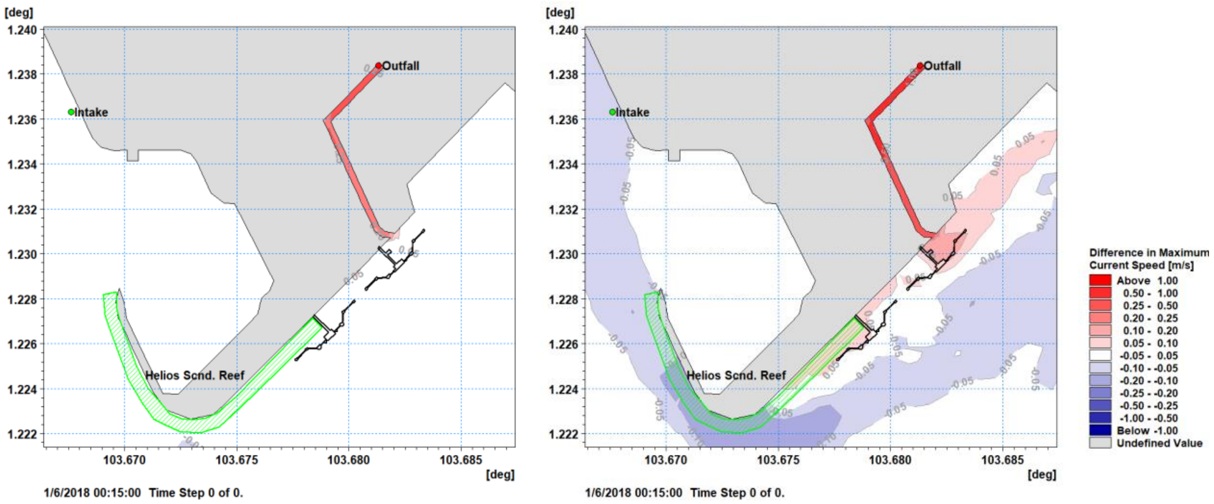


*Figure 6-12 Difference in Mean (left) and maximum (right) depth averaged current between **operational phase - future baseline** during SW monsoon*

6.2.1.3 Changes in current speed exceedance limits

In this section, exceedance of current speed was assessed based on the MPA berthing and fairway guidelines of 2 knots and 3.5 knots, respectively. Percentage exceedance for both the NE and SW monsoons was calculated for these thresholds, and difference maps were prepared to assess the potential impact of the CCGT operation.

Figure 6-13 Figure 6-14 show that exceedance of current speeds above 2.0 knots and 3.5 knots occur only in offshore areas, away from the outfall location. No elevated current speeds are observed in the vicinity of the outfall.

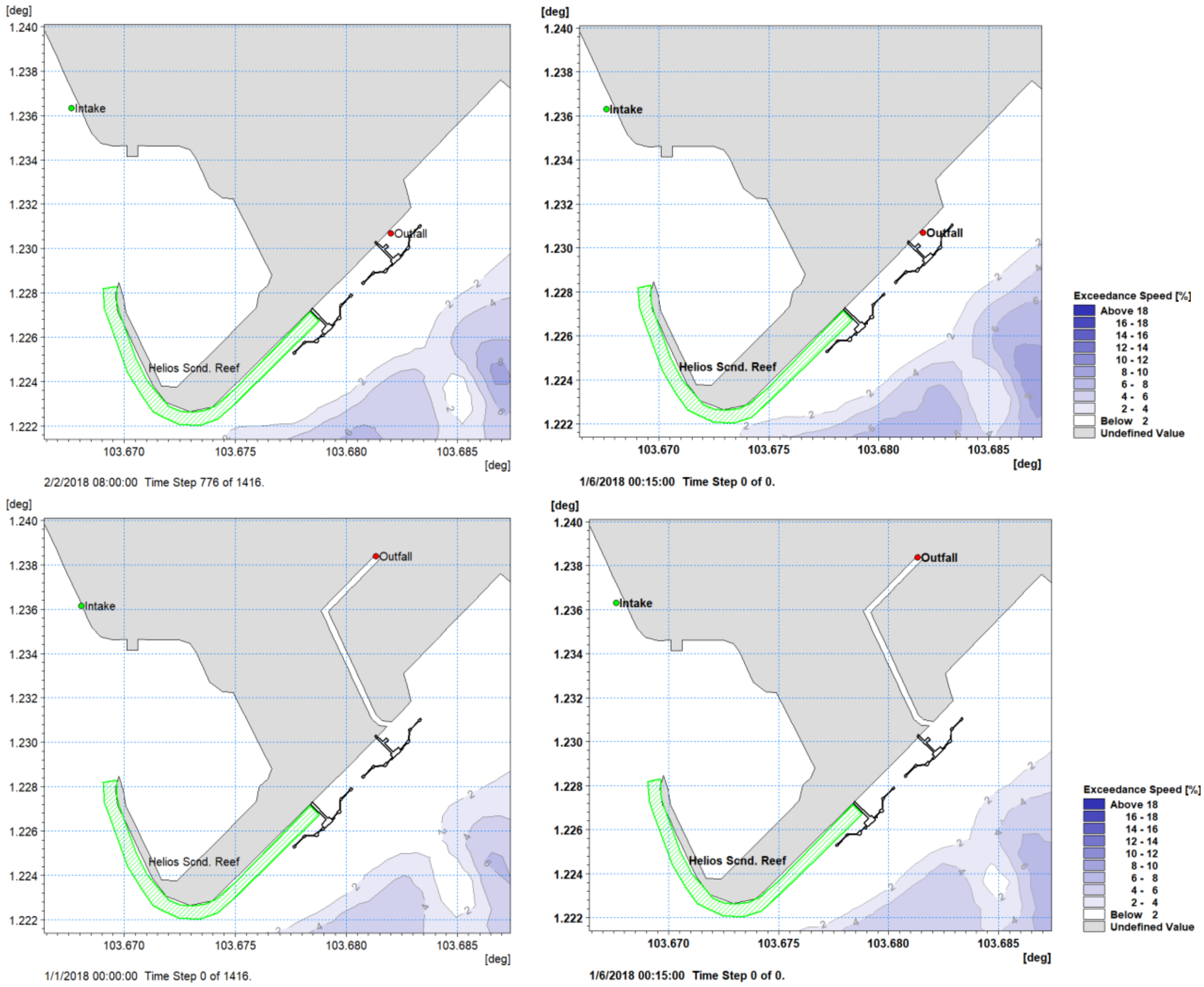


*Figure 6-13 Depth averaged percentages of 2.0 knots current exceedance for **future baseline** during NE (top left) and SW (top right) monsoon and for **operational phase** during NE (bottom left) and SW (bottom right) monsoon*

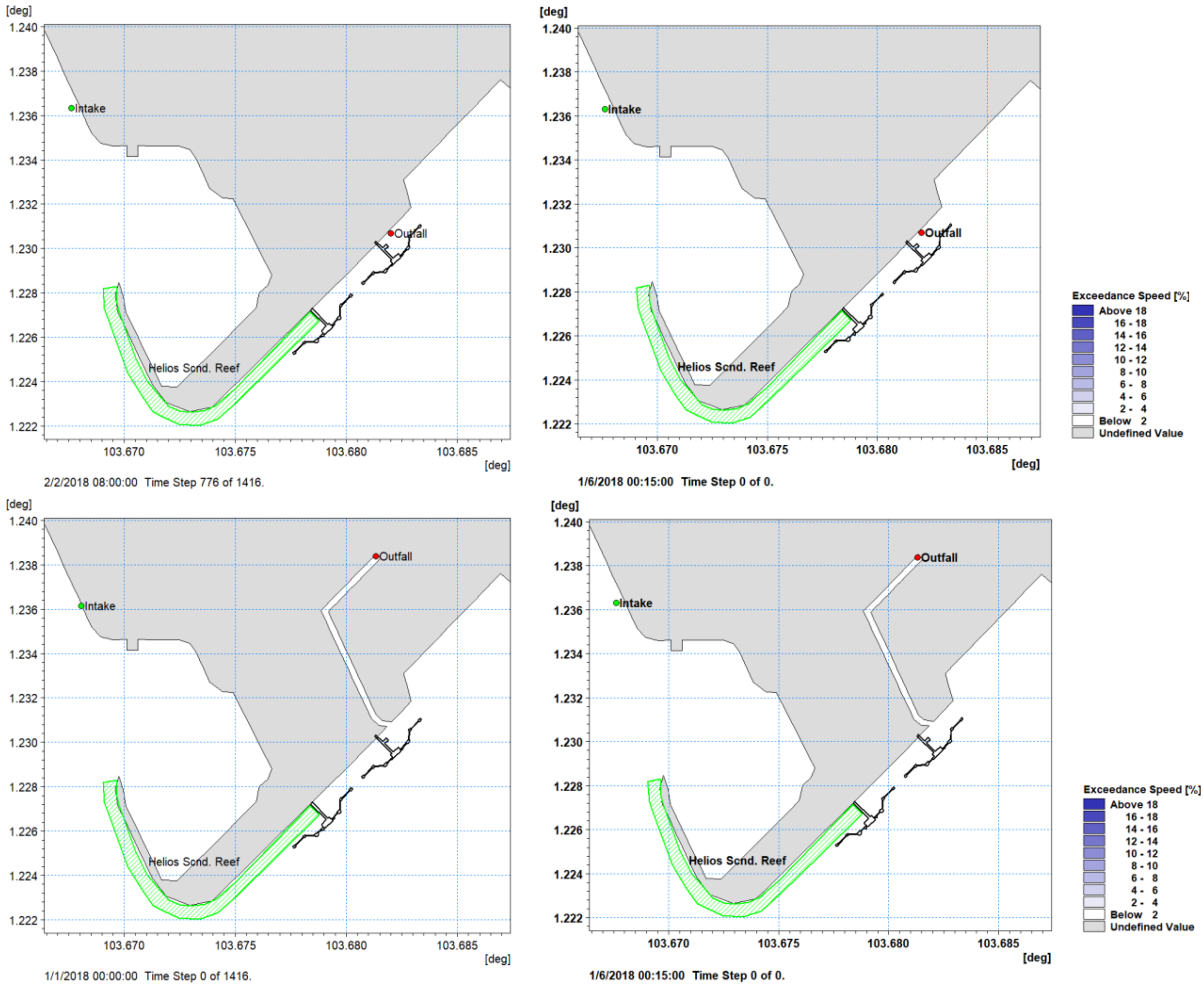


*Figure 6-14 Depth averaged percentages of 3.5 knots current exceedance for **future baseline** during NE (top left) and SW (top right) monsoon and for **operational phase** during NE (bottom left) and SW (bottom right) monsoon*

The difference plots for the NE and SW monsoons are presented in Figure 6-15 and Figure 6-16 for 2.0 knots and 3.5 knots, respectively. The exceedance shows that the difference is typically less than 2% across both monsoons and for both thresholds at the outfall and surrounding areas, indicating no discernible impact attributable to CCGT development.

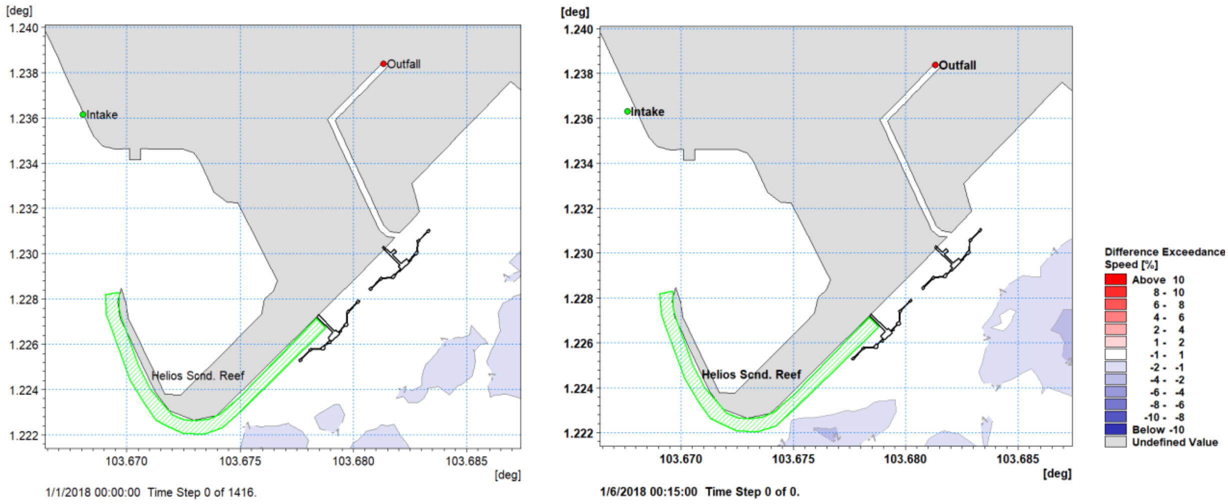


*Figure 6-15 Depth averaged percentages difference of 2.0 knots current exceedance between **operational phase - future baseline** during NE (left) and SW (right) monsoon*

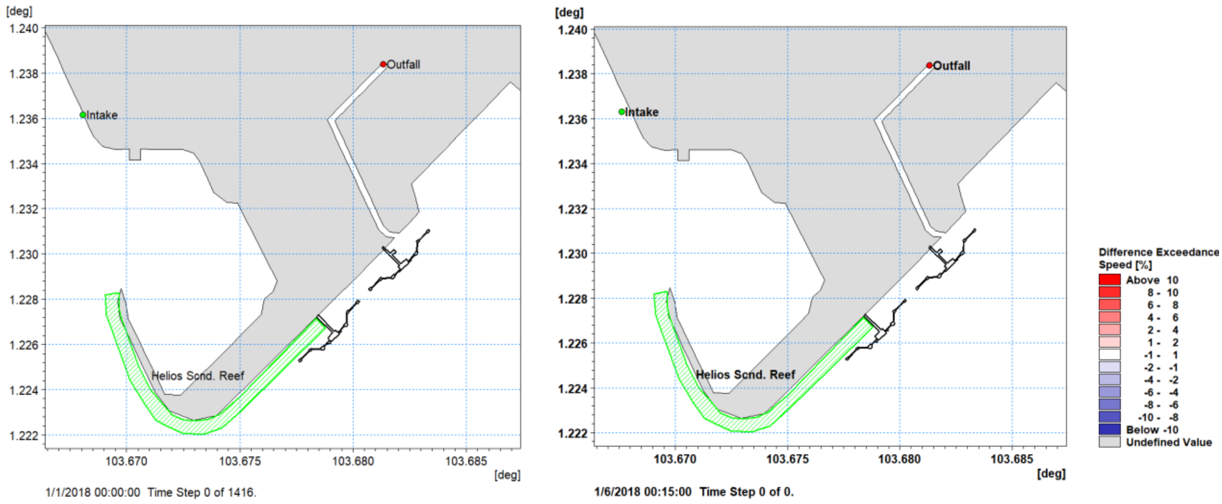


*Figure 6-16 Depth averaged percentages difference of 3.5 knots current exceedance between **operational phase - future baseline** during NE (left) and SW (right) monsoon*

6.2.1.4 Changes in slack water time

In this section, potential changes in slack water time are presented. Slack water refers to the brief period during tidal transitions when current speeds drop below 0.25 m/s (0.49 knots), which reduces vertical and horizontal mixing and can lead to localised accumulation of pollutants or reduced water quality. The percentage of slack water time was calculated for both the NE and SW monsoons under future baseline and operational phase, and the difference was determined by subtracting the future baseline from the operational phase.

The resulting difference map is presented in Figure 6-17 shows up to a 25% reduction in slack water areas around the mouth of the outfall channel and extending eastward. This finding aligns with Section 6.2.1.2, which identified an increase in current speed in this region, resulting in fewer instances of current speeds below 0.25 m/s. Conversely, in areas where current speeds decrease, such as near the bend of the Helios Secondary Reef, the percentage of slack water increases by approximately 5%. Overall, the CCGT development is expected to influence slack water duration, though the impact remains localised along the CCGT coastline.

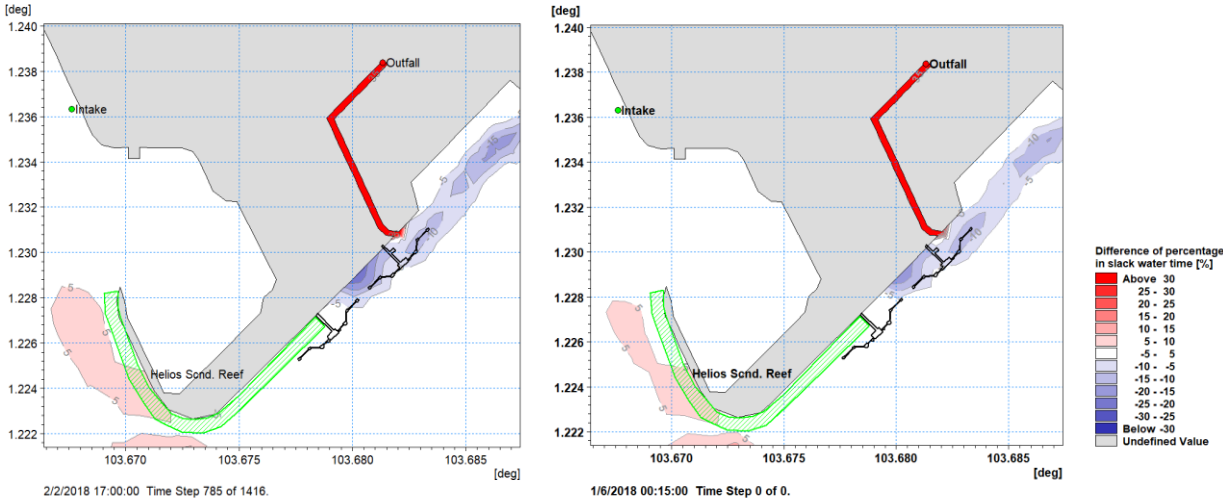


Figure 6-17 Depth-averaged percentages difference in slack water (<0.25 m/s) between ***operational phase - future baseline*** *during NE (left) and SW (right) monsoon*

6.2.2 Thermal Plume

6.2.2.1 Mean and maximum excess temperature

Figure 6-18 and Figure 6-19 present the differences in mean and maximum temperatures between the future baseline condition and the operational phase during the NE monsoon. Similarly, Figure 6-20 and Figure 6-21 present the same comparison under SW monsoon conditions. The plots for temperature changes are capped to +2.0°C to align with the rise of temperature in the receiving water criteria outlined in AMWQC. To provide a broader view of spatial variation, the plots also include 100-m and 300-m radius boundaries, illustrating temperature distribution within and beyond the immediate discharge area (mixing zone).

Across all figures, temperature dispersion is most pronounced at the surface layer, where thermal dynamics are influenced by atmospheric interactions and wind-driven mixing. This dispersion gradually decreases toward the bottom layer, consistent with vertical stratification and lower mixing rates. Overall, the mean temperature discharge from the CCGT outfall remains within guideline limits. Specifically, Figure 6-18 and Figure 6-20 show that the mean surface temperature increase during both monsoon seasons is limited to +2.0°C within the 100-m radius, with the affected zone confined to the immediate vicinity of the outfall.

Exceedances above the +2°C temperature threshold from the 100-m boundary are observed only in the maximum temperature plots for the surface layer during both the NE and SW monsoon seasons. These results highlight the influence of monsoonal winds on thermal dispersion. During the NE monsoon, prevailing northeasterly winds drive the thermal plume south-westward along the coastline, resulting in a slightly broader spread than the SW monsoon. Importantly, excess temperatures of +2°C do not extended to the nearest environmentally sensitive receptor, the Helios Secondary Reef, indicating minimal thermal impact under these conditions.

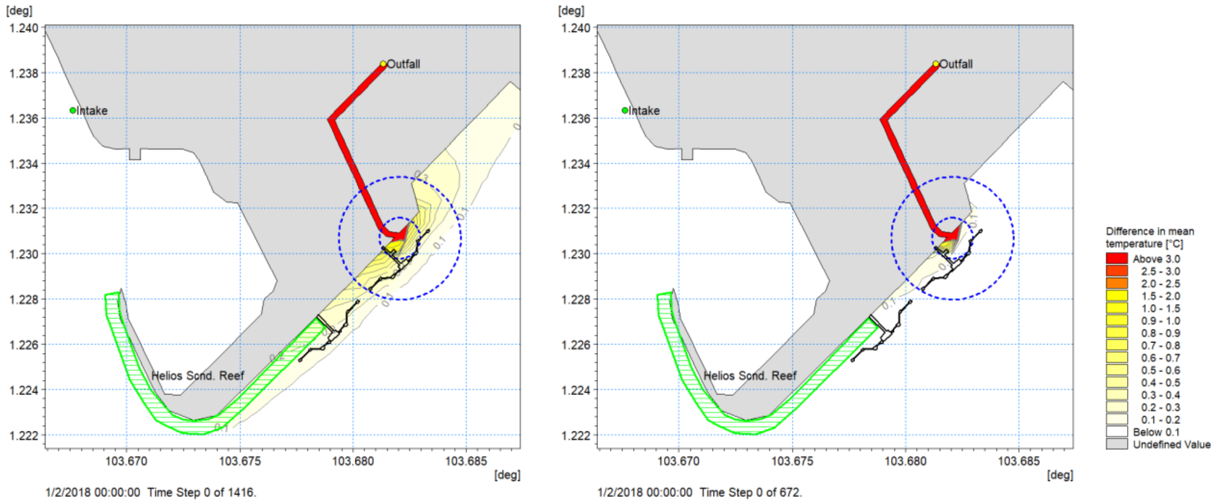


*Figure 6-18 Difference in mean temperature between **operational phase - future baseline** at surface (left) and bottom (right) layer during NE monsoon; plotted with 100-m and 300-m boundaries*

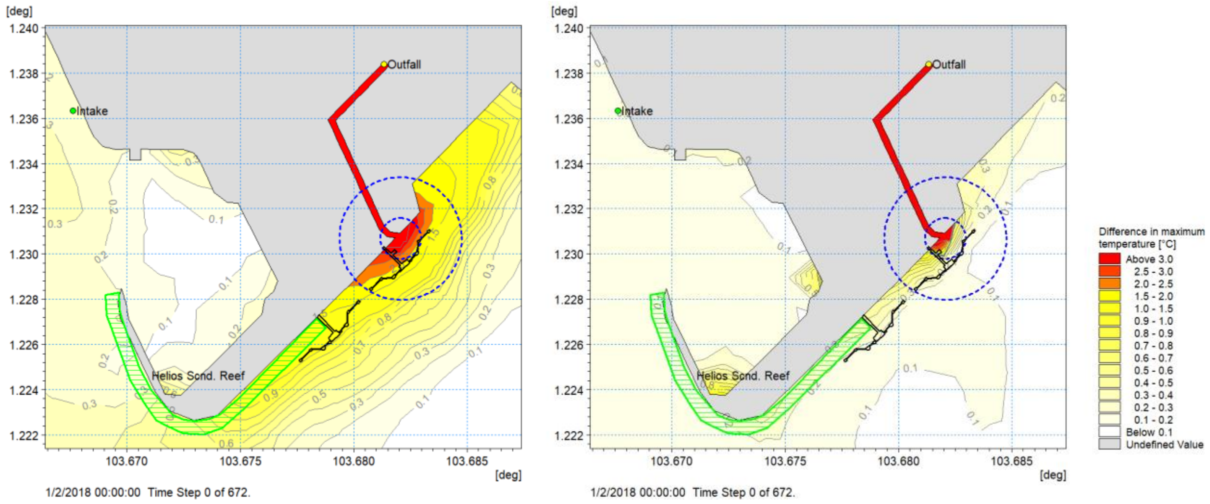


*Figure 6-19 Difference in maximum temperature between **operational phase - future baseline** at surface (left) and bottom (right) layer during NE monsoon; plotted with 100-m and 300-m boundaries*

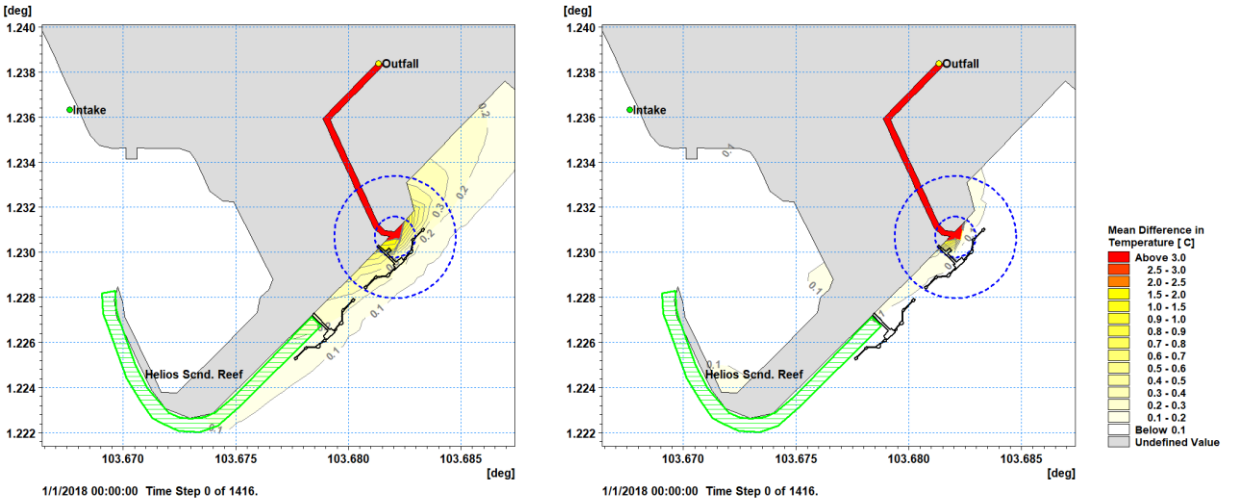


Figure 6-20 Difference in mean temperature between ***operational phase - future baseline*** *at surface (left) and bottom (right) layer during SW monsoon; plotted with 100-m and 300-m boundaries*

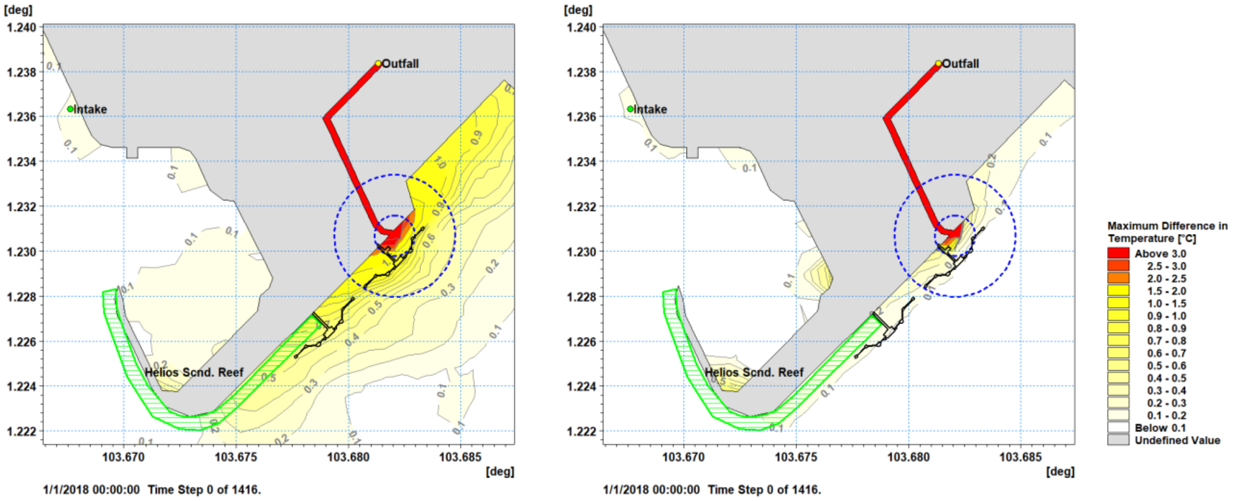


Figure 6-21 Difference in maximum temperature between ***operational phase - future baseline*** *at surface (left) and bottom (right) layer during SW monsoon; plotted with 100-m and 300-m boundaries*

Based on the temperature plots, maximum surface temperature increases at the Helios Secondary Reef ranges from approximately +0.1°C at the western end to nearly +1.5°C at the eastern end of the reef during both monsoon seasons. This suggests that the monthly average temperature remains below the critical threshold for coral sustainability of +1.0°C to +2.0°C (Manzello, 2023). At the bottom layer, temperature increase is less than +0.3°C, resulting in a negligible impact on coral reefs located on the seabed. However, since some coral reefs at Helios Secondary Reef are situated on a seawall or revetment structures, there may be some impact on coral habitats in shallower depths near the surface.The detailed assessment of the Helios Secondary Reef is presented in Section 6.3.1.

The AMWQC stipulates that temperature increases across the broader marine area should remain below +2.0°C. As shown in the plots above, areas exceeding the +2.0°C threshold is confined within approximately 300 m of the outfall location. Model results indicate that the majority of the marine area complies with this criterion, suggesting that the thermal impact is limited. In practice, marine biota, such as fish tend to naturally avoid areas with elevated temperatures. Furthermore, there are no other environmentally sensitive receptors located within the 300-m radius boundary. Therefore, it can be concluded that the operation of the CCGT facility does not pose a significant risk to aquatic life under AMWQC standards beyond this boundary.

To evaluate changes in temperature around the CCGT area within the designated mixing zones, several observation points were selected (see Figure 6-22). These points are located within two boundary / mixing zones: a 100-m radius and a 300-m radius from the end of the outfall channel. Observation points P4, P5, and P6 are positioned along the perimeter of the 100-m zone, while points P7 and P8 lie at the edge of the 300-m boundary. Additionally, points P9 through P12 were included to capture temperature changes at the Helios Secondary Reef, with results discussed in Section 6.3.1. Note that observation points P1, P2, and P3 are located inside the discharge channel (not shown in Figure 6-22) and used for our internal quality control only, not part of the assessment.

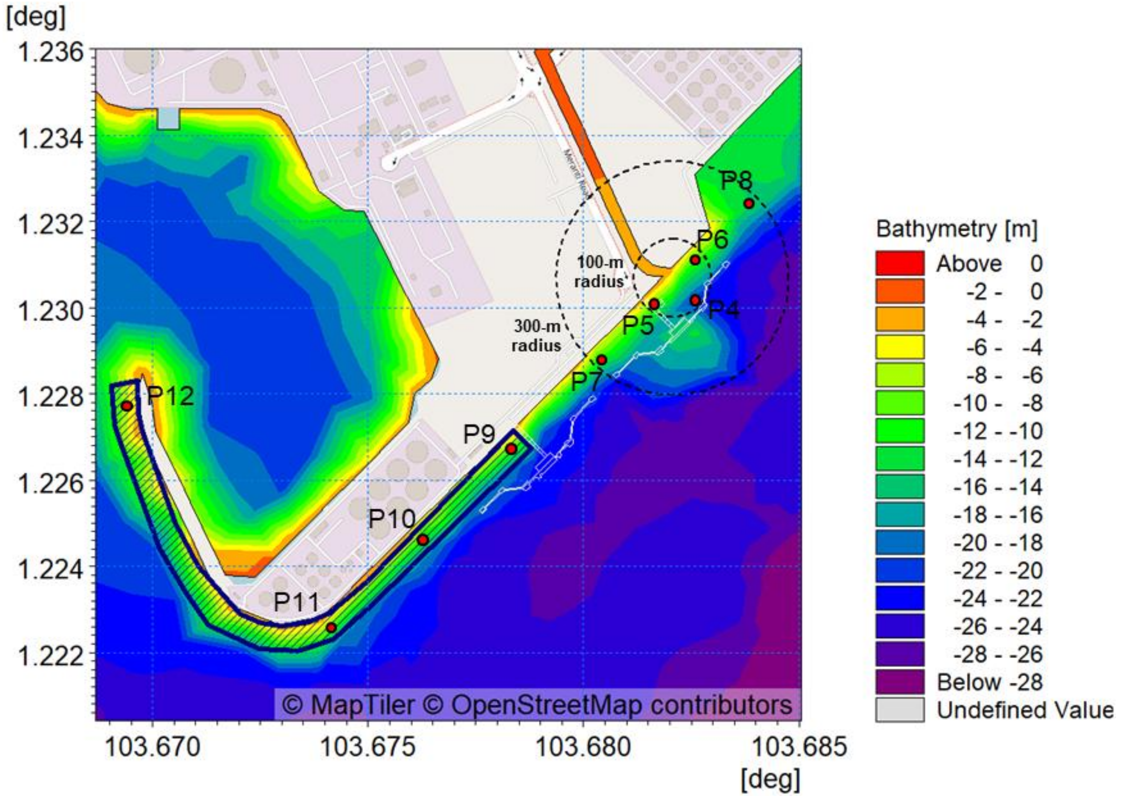
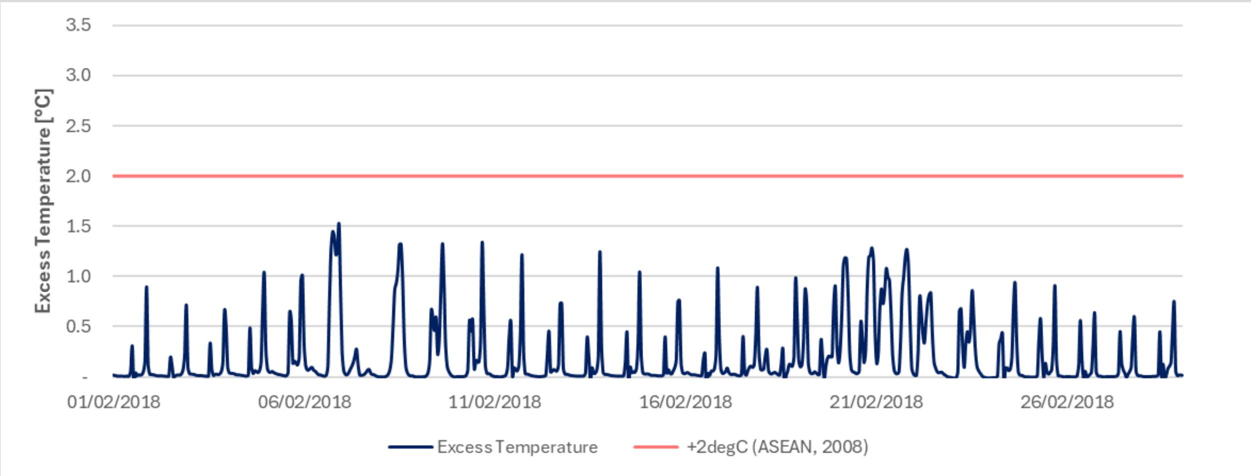
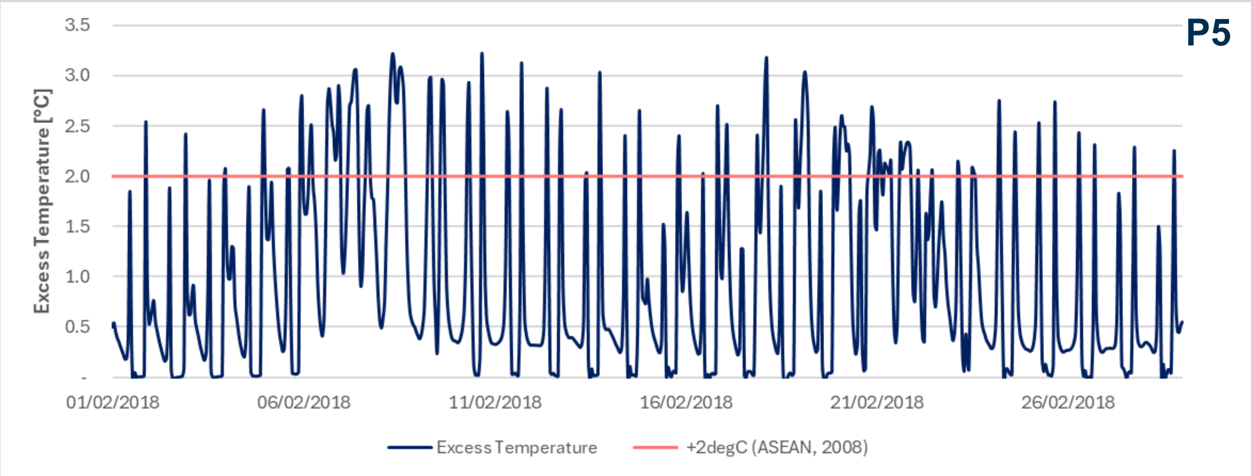


Figure 6-22 Location of observation points for temperature and chlorine concentration at the edge of 100-m radius and 300-m radius boundaries, as well at the Helios Secondary Reef

Figure 6-23 and Figure 6-24 present the time series of excess temperature within the 100-meter boundary for observation points P4 to P6 during the NE and SW monsoons simulation period. At Point P4, located seaward and perpendicular to the shoreline from the outfall, the excess temperatures consistently remained below the +2.0°C threshold, indicating compliance with AMWQC criteria.

The temperature distribution pattern indicates that thermal dispersion primarily follows the prevailing ebb and flood current directions, moving east and west along the coastline. Consequently, higher excess temperatures are observed at Points P5 and P6, located west and east of the outfall respectively. Point P5 located on the west side of outfall shows a lower frequency of excess temperatures above +2.0°C threshold compared to Point P6 for both monsoons. Less exceedance is observed for SW monsoon compared to NE monsoon at Point P5 and P6.





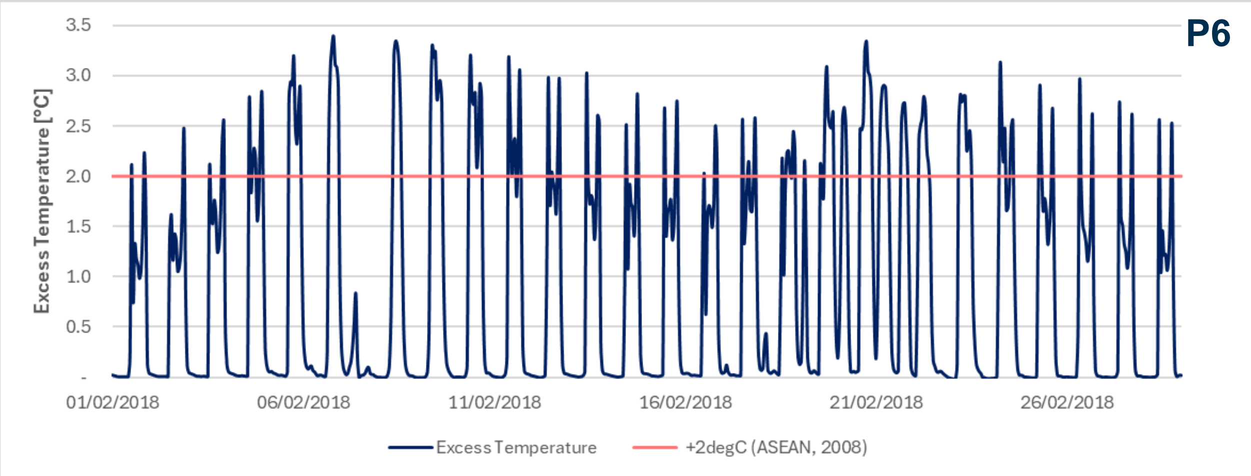


Figure 6-23 Excess temperature at the surface layer during NE monsoon within the 100-m radius against the +3°C threshold

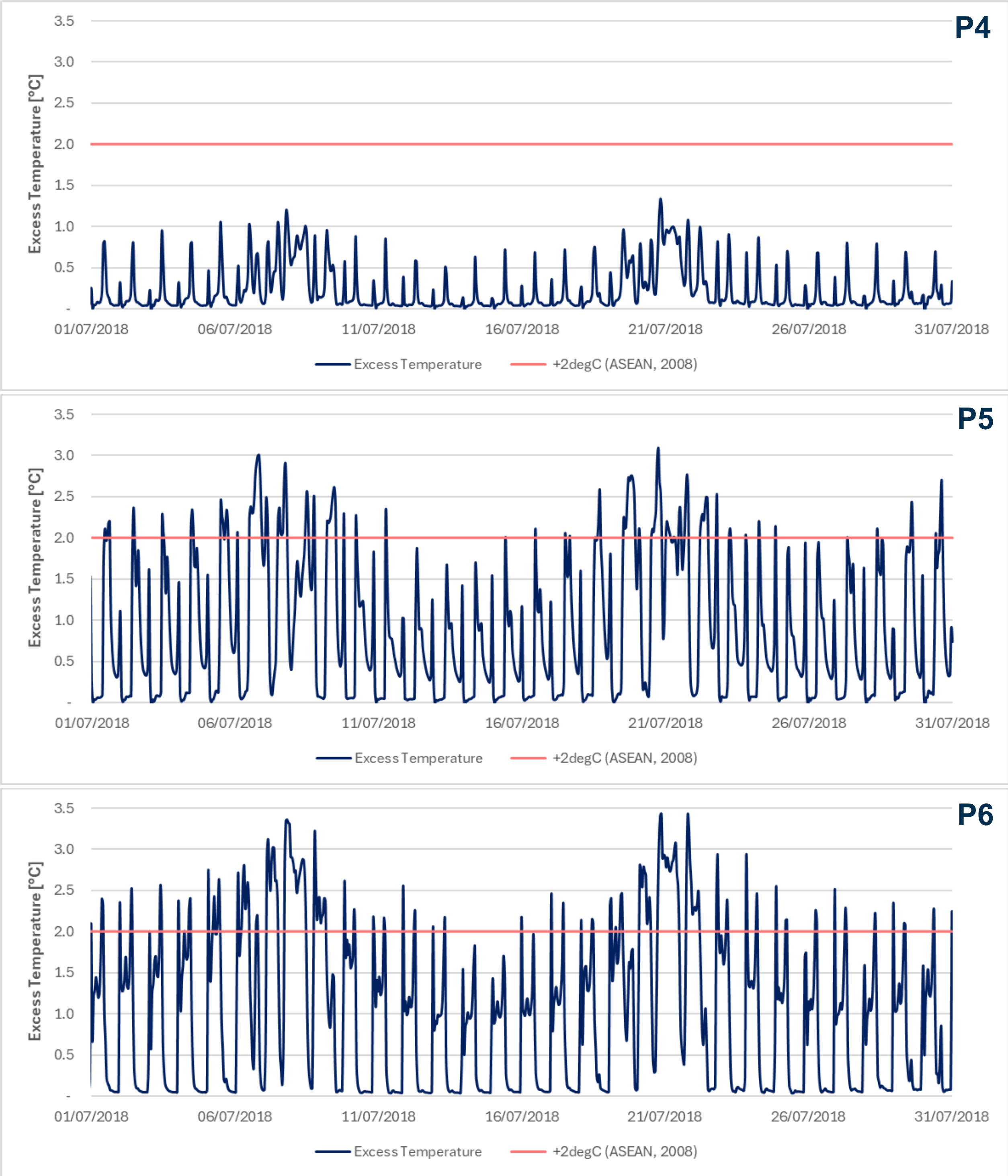


Figure 6-24 Excess temperature at the surface layer during SW monsoon within the 100-m radius against the +2°C threshold

Further from the outfall location, within the 300-m boundary, excess temperatures at Points P7 and P8 during NE and SW monsoons remained below the +2.0°C threshold for the majority of the simulation period. Only a few hours during the one-month simulation showed exceedances above +2.0°C threshold. Beyond the 300-m radius boundary, exceedances of excess temperature above the +2.0°C threshold are expected to be negligible as seen in Figure 6-25 and Figure 6-26, temperature variations only exceed this threshold on a few occasions, indicating compliance with ASEAN thermal discharge criteria and minimal thermal impact on surrounding waters outside the designated mixing zone.

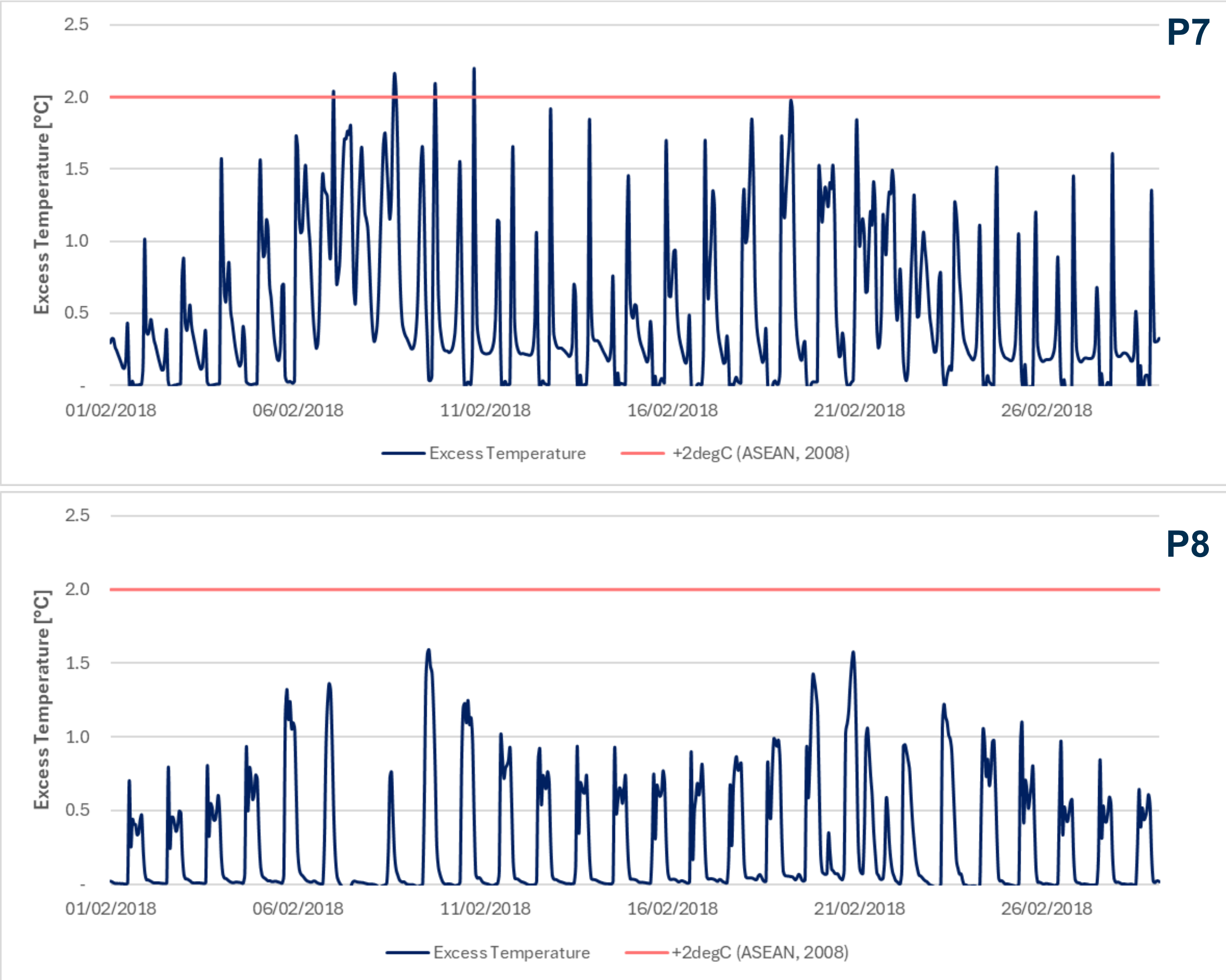


Figure 6-25 Excess temperature at the surface layer during NE monsoon within the 300-m radius against the +2°C threshold

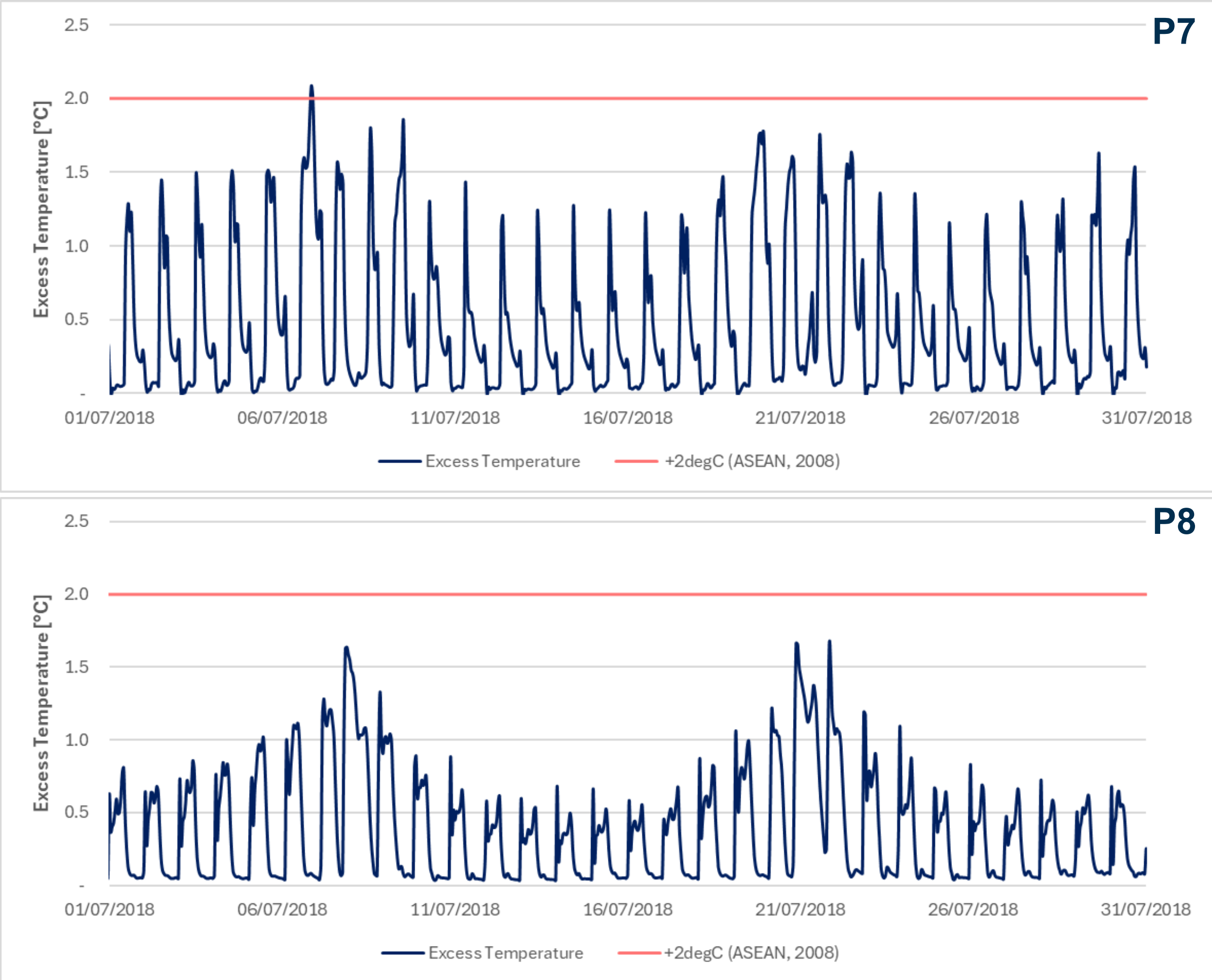


Figure 6-26 Excess temperature at the surface layer during SW monsoon within the 300-m radius against the +2°C threshold

6.2.2.2 Temperature exceedance limit

Figure 6-27 and Figure 6-28 present the percentage of exceedance beyond the AMWQC +2.0°C threshold within the 100-m radius and additionally with the 300-m radius of the outfall location. The plots were done for the NE and SW monsoon seasons, respectively. Exceedances above +2.0°C are localised near the outfall source. Beyond the 100-m radius, the percentage of exceedance drops significantly, typically ranging between 1% and 10%, but remains within the 300-m boundary for NE monsoon. For SW monsoon, exceedance above 1% is even more confined within 100-m, indicating more limited spatial impact.

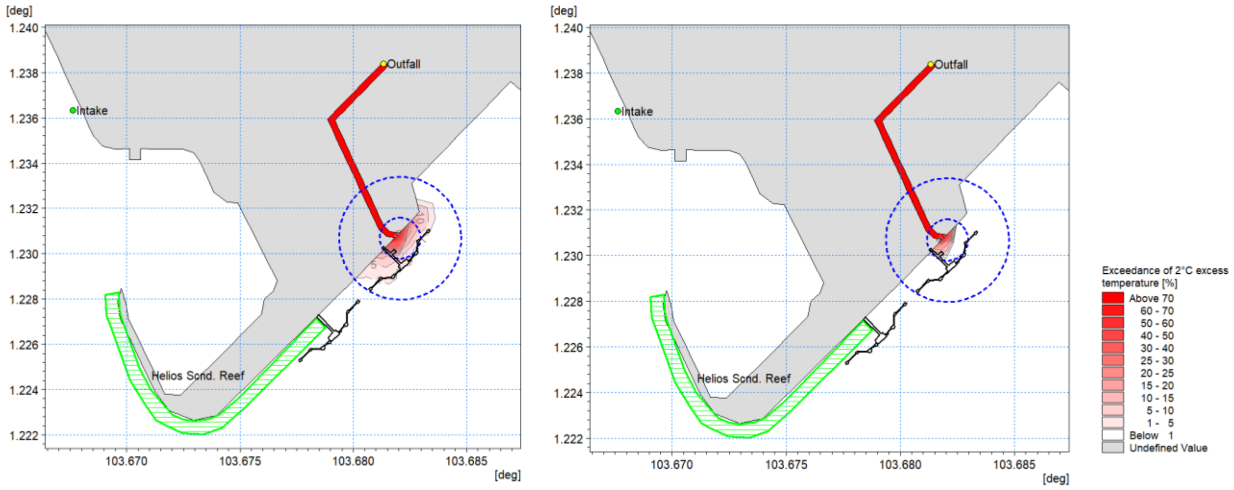


Figure 6-27 Exceedance of 2°C excess temperature between ***operational phase - future baseline*** *at surface (left) and bottom (right) layer during NE monsoon*; *plotted with 100-m and 300-m boundaries*

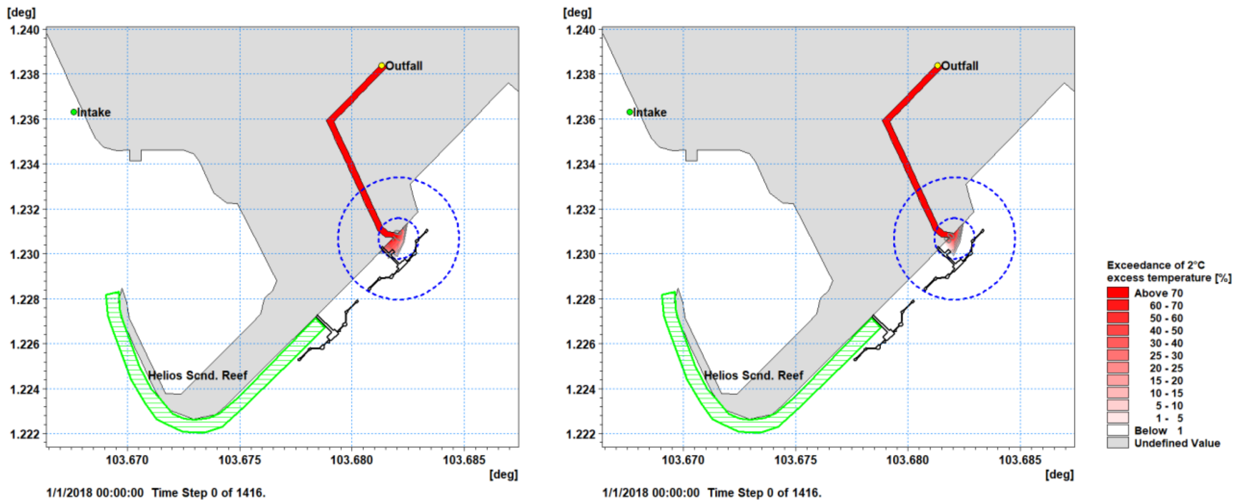


Figure 6-28 Exceedance of with 2°C excess temperature between ***operational phase - future baseline*** *at surface (left) and bottom (right) layer during SW monsoon*; *plotted with 100-m and 300-m boundaries*

6.2.3 Chlorine Plume

6.2.3.1 Mean and maximum excess chlorine concentration

Figure 6-29 and Figure 6-30 illustrate the mean and maximum excess chlorine plume during the NE monsoon, while Figure 6-31 and Figure 6-32 present the same for the SW monsoon. These results are based on a one-month continuous dosing regime, combining 0.25 ppm for normal dosing and 0.50 ppm for shock dosing, as detailed in Section 4.7. Each figure shows chlorine dispersion at both the surface and bottom layers.

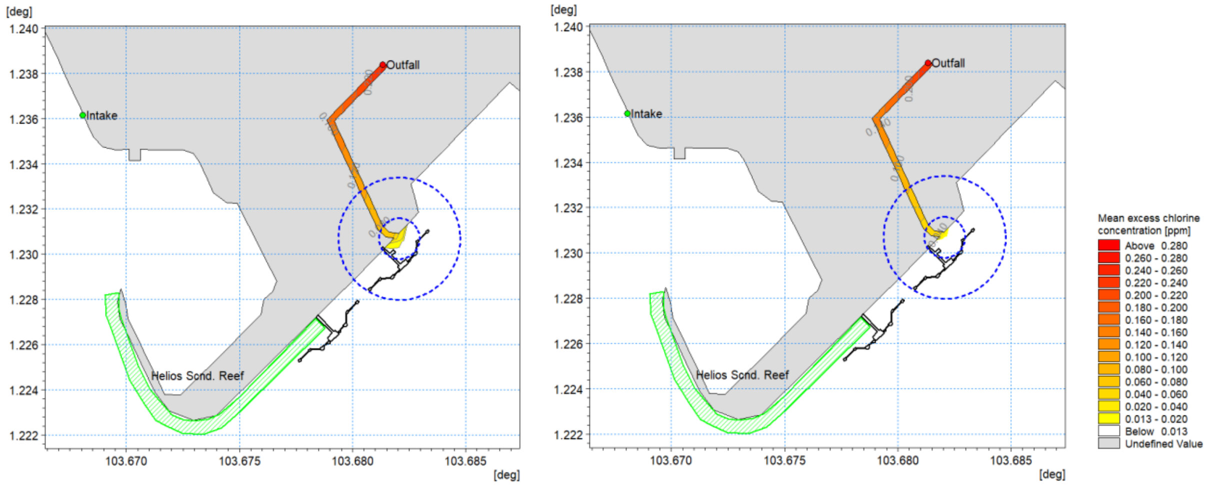


*Figure 6-29 Mean excess chlorine between **operational phase - future baseline** at surface (left) and bottom (right) layer during NE monsoon*; plotted with 100-m and 300-m boundaries

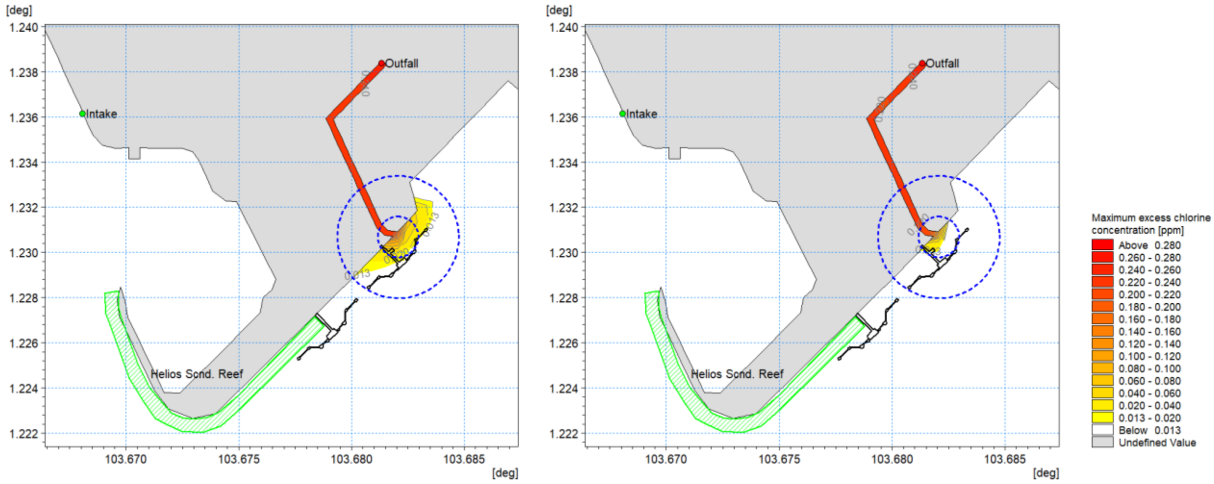


*Figure 6-30 Maximum excess chlorine between **operational phase - future baseline** at surface (left) and bottom (right) layer during NE monsoon*; plotted with 100-m and 300-m boundaries

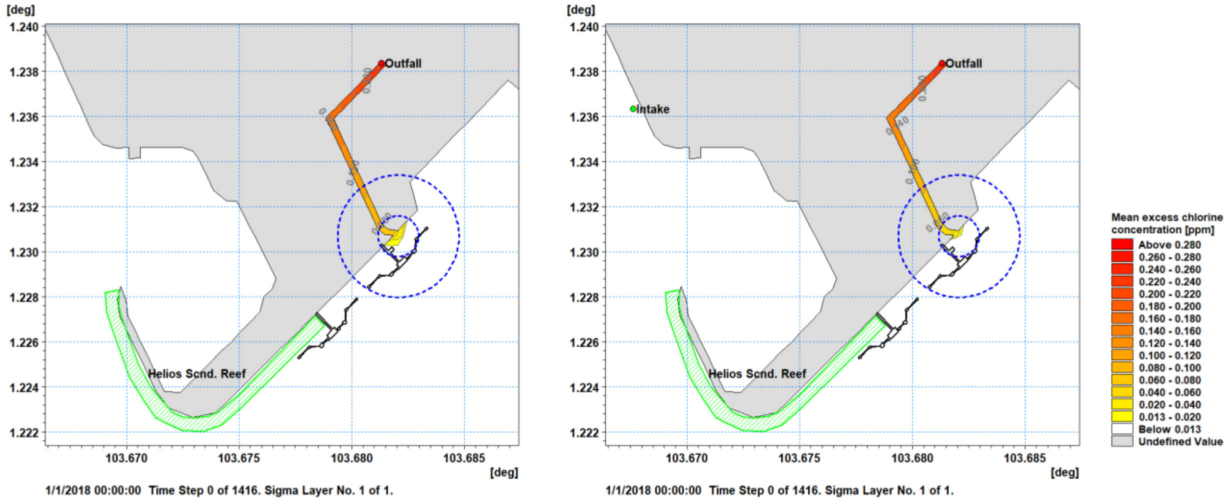


*Figure 6-31 Mean excess chlorine between **operational phase - future baseline** at surface (left) and bottom (right) layer during SW monsoon; plotted with 100-m and 300-m boundaries*

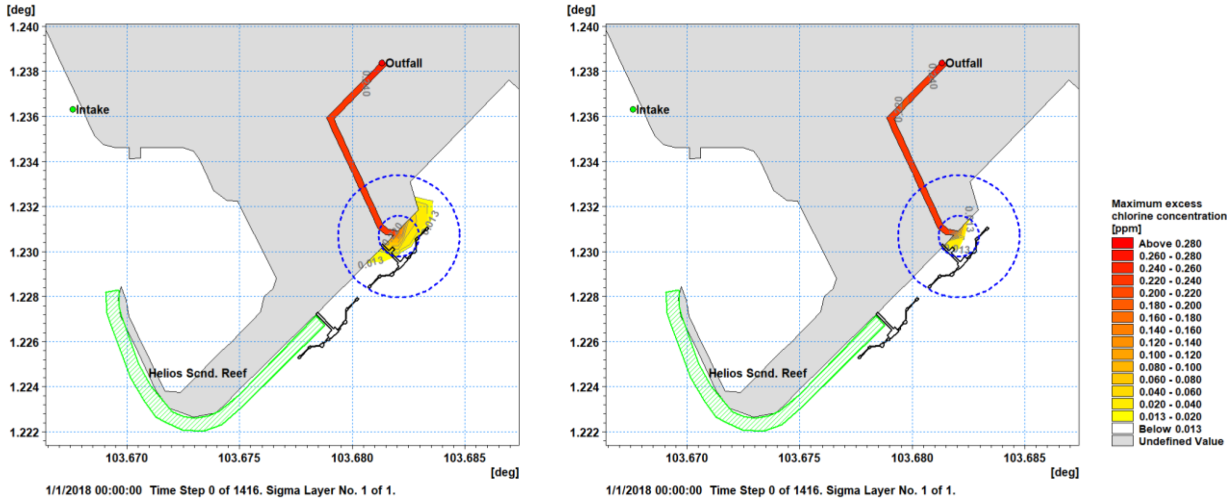


*Figure 6-32 Maximum excess chlorine between **operational phase - future baseline** at surface (left) and bottom (right) layer during SW monsoon; plotted with 100-m and 300-m boundaries*

Across all figures, a rapid vertical reduction in chlorine concentration is observed from the outfall source at the surface to the bottom layer. Even in the maximum excess plots, chlorine concentrations at the bottom layer remain localised near the outfall and are significantly lower than the discharge concentration. Specifically, concentrations at the bottom layer are below 0.02 ppm; it is well below the maximum shock dosing level of 0.50 ppm. This observation indicates a limited vertical and horizontal spread.

In terms of spatial distribution, the concentration plume remains closely confined to the coastline, with limited dispersion seaward. The chlorine plume is most extensive at the surface layer during NE monsoon condition (see Figure 6-30). Under these conditions, the maximum excess chlorine concentration from shock dosing, initially 0.25 - 0.50 ppm, is rapidly reduced to 0.02 ppm within approximately 300-m from the proposed CCGT outfall. This limited spread is expected as the chlorine has relatively fast decay rate of 1.185/hr, meaning the chlorine concentration decreases rapidly over time. After just one hour, only about 30.6% of the original concentration remains, significantly reducing its potential impact further from the source.

The spatial distribution of the chlorine plume is influenced by monsoonal wind patterns, similar to temperature variations. During the NE monsoon, prevailing northeasterly winds cause the plume to shift slightly south-westward. Despite this shift, chlorine concentrations remain well below threshold levels at the nearest environmentally sensitive receptor, the Helios Secondary Reef, indicating no impact under these conditions.

6.2.3.2 Chlorine concentration exceedance limit

As highlighted in Section 2.3, chlorine concentrations at the discharge point comply with Singapore's Environmental Protection and Management (Trade Effluent) Regulations 2008, with both normal and shock dosing scenarios remaining below the permissible limit of 1 ppm. In addition to this regulatory benchmark, we also refer to the USEPA R.E.D. FACTS for chlorine gas, which sets a more stringent concentration limit of 0.013 ppm. Figure 6-33 and Figure 6-34 present the percentage of exceedance relative to this USEPA threshold under SW and NE monsoons, respectively. Both figures illustrate the extent of exceedance across surface and bottom layers.

Similar to the excess chlorine distribution patterns, the exceedance of the 0.013 ppm threshold occurs within 300-m from the point source along the coastline which reduced quite significantly from above 70% to only 1%. Based on the spatial plots in Figure 6-33, the Helios Secondary Reef shows only below 1% exceedance, while all other environmentally sensitive receptors remain unaffected, with 0% exceedance observed.

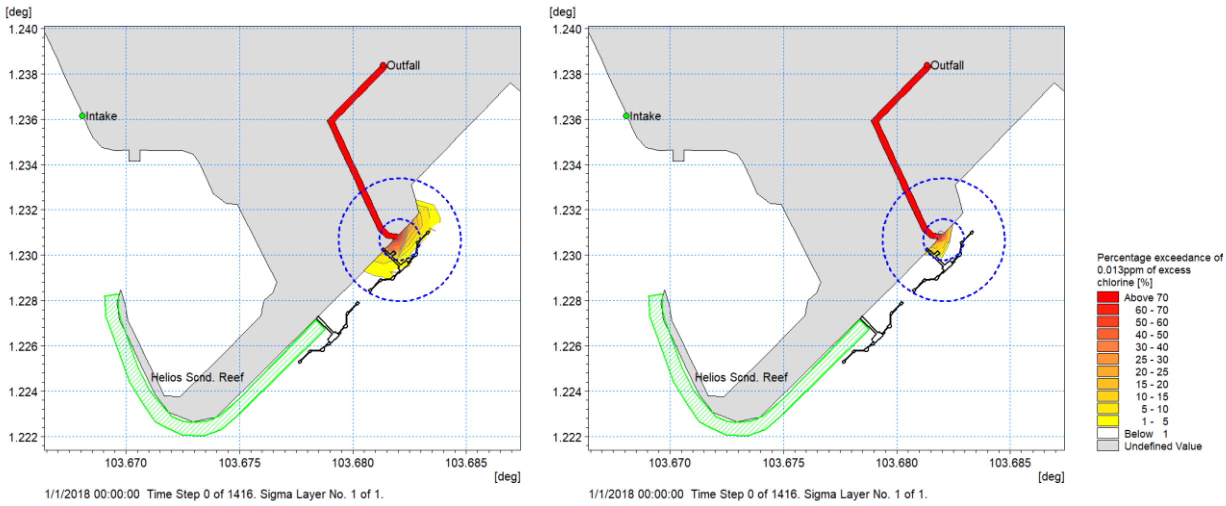


*Figure 6-33 Exceedance of 0.013 ppm maximum excess chlorine between **operational phase - future baseline** at surface (left) and bottom (right) layer during NE monsoon; plotted with 100-m and 300-m boundaries*

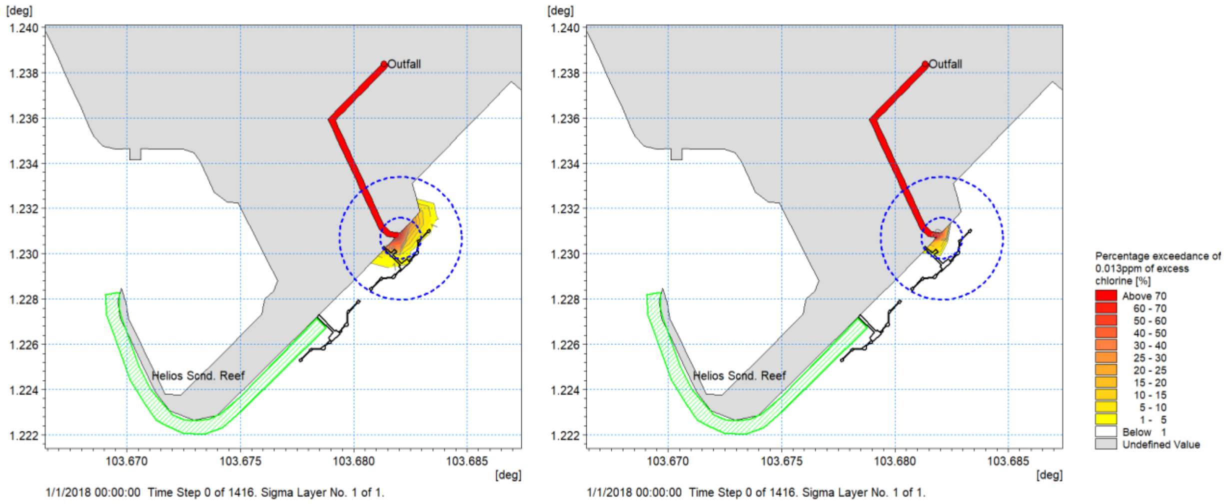


Figure 6-34 Exceedance of 0.013 ppm maximum excess chlorine between ***operational phase - future baseline*** *at surface (left) and bottom (right) layer during SW monsoon*; *plotted with 100-m and 300-m boundaries*

Since the regulatory boundary for USEPA criterion is not clearly defined, a similar assessment of chlorine concentration at the surface layer for NE and SW monsoons was conducted; following the same approach used for excess temperature analysis to further assess the extent and significance of these exceedances. The selected observation points, representing conditions within the 100-m and 300-m radius boundaries, are plotted in Figure 6-22. These locations were chosen to evaluate chlorine dispersion relative to regulatory compliance zones and to understand the spatial distribution of chlorine concentrations around the outfall.

Figure 6-35 and Figure 6-37 present the time series of chlorine concentrations within the 100-m boundary for observation points P4 to P6. At Point P4, which is located perpendicular to the shoreline and seaward from the outfall during NE and SW monsoon, respectively. The 1-hour chlorine concentration consistently remained below the USEPA acute criterion (CMC) of 0.013 ppm throughout the simulation period, indicating compliance with short-term exposure standards. Furthermore, the 4-day average concentration also remained within the USEPA chronic criterion (CCC) of 0.0075 ppm, indicating adherence to long-term exposure limits.

This outcome aligns with expectations, as coastal currents near the CCGT area tend to oscillate between the northeast and southwest directions. Consequently, chlorine dispersion is largely confined along the coastline rather than spreading into the open sea. This pattern is further supported by the time series data from Points P5 and P6, located west and east of the outfall respectively, both of which show exceedances of the CMC (for the 1-hour average) and the CCC for the (4-day average) concentrations.

Figure 6-33 and Figure 6-34 illustrate that chlorine dispersion remains largely confined within the 300-meter boundary. This is further supported by the time series results in Figure 6-36 and Figure 6-38 for Points P7 and P8 during NE and SW monsoon, respectively. Both of which demonstrate compliance with the USEPA CMC limit for 1-hour average concentrations and the CCC limit for 4-day average concentrations.

These results indicate that the impact of CCGT operations is highly localised, with any exceedances of acute or chronic thresholds restricted to the immediate vicinity of the outfall and well within the expected 300-m radius. Beyond this boundary, both criteria are consistently met, suggesting no significant risk to marine life or water quality. Notably, the nearest sensitive receptor, the Helios Secondary Reef, remains unaffected, as the chlorine plume dissipates well before reaching its location.

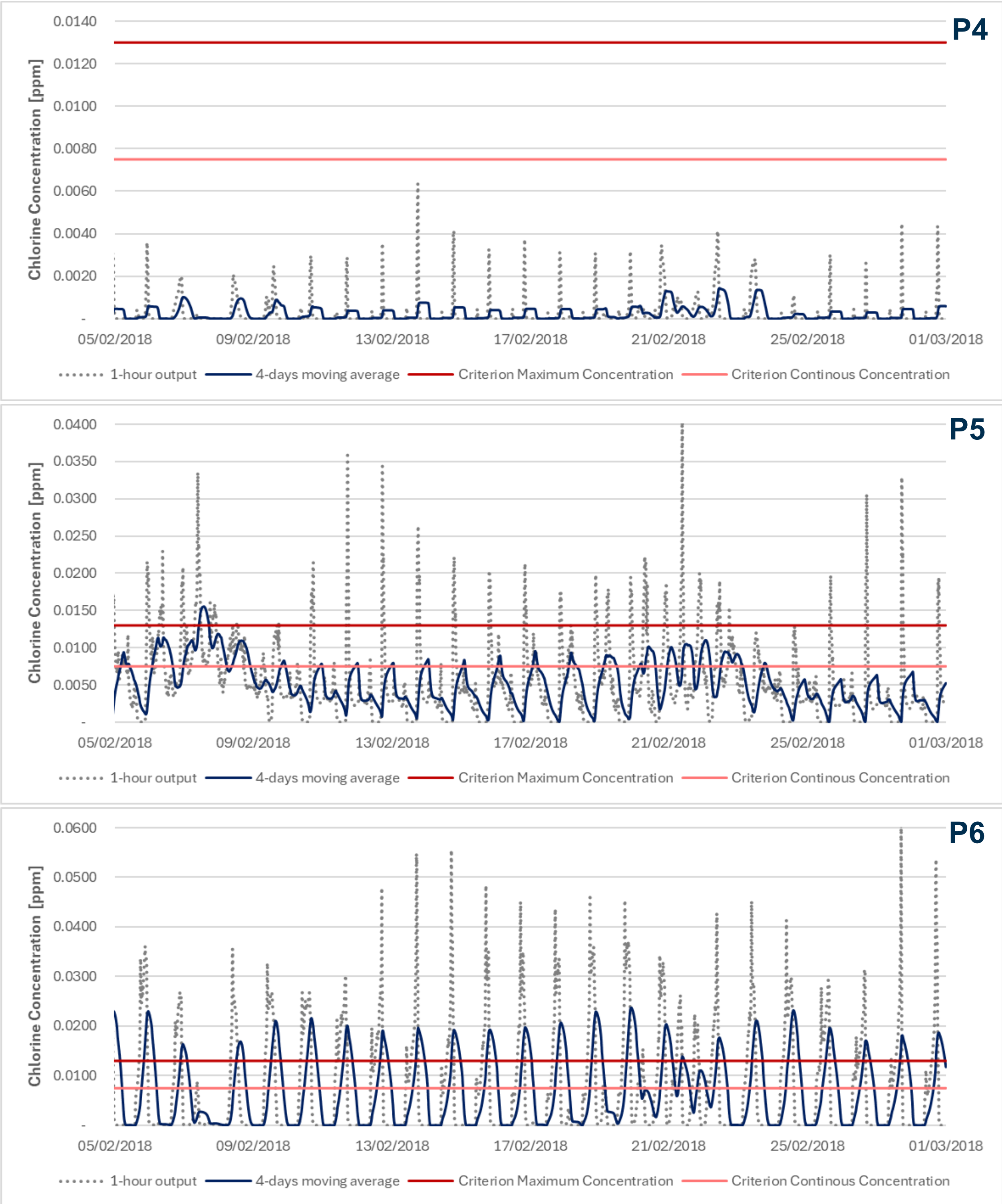


*Figure 6-35 Chlorine concentration at the surface layer during NE monsoon **within the 100-m radius** against the CMC (0.013 ppm) and CCC (0.0075 ppm) criteria*

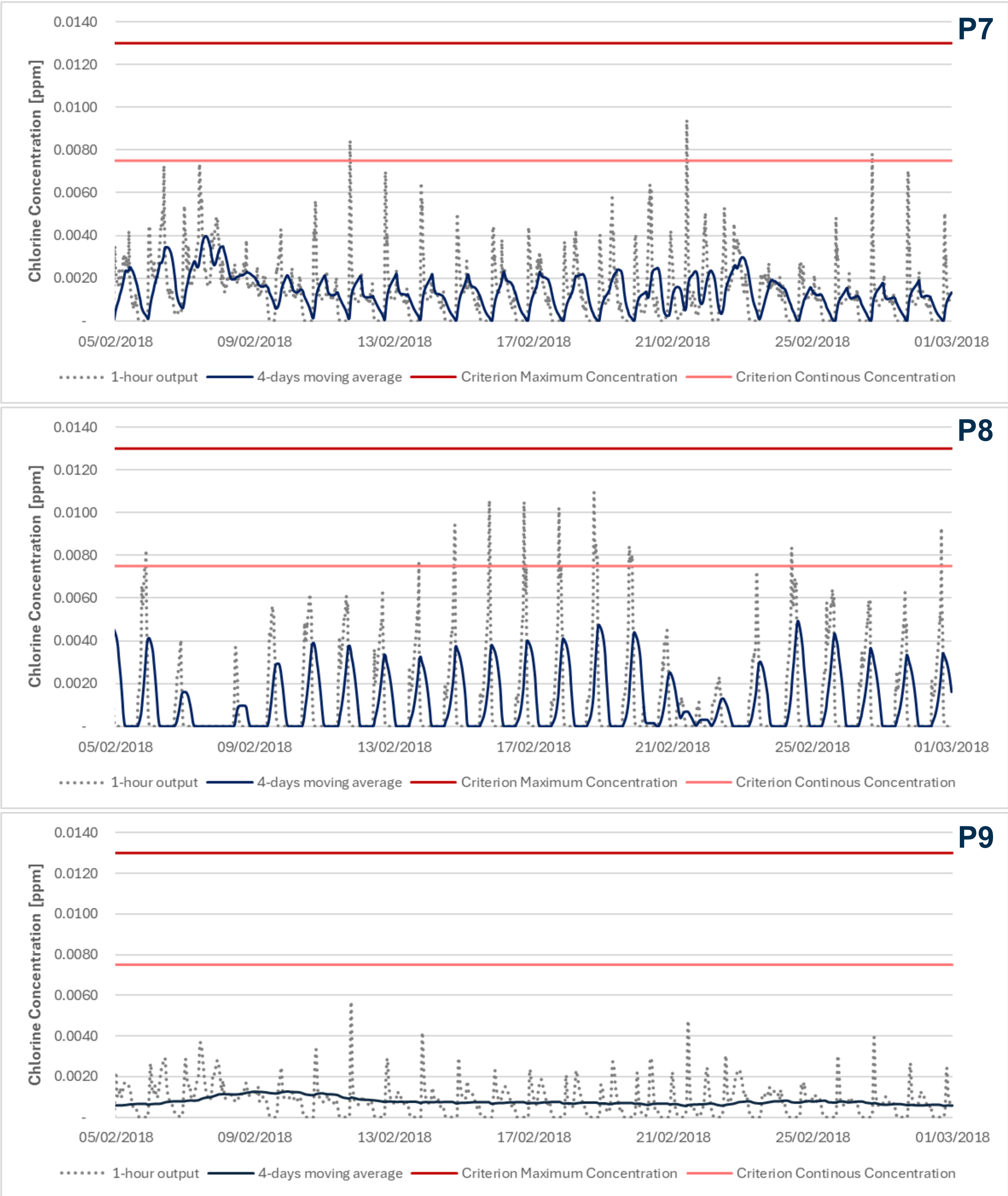


Figure 6-36 Chlorine concentration at the surface layer during NE monsoon ***within the 300-m radius (P7, P8)*** *and* ***at Helios Reef (P9)*** *against the CMC (0.013 ppm) and CCC (0.0075 ppm) criteria*

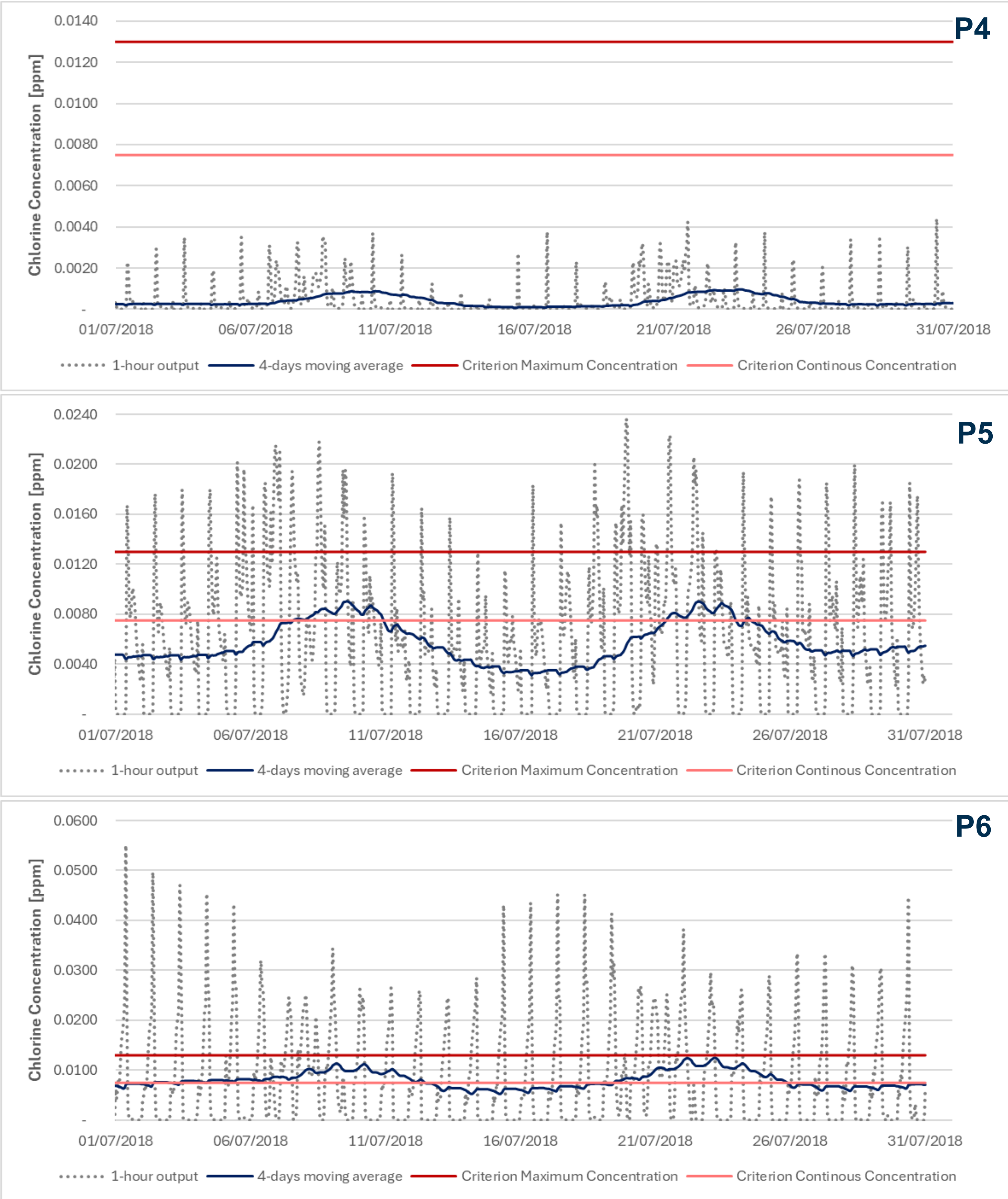


*Figure 6-37 Chlorine concentration at the surface layer during SW monsoon **within the 100-m radius** against the CMC (0.013 ppm) and CCC (0.0075 ppm) criteria*

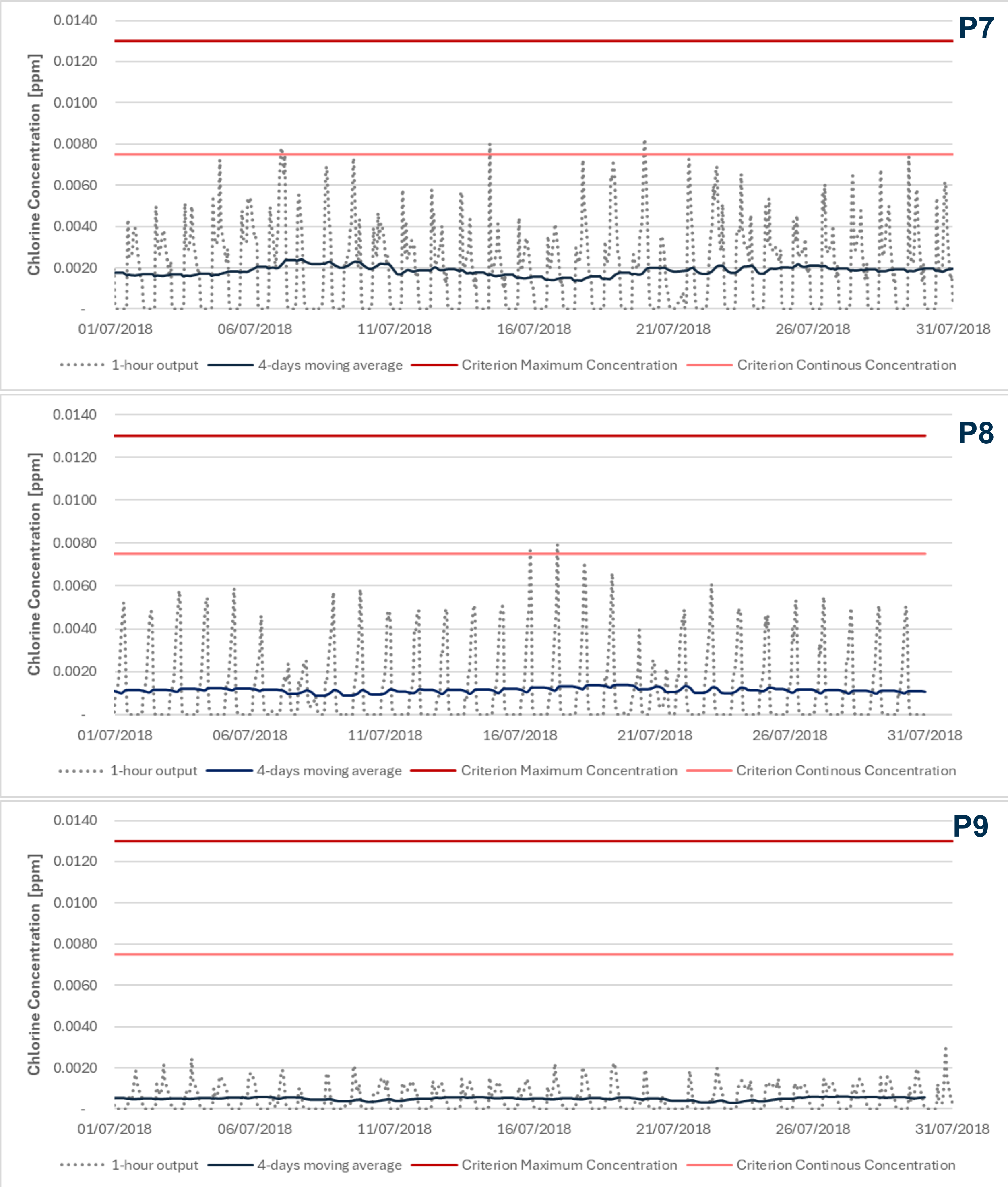


*Figure 6-38 Chlorine concentration at the surface layer during SW monsoon **within the 300-m radius (P7, P8)** and **at Helios Reef (P9)** against the CMC (0.013 ppm) and CCC (0.0075 ppm) criteria*

6.2.4 Summary of impacts from CCGT

From the discussions above, it is known that there will be changes due to CCGT operation in hydrodynamic, temperature, and chlorine plume results show exceedance above the referred guidelines, which are:

- The outfall discharge induces notable hydrodynamic changes in the surrounding area. An increase in maximum current speeds, reaching up to 0.20 m/s, has been observed near the discharge mouth and along the CCGT coastline during both monsoon seasons. Conversely, a reduction in maximum current speed of approximately 0.20 m/s is evident near the intake location in the western part of Jurong.
- There is 25% reduction in slack water areas near the outfall mouth and eastward, consistent with increased current speeds in that region. In contrast, slack water increases by about 5% near the Helios Secondary Reef, where current speeds decrease.
- Exceedance of +2.0°C AMWQC threshold is confined within approximately 300-m of the outfall location for both monsoons.
- Exceedance of the USEPA thresholds, 0.013 ppm for CMC and 0.0075 ppm for CCC, are confined within a 300-m radius from the seaside point source and are localised along the coastline. Within this boundary, the frequency of CMC exceedance drops significantly, from over 70% near the outfall to 0% at the edge of the 300-m limit. This demonstrates effective dilution and dispersion of chlorine, with concentrations stabilising to safe levels beyond the immediate discharge zone.

The key findings on the impacts of the CCGT facility alone are summarised in the table below, focusing on the main parameters assessed in this study.

Table 6-1 Summary of key findings of impacts from CCGT

Component	Parameter	Key Findings of Impact from CCGT
Hydrodynamics	Current field	The variation in current speed due to CCGT operation is about 0.20 m/s, but no significant change in the current patterns. Changes are localised along the CCGT coastline.
	Mean / max current speed	Variations in mean and maximum current speeds of up to 0.20 m/s are observed near the outfall and its surrounding area, exceeding the threshold for insignificant change, set at 0.05 m/s. Nevertheless, the impact remains localised along the CCGT coastline.
	Current speed exceedance	Exceedances of 2.0 knots and 3.5 knots are observed only in offshore areas, well away from the outfall location. The operation of the CCGT facility does not contribute to these exceedances, indicating no impact on current speeds that would breach the specified criteria.
	Slack water duration	The operation of the CCGT outfall results in a 25% reduction in slack water near the discharge point, while a 5% increase is observed near the Helios Secondary Reef due to decreased current speeds. Although the CCGT development influences slack water duration, its impact remains localised along the CCGT coastline.
Temperature	+2°C exceedance for ambient waters	The area exceeding the +2°C AMWQC threshold is confined within approximately 300 m of the outfall location for both monsoons. While CCGT operations are not in compliance with this criterion, the impact remains localised.
Chlorine	+0.013 ppm exceedance for acute, CMC	An exceedance of the USEPA threshold of 0.013 ppm of approximately 70% is visible at the outsource point and gradually reduces to 0% within 100-m boundary. Beyond this zone, the CCGT operation remains in compliance with CMC limit.

Component	Parameter	Key Findings of Impact from CCGT
	+0.0075 ppm exceedance for chronic, CCC	An exceedance of the USEPA CCC threshold of 0.0075 ppm is confined within the 300-m boundary. Beyond this boundary, the CCGT operation remains in compliance with CCC limit.

6.3 Impact of CCGT on sensitive receptors

As the CCGT outfall discharges into high-energy open waters, modelling results indicate that hydrodynamic changes caused solely by the operation of the proposed CCGT facility are localised, with no significant impact on the broader surrounding marine environment. The changes driven by external factors such as sea level rise, increased wind forcing and temperature due to climate change are more extensive than those resulting from CCGT operations alone. As the majority of the sensitive receptors are located well beyond the immediate influence of the proposed CCGT facility, this section focuses specifically on the Helios Secondary Reef, the only environmentally sensitive receptor situated within the vicinity of the CCGT site. The impacts coming from CCGT operations combined with external factors such as climate change and land reclamation, are discussed in a separate assessment note.

6.3.1 Impact of CCGT on Helios Secondary Reef

The Helios Secondary Reef is the closest environmentally sensitive receptor to the proposed CCGT outfall, situated approximately 1.1 km southwest of the discharge point. Due to its proximity, this reef is considered a priority site for assessing potential hydrodynamic and thermal impacts arising from the CCGT operation and also considered important to the regional / national interests. The score is 4 in terms of importance component (I) for all impacts.

Hydrodynamic impact

As assessed in Section 6.2.1, the maximum current speed across the reef decreases by up to 0.20 m/s, indicating calmer conditions compared to the existing state. Changes in mean current speed are within ±0.05 m/s, which is considered negligible. Therefore, the operation of the CCGT facility is not expected to pose any significant risk to the reef ecosystem.

The eastern side of Helios Secondary Reef, which faces the open sea, is naturally exposed to high current velocities, reaching up to 1.1m/s during peak ebb conditions across both monsoon seasons. These strong currents contribute to effective flushing and mixing, which are generally beneficial for coral reef health by preventing stagnation and supporting nutrient exchange.

Reductions in current speed can influence coral reef ecosystems by altering sediment transport, nutrient delivery, and larval dispersal. Given that changes in mean current speed remain within ±0.05 m/s, no significant impact on the coral or associated marine biota is expected in this area. Coral reefs typically thrive in environments with moderate to high current speed (0.1–0.5 m/s), which supports metabolic processes and reduces thermal stress (Manzello, 2023). Given that the eastern side maintains high flow and the overall reef remains well-flushed, the impact is assessed as not significant.

Using RIAM framework (see Section 2.5), the hydrodynamic impact on Helios Secondary Reef for other components is evaluated as follows:

- **Magnitude (M):** 0 – No measurable change in ecological function; variations are minor and within natural variability.
- **Permanence (P):** 2 – Changes are temporary, occurring only during peak tidal phases.
- **Reversibility (R):** 2 – Fully recoverable within each tidal cycle.

- **Cumulative Impact (C):** 3 – Hydrodynamic changes may interact with thermal and chlorine dispersion, though effects remain localised.

Applying the RIAM formula (ES = I × M × (P + R + C)), the resulting Environmental Score (0) indicates "**No Impact**" from a hydrodynamic perspective.

Temperature impact

Temperature changes resulting from CCGT operations comply with the +2.0°C limit above ambient conditions, as regulated by the AMWQC. Due to its proximity to the proposed CCGT outfall, the Helios Secondary Reef is expected to experience surface-layer temperature increases of up to between +1.0°C to +1.5°C during the NE monsoon, but below +1.0°C during the SW monsoon. These values suggest that the monthly average temperature is likely to remain below the critical threshold for coral sustainability. Importantly, temperature changes are largely confined to the surface layer where heated water is discharged. At the bottom layer, temperature increase is less than +0.3°C, resulting in a negligible impact on coral reefs located on the seabed.

Nevertheless, since the coral reef at Helios Secondary Reef is situated on seawall or revetment structures, Figure 6-39 and Figure 6-40 have been included to evaluate potential impacts on coral habitats in shallower depths near the surface. These figures present time-series plots of surface-layer temperature changes at points P9 to P12 (see location in Figure 6-22) during both monsoon seasons.

Coral reefs are highly sensitive to thermal stress, with sustained temperature increases of +1.0°C to +2.0°C above ambient conditions known to trigger bleaching, particularly under prolonged exposure (Manzello, 2023). More stringent thresholds indicate that corals can begin to bleach when ocean temperatures exceed the highest monthly mean by approximately +1.0°C (Glynn & D'Croz, 1990). This limit aligns with the permissible seawater temperature changes based on NParks' coral conservation approach. However, to comply with AMWQC criteria for marine life sustainability, the time-series plots are referenced against the +2.0 °C threshold.

At the eastern end (Point P9), which is closest to the outfall, temperature increases occasionally exceed +1.0 °C during both the NE and SW monsoon periods but remain below +2.0°C. Moving westward from Point P9 to Point P12, temperature changes gradually decrease and consistently stay under the +2.0°C threshold. Across both monsoon simulations, exceedances are intermittent rather than continuous, and temperatures return to normal between these short events (couple of hours). This recovery period suggests that corals would have time to recover, indicating that the results remain within acceptable tolerance and the overall impact on coral health and sustainability is expected to be minimal.

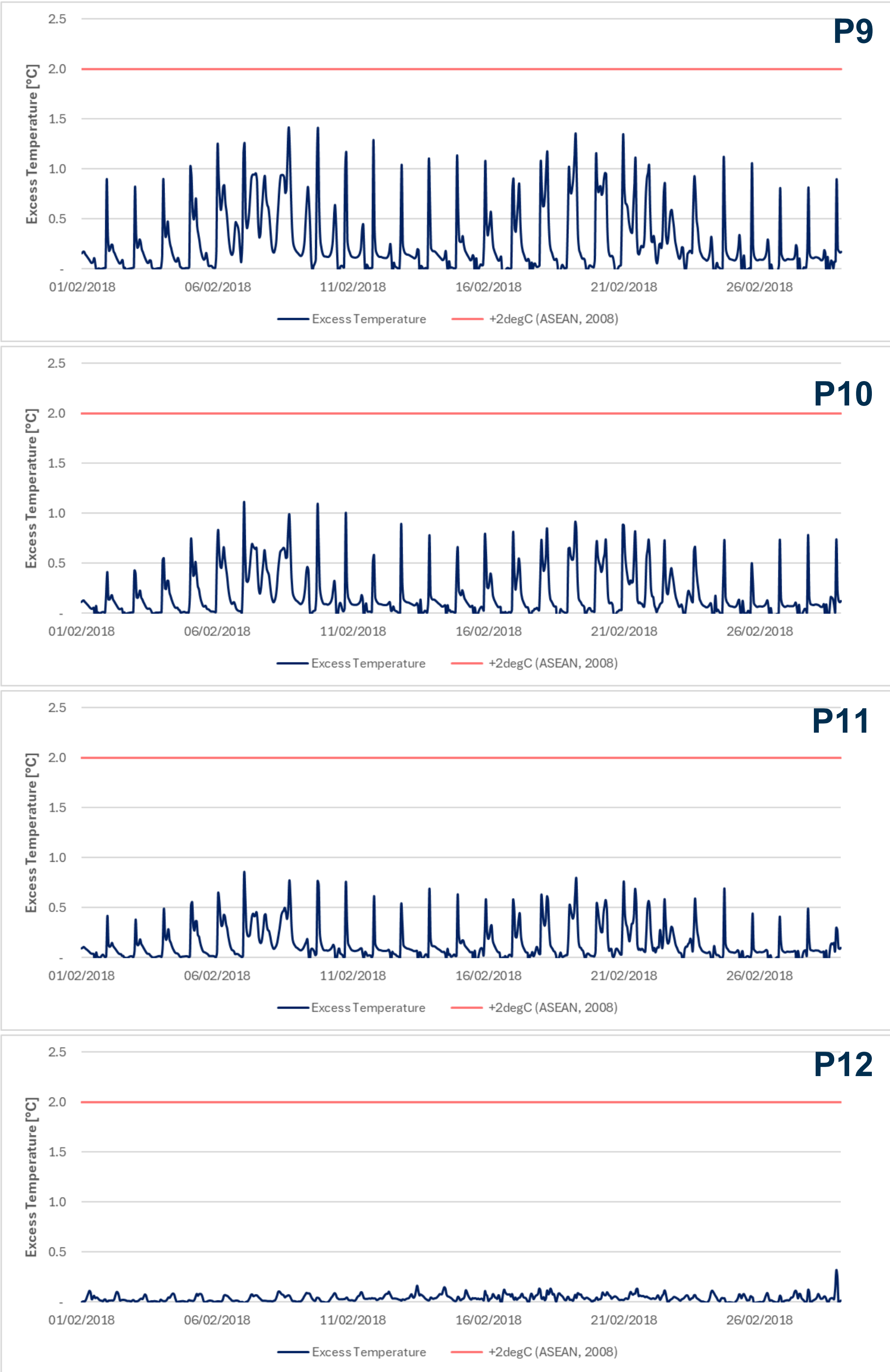


Figure 6-39 Excess temperature at the surface layer during NE monsoon ***at the Helios Reef*** *against the +2°C threshold*

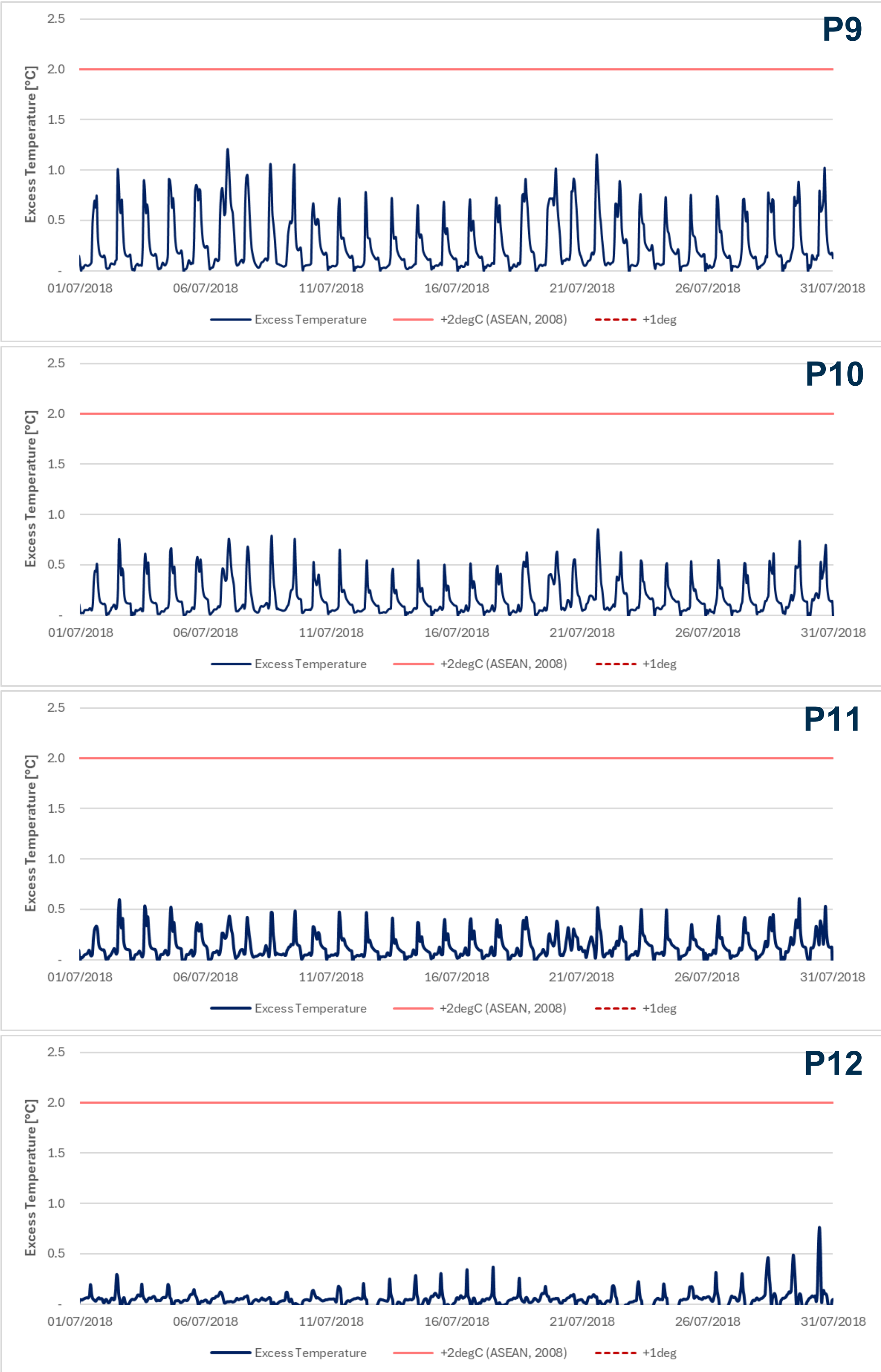


*Figure 6-40 Excess temperature at the surface layer during SW monsoon **at the Helios Reef** against the +2°C threshold*

Using RIAM framework (see Section 2.5), the thermal impact on Helios Secondary Reef for other components is evaluated as follows:

- **Magnitude (M):** -1 – Minor negative change; surface temperatures increasing by up to between +1° C to +1.5°C for NE monsoon, but below +1° C for SW monsoon. Meanwhile, at the bottom layer the increase remains low at less than +0.3°C for both monsoons.
- **Permanence (P):** 2 – Short-term; variations occur during peak tidal and monsoonal conditions. These exceedances occur only for short periods rather than continuously.
- **Reversibility (R):** 2 – Fully recoverable; conditions normalise within tidal cycles.
- **Cumulative Impact (C):** 2 –The warm water can lead to marine cyanobacteria bloom. However, such condition is applicable within slow-moving or stagnant waters, while in this case the outfall is directly exposed to the open sea and fast-moving (high current speeds) water and no cascading effects expected.

Applying the RIAM formula (ES = I × M × (P + R + C)), the resulting Environmental Score (-24) indicates "**Slight Negative Impact**" from a temperature changes perspective.

Chlorine impact

There is no impact on the Helios Secondary Reef, as chlorine concentrations remain below USEPA regulatory thresholds for both CMC and CCC beyond the mixing zone, and the chlorine plume does not reach this environmentally sensitive area.

Using RIAM framework (see Section 2.5), the chlorine impact on Helios Secondary Reef for other components is evaluated as follows:

- **Magnitude (M):** 0 – Residual chlorine is fully decayed before reaching the reef.
- **Permanence (P):** 2 – Short-term; variations occur only during dosing cycles.
- **Reversibility (R):** 2 – Fully recoverable; concentrations return to baseline within hours.
- **Cumulative Impact (C):** 2 – No cascading effects expected due to high-energy environment and rapid decay.

Applying the RIAM formula (ES = I × M × (P + R + C)), the resulting Environmental Score (0) indicates "**No Impact**" from a chlorine perspective.

6.3.2 Impact of CCGT on navigation and terminal operation

From a navigation and terminal operations perspective, the proposed CCGT facility remains compliant with two key hydrodynamic indicators:

- **Current speed exceedance**
  According to the Maritime and Port Authority of Singapore (MPA), the recommended thresholds are 2.0 knots for berthing zones and 3.5 knots (approximately 1.80 m/s) for fairways, as outlined in the Port Designer's Handbook. Modelling results show no exceedance of the 3.5 knots threshold within the study area under either baseline or CCGT-only operational phase.

- **Slack water duration**
  Periods where current speeds fall below 0.25 m/s can lead to reduced mixing, sediment deposition, and potential stagnation, which may affect water quality and berthing efficiency. The modelling results indicate 25% reduction in slack water areas around the mouth of the outfall channel and extending eastward and reduction of 5% near the bend of the Helios Secondary Reef when CCGT is in operation compared to the baseline or existing condition. From a navigational perspective,

increased current speeds near the outfall may affect vessel berthing operations around the jetty area. These stronger currents could also contribute to localised sediment erosion, which should be considered in the design and operational planning of the jetty.

Using RIAM framework (see Section 2.5), the hydrodynamic impact on navigation and terminal operation is evaluated as follows:

- **Importance (I) :** 4 – Navigation and terminal operations are of regional/national significance.
- **Magnitude (M):** -1 – Slight negative impact; localised increase in current speeds near the outfall may affect berthing efficiency but remains within operational tolerance.
- **Permanence (P):** 2 – Temporary; variations occur during tidal cycles and operational phases.
- **Reversibility (R):** 2 – Fully recoverable; conditions normalize within tidal cycles.
- **Cumulative Impact (C):** 2 – No cascading effects expected; impacts are confined to hydrodynamic conditions only.

Applying the RIAM formula (ES = I × M × (P + R + C)), the resulting Environmental Score (-24) indicates "**Slight Negative Impact**" from a hydrodynamic perspective.

7 Conclusions

7.1 Compliance with assessment criteria

Modelling results indicate that the operation of the CCGT facility will alter the hydrodynamic conditions near the seaside outfall and its surrounding area. These changes also influence temperature and chlorine concentrations. However, the effects are spatially limited, with noticeable changes confined within 300-m for temperature and chlorine of the project site. Importantly, no impacts are observed on the nearest sensitive receptor, the Helios Secondary Reef, or on other environmentally sensitive areas, which are located at a considerable distance from the zone of influence.

Overall, the proposed CCGT development is largely compliant with the environmental guidelines referenced in this study (see Table 7-1).

Table 7-1 Summary of CCGT operational compliance

Modelling component	Parameter	Criterion	Source	Result
Hydrodynamics	Change in current field	N/A	N/A	Variations remain localised along the CCGT coastline
	Mean and max current speed	< 0.05 m/s = No Change	N/A	Variations remain localised along the CCGT coastline
	Current speed exceedance limits	⩽ 2.0 knots (berthing) ⩽ 3.5 knots (fairways)	MPA ICE, 2018	In compliance
	Change in slack water time	N/A	N/A	Variations remain localised along the CCGT coastline
Temperature	Temperature at discharge point	< 45°C at the point of discharge	Environmental Protection and Management (Trade Effluent) Regulations 2008	In compliance
	Temperature in receiving water	ΔT < 2°C above ambient	ASEAN Marine Water Quality Criteria (AMWQC)	In compliance (beyond the 300-m zone from the outfall)
Chlorine	Concentration at discharge point	< 1 mg/L (1ppm) at point of entry to water	Environmental Protection and Management (Trade Effluent) Regulations 2008	In compliance
	Concentration in receiving water	< 0.013 ppm (1-hr average, acute)	USEPA R.E.D. FACTS Chlorine Gas, 1999 (USEPA, Technical Support Document for WQ-based toxics control, 1991)	In compliance (beyond the 300-m zone from the outfall)
	Concentration in receiving water	< 0.0075 ppm (4-day average, chronic)	USEPA R.E.D. FACTS Chlorine Gas, 1999	In compliance (beyond the 300-m zone from the outfall)

Modelling component	Parameter	Criterion	Source	Result
			(USEPA, Technical Support Document for WQ-based toxics control, 1991)	

7.2 Impact assessment

Using RIAM evaluation framework specified in Section 2.5, the environmental impact due to CCGT development based on the hydrodynamic, thermal plume, and chlorine plume modelling are assessed and summarised in Table, along with the mitigation measures and their corresponding mitigated impacts.

Table 7-2 Summary of predicted impacts due to CCGT operation

Impacts	Predicted impacts							Mitigation measures	Mitigated impact
	Potential impact	ES	I	M	P	R	C		
Change in current conditions	No impact.	0	4	0	2	2	3	No mitigation measures required.	Still no impact.
Thermal release from the outfall to the seawater	Slight negative impact.	-24	4	-1	2	2	2	Cooling tower to reduce the discharge temperature even further.	Change to no impact.
Chlorine release from the outfall to the seawater	No impact.	0	4	0	2	2	2	No mitigation measures required.	Still no impact.
Impact on navigation and terminal operation	Slight negative impact.	-24	4	-1	2	2	2	Operational timeline management based on the tidal cycle.	Change to no impact.

7.3 Considerations of external influences

As this study is intended to isolate and evaluate the impacts specifically associated with the implementation of the CCGT plant, the analysis and conclusions presented in this report are limited to those direct effects. Nonetheless, it is important to recognise that broader external influences, i.e., climate change and sea level rise, are likely to have a more pronounced impact on Singapore's marine environment than the operational contributions of the CCGT alone.

For example, a projected increase in average atmospheric temperature of approximately +1.6ºC under future climate scenarios may alter regional water characteristics. Furthermore, higher wind speeds and modifications to the coastal geometry resulting from ongoing land reclamation activities could significantly affect local hydrodynamics, which in turn may influence the dispersion and distribution of temperature and chlorine from the discharge outfall into surrounding waters. The potential impacts of these future climate-related changes are addressed in a separate assessment to complement this study.

These external factors are beyond the influence of the end Client yet highlight the potential joint probability of impacts arising from both the CCGT and external influences.

8 References

ABPmer. (2013). *Numerical Model Calibration and Validation Guidance.* Southampton: ABP Marine Environmental Research Ltd.

ASEAN. (2008). *ASEAN Marine Water Quality: Management Guidelines and Monitoring Manual.* Retrieved from Retrieved from https://www.h2i.sg/wp-content/uploads/ASEAN-MarineWaterQualityManagementGuidelinesandMonitoringManual.pdf

Bennett, S., Vaquer-Sunyer, R., Jordá, G., Forteza, M., Roca, G., & Marba, N. (2022). Seagrass thermal limits and vulnerability to future warming. *Frontiers in Marine Science, 9*.

Borain, H. (2022). Consequences of Waves and Currents on Floating Fish Farms. *Journal of Coastal Zone Management, 25(6)*.

Christianen, M., Herman, P., Bouma, T., Lamers, L., Katwijk, M., Heide, T., . . . van de Koppel, J. (2013). Habitat collapse due to overgrazing threatens turtle conservation in marine protected areas. *Global Ecology and Conservation,1*, 1-15.

Eppley, R., Renger, E., & Williams, P. (1976). Chlorine reactions with seawater constituents and the inhibition of photosynthesis of natural marine phytoplankton. *Estuarine and Coastal Marine Science, Volume 4, Issue 2*, 147-161.

Evans, G. (1993). *A framework for marine and estuary model specification in the UK.* Foundation for Water Research.

Faltinsen, O. M., & Shen, Y. (2018). Wave and Current Effects on Floating Fish Farms. *Journal of Marine Science and Application, 17*, 284–296.

Glynn, P., & D'Croz, L. (1990). Experimental evidence for high temperature stress as the cause of El Niño coincident coral mortality. *Coral Reefs*, 181-191.

Hench, J. L., & Rosman, J. H. (2013). Observations of spatial flow patterns at the coral colony scale on a shallow reef flat. *Journal of Geophysical Research: Oceans, 118*, 1142–1156.

Hoegh-Guldberg, O., Anthony, K. R., & Connolly, S. R. (2007). Bleaching, energetics, and coral mortality risk: Effects of temperature, light, and sediment regime. *Limnology and Oceanography, 52(2)*, 716–726.

IFC, I. F. (1998). *Thermal Power: Guidelines for New Plants (Pollution Prevention and Abatement Handbook).* Washington, DC: World Bank Group. Retrieved from Retrieved from https://www.ifc.org/content/dam/ifc/doc/1990/thermnew-ppah.pdf

Manzello, D. (2023, July 26). *Rising Ocean Temps Raise New Concerns for Coral Reefs*. Retrieved September 17, 2025, from https://www.nesdis.noaa.gov/news/rising-ocean-temps-raise-new-concerns-coral-reefs

McKenzie, L. J., Yaakub, S. M., Tan, R. S., & Yoshida, R. L. (2016). Seagrass habitats in Singapore: Environmental drivers and key processes. *Raffles Bulletin of Zoology, Supplement No. 34*, 60–77.

Moriasi, D., Gitau, M., Pai, N., & Daggupati, P. (2015). Hydrologic and Water Quality Models: Performance Measures and Evaluation Criteria. *ASABE (American Society of Agricultural and Biological Engineers) 58*, 1763-1785.

MSS, M. S.-C. (2023). *V3 Climate Projections: Third National Climate Change Study (V3). National Environment Agency.* Retrieved from Retrieved from https://www.mss-int.sg/docs/default-source/v3_reports/v3-science-report-full.pdf

NOAA. (2025, September 03). *How does land-based pollution threaten coral reefs?* Retrieved from https://oceanservice.noaa.gov/facts/coral-pollution.html

Powell, J., Hallam, N., West, J., Forster, C., & Simms, J. (2000). Factors which control bulk chlorine decay rates. *Water Research, 34*(1), 117–126. doi:https://doi.org/10.1016/S0043-1354(99)00097-4

Rogers, J. S., Monismith, S. G., Koweek, D. A., Torres, W. I., & Dunbar, R. B. (2016). Thermodynamics and hydrodynamics in an atoll reef system and their influence on coral cover. *Limnology and Oceanography*.

Sáez-Arteaga, A., Viegas, I., Palma, M., Dantagnan, P., Valdebenito, I., Villalobos, E. F., . . . Heyser, C. (2024). Impact of increasing temperatures on neuroendocrine and molecular responses of skeletal muscle and liver in fish: A comprehensive review. *Aquaculture Reports, 39*.

Saidan, M., Rawajfeh, K., Nasrallah, S., Meric, S., & Mashal, A. (2017). Evaluation of factors affecting bulk chlorine decay kinetics for the Zai water supply system in Jordan: Case study. *Environment Protection Engineering, 43*(4). doi:https://doi.org/10.37190/epe170417

Singapore Meteorological Service. (2024). *Climate of Singapore*. Retrieved from https://www.weather.gov.sg/climate-climate-of-singapore/

The Straits Times. (2024, November 01). *Two lots for new seafood farms in waters off Pulau Bukom open for tender*. Retrieved from https://www.straitstimes.com/singapore/2-lots-for-new-seafood-farms-in-waters-off-pulau-bukom-open-for-tender

Thoresen, C. A. (2018). *Port designer's handbook: Recommendations and guidelines* (4th Ed. ed.). ICE Publishing.

USEPA-a, U. S. (1991). *Technical support document for water quality–based toxics control.* Washington, DC. Retrieved from Retrieved from https://www.epa.gov/system/files/documents/2024-07/technical-support-document-for-water-quality-based-toxics-control.pdf

USEPA-b, U. S. (1999). *Reregistration Eligibility Decision (RED) for Chlorine Gas.* Washington, D.C.

Wang, J.-T., Chen, M.-H., Lee, H.-J., Chang, W.-B., Chen, C.-C., Pai, S.-C., & Meng, P.-J. (2008). A Model to Predict Total Chlorine Residue in the Cooling Seawater of a Power Plant Using Iodine Colorimetric Method. *International Journal of Molecular Sciences*, 542-553.

Waycott, M., Duarte, C., Carruthers, T., Orth, R., Dennison, W., Olyarnik, S., . . . Williams, S. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *PNAS, 106(30)*, 12377–12381.

Yi, J., Lee, J., Fikri, M. A., Sang, B.-I., & Kim, H. (2020). Application of Computational Fluid Dynamics in Chlorine-Dynamics Modeling of In-Situ Chlorination Systems for Cooling Systems. *Appl. Sci., 10*(13), 4455. doi:https://doi.org/10.3390/app10134455

A1 Sensitivity analysis for the exclusion of other industrial outfalls and intakes

As mentioned in Section 4.2.1 of the Main Report, excluding existing intakes and outfalls as sources in the model may be a concern if it significantly changes the current pattern of the hydrodynamic baseline conditions, because this inherently affects the temperature dispersion. Hence, a sensitivity analysis was carried out prior to the actual scenario analysis to ensure that the exclusion of these sources has a negligible impact on hydrodynamic conditions in the vicinity of the CCGT intake and outfall, and do not affect the overall analysis of the impact assessment.

Some key points of the methodology for this sensitivity analysis are outlined below:

- The sensitivity analysis follows the same criteria used in the calibration against baseline conditions for water levels (WL) and current speeds (CS) during both NE and SW monsoon (see Section 5.1 in the Main Report).
- February and July are selected as representative months for the NE and SW monsoons, respectively, to align with Section 4.1.2 in the Main Report.
- The same model setups are used for the baseline conditions to allow for a direct comparison, but different scenarios are specified *with* sources (v1.1) and *without* sources (v1.2). Scenario v1.1 is used for reference conditions.
- Comparisons are also visualised as timeseries graphs and 2D difference maps to identify temporal and spatial differences, particularly in the vicinity of proposed CCGT intake and outfall.
- A sensitivity analysis for cumulative temperature is only performed to assess the variation in temperature differences, however since temperature differences are expected to occur, this analysis is purely informational and will not affect the decision to proceed with Scenario v1.2.

A1.1 Hydrodynamic model sensitivity analysis

The results of the sensitivity analysis for hydrodynamic conditions based on the criteria are summarised in Table A and Table A for the NE Monsoon and SW Monsoon, respectively. Furthermore, timeseries comparisons are provided in Figure A-1 and Figure A-2 for water levels and current speeds, respectively. 2D maps for the current speed difference at peak ebb, peak flood, and mean current speeds are presented in Figure A-3, Figure A-4, and Figure A-5, respectively.

Model results comparing scenarios *with* and *without* existing intakes/outfalls show negligible differences in both water levels and current speeds, with:

- Bias and RMSE values near-zero.
- Correlation coefficients approaching 1.0, indicating excellent agreement.

The sensitivity analysis confirms that excluding existing intakes and outfalls does not significantly alter the hydrodynamic baseline, supporting the validity of current model assumptions.

Table A-1 Summary of the sensitivity analysis for hydrodynamic conditions for the NE monsoon

Items	Criteria	Sensitivity target	Near Intake	Near Outfall
Water levels	Bias (Mean error)	±0.20m	-0.001 m	-0.001 m
	Root Mean Square Error (RMSE)	<0.20m	+0.001 m	+0.002 m
	Correlation coefficient (R)	> 0.80 (very good fit)	1.00 (very good fit)	1.00 (very good fit)
Currents	Bias (Mean error)	±0.20m/s or ±10–20%	-0.009 m/s	+0.000 m/s
	Root Mean Square Error (RMSE)	< 0.20m/s	+0.011 m/s	+0.002 m/s

Items	Criteria	Sensitivity target	Near Intake	Near Outfall
	Correlation coefficient (R)	>0.80 (very good fit)	0.98 (very good fit)	1.00 (very good fit)

Table A-2 Summary of the sensitivity analysis for hydrodynamic conditions for the SW monsoon

Items	Criteria	Sensitivity target	Near Intake	Near Outfall
Water levels	Bias (Mean error)	±0.20m	-0.011 m	+0.007 m
	Root Mean Square Error (RMSE)	<0.20m	+0.041 m	+0.040 m
	Correlation coefficient (R)	> 0.80 (very good fit)	0.99 (very good fit)	0.99 (very good fit)
Currents	Bias (Mean error)	±0.20m/s or ±10–20%	-0.008 m/s	+0.000 m/s
	Root Mean Square Error (RMSE)	< 0.20m/s	0.010 m/s	+0.002 m/s
	Correlation coefficient (R)	>0.80 (very good fit)	0.98 (very good fit)	1.00 (very good fit)

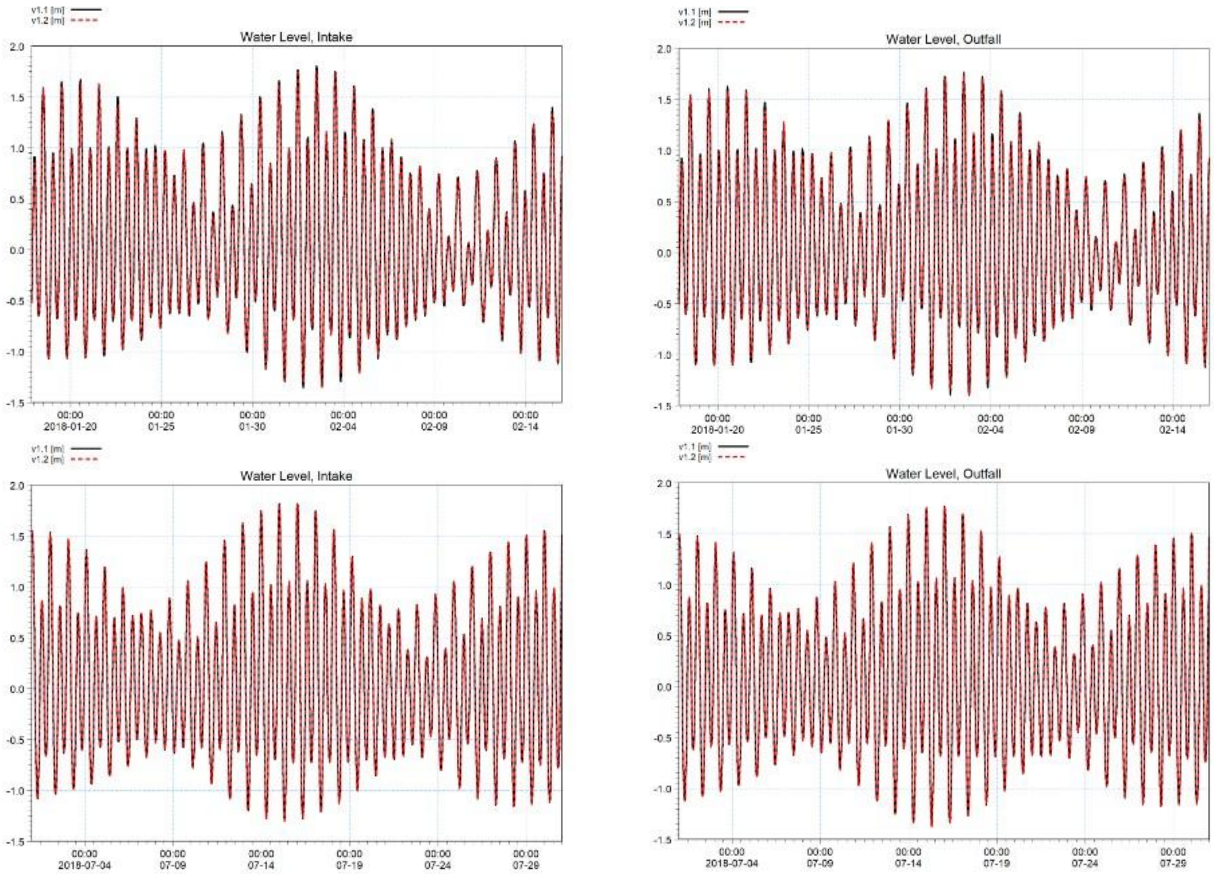


Figure A-1 Timeseries comparisons of water levels for the NE monsoon (top) and SW monsoon (bottom). v1 refers to the results with an outfall source and v2 refers to the results without an outfall source.

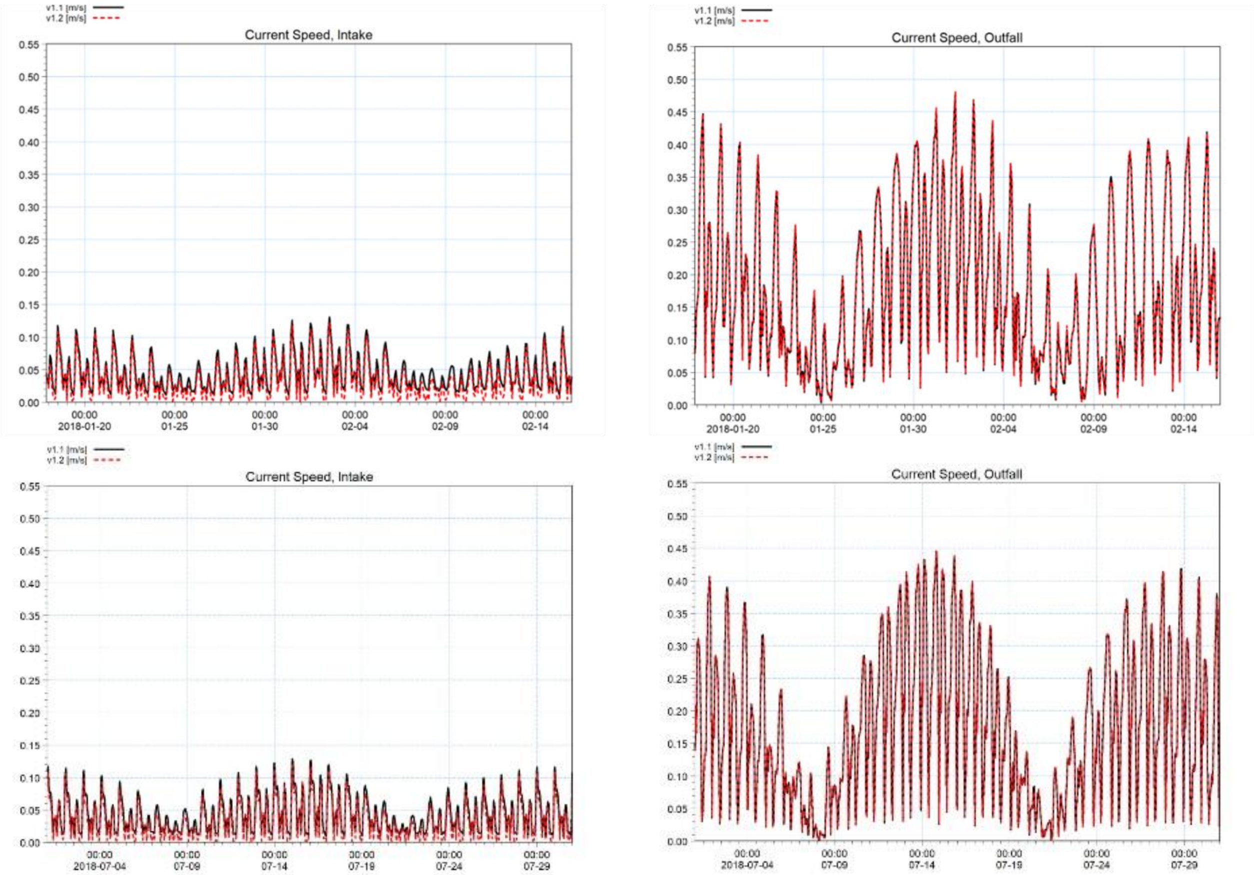


Figure A-2 Timeseries comparisons of current speeds for the NE monsoon (top) and SW monsoon (bottom). v1 refers to the results with an outfall source and v2 refers to the results without an outfall source.

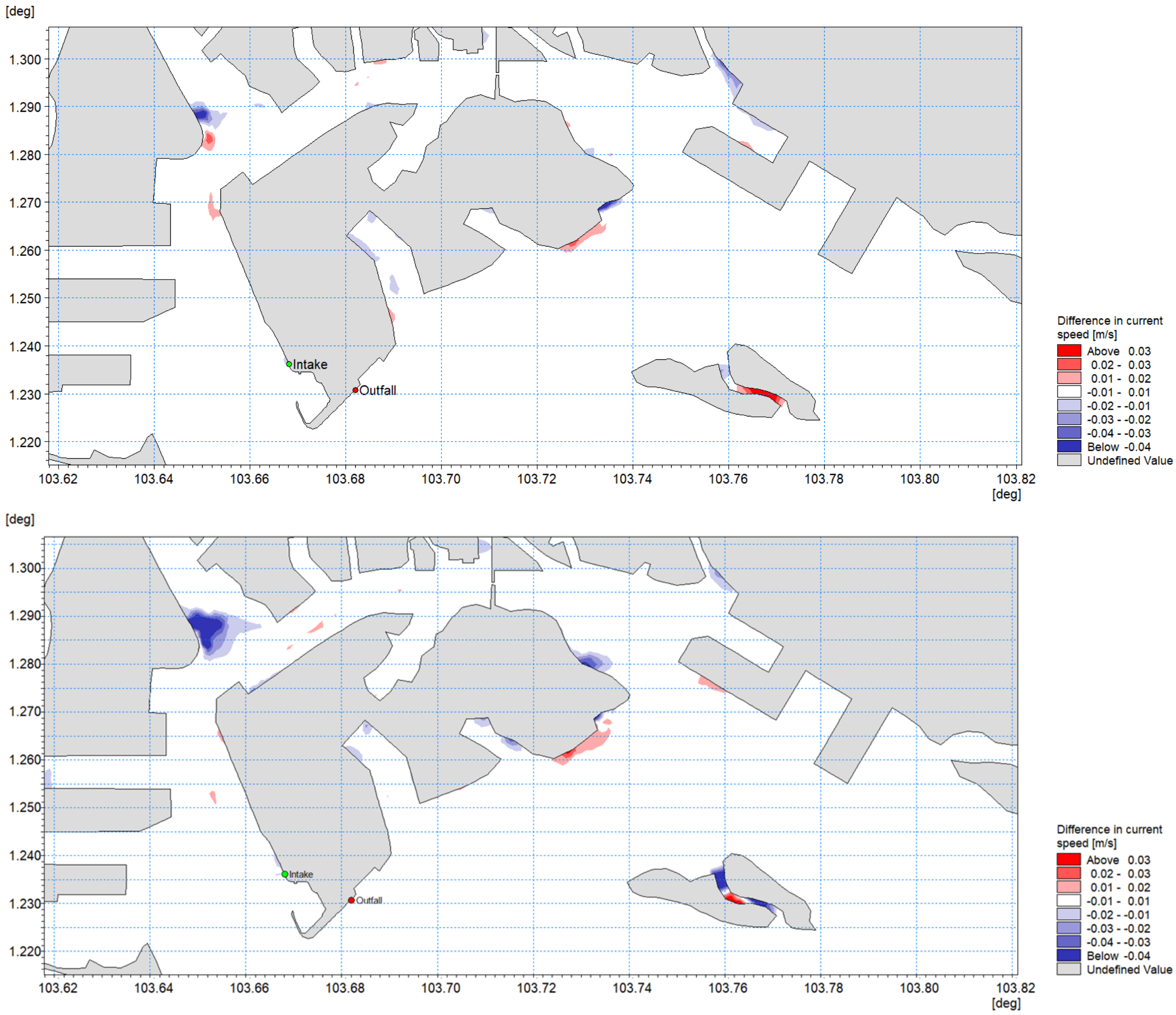


Figure A-3 2D maps of current speed difference at peak ebb conditions for NE monsoon (top) and SW monsoon (bottom).

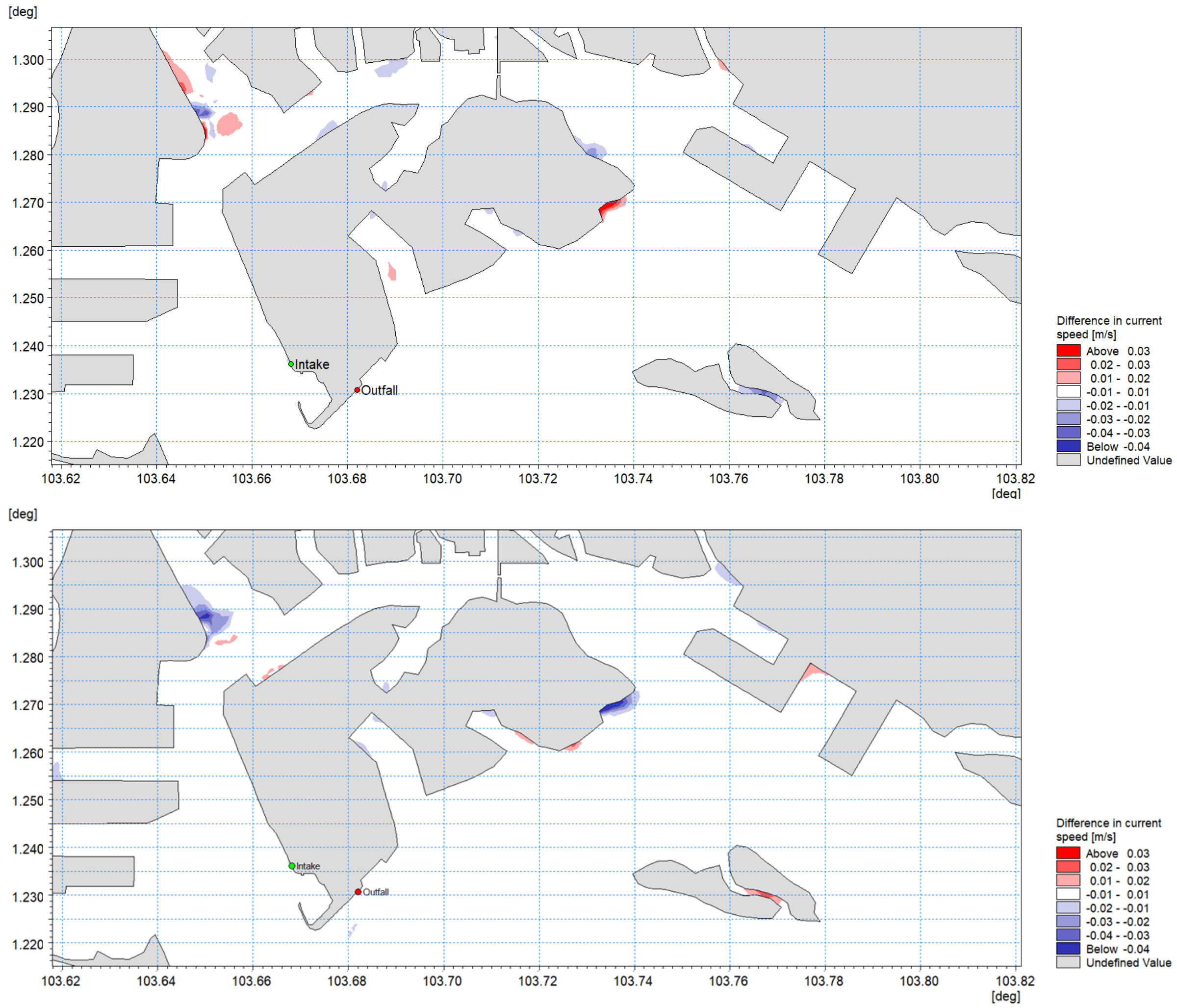


Figure A-4 2D map of current speed difference at peak flood conditions for the NE monsoon (top) and SW monsoon (bottom).

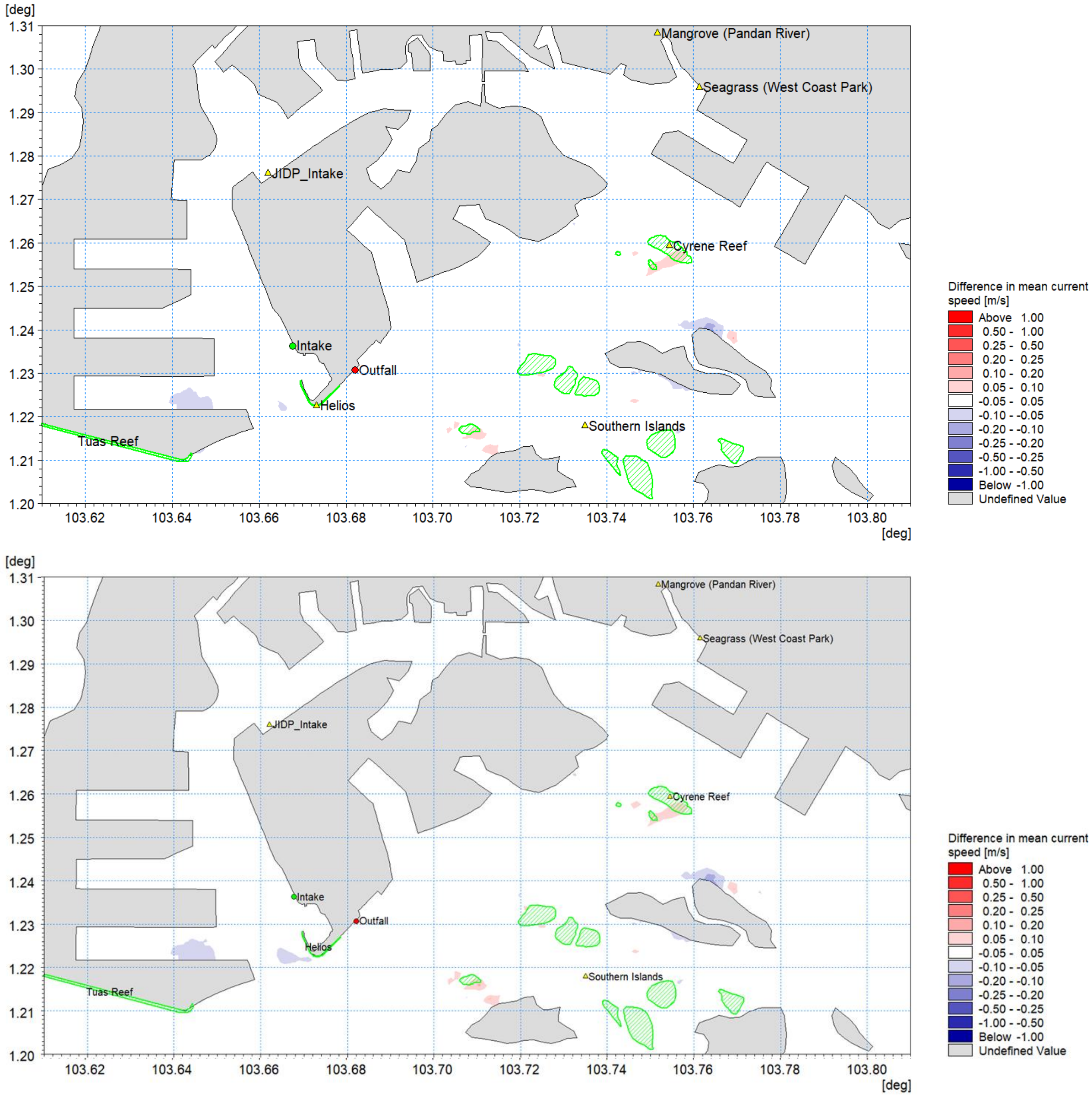


Figure A-5 2D map of mean current speed difference for the NE monsoon (top) and SW monsoon (bottom).

A1.2 Temperature model sensitivity analysis

The results of the sensitivity analysis for thermal conditions are presented as 2D maps of the mean and maximum temperature difference for both monsoons (Figure A-6 and Figure A-7). In addition, timeseries comparisons for different layers of depth in the vicinity of the intake and outfall locations are presented in Figure A-8.

Key findings for temperature differences at different layers comprise:

- <1°C at the surface at both the intake and outfall.
- ± 0.5°C at mid-depth at both the intake and outfall.

Haskoning
Enhancing Society Together

- ± 0.5°C at the bottom layer near the outfall, since most of the outfall sources are defined at the bottom layer. In contrast, temperature changes near the intake are minimal due to the limited presence of outfall sources in the vicinity of the intake.

Generally, a reduction between -0.1 to -0.5ºC in water temperature was observed when external outfalls were excluded. This slight difference in water temperature is deemed not critical for this study, since the objective of the study is to evaluate temperature dispersion from the proposed outfall only, not the cumulative thermal impact. The focus of the study is on the relative changes between pre- and post-development conditions near the proposed intake and outfall. Based on the above, the analysis provides robust justification that the project can proceed without requiring detailed information on all existing intake and outfall systems.

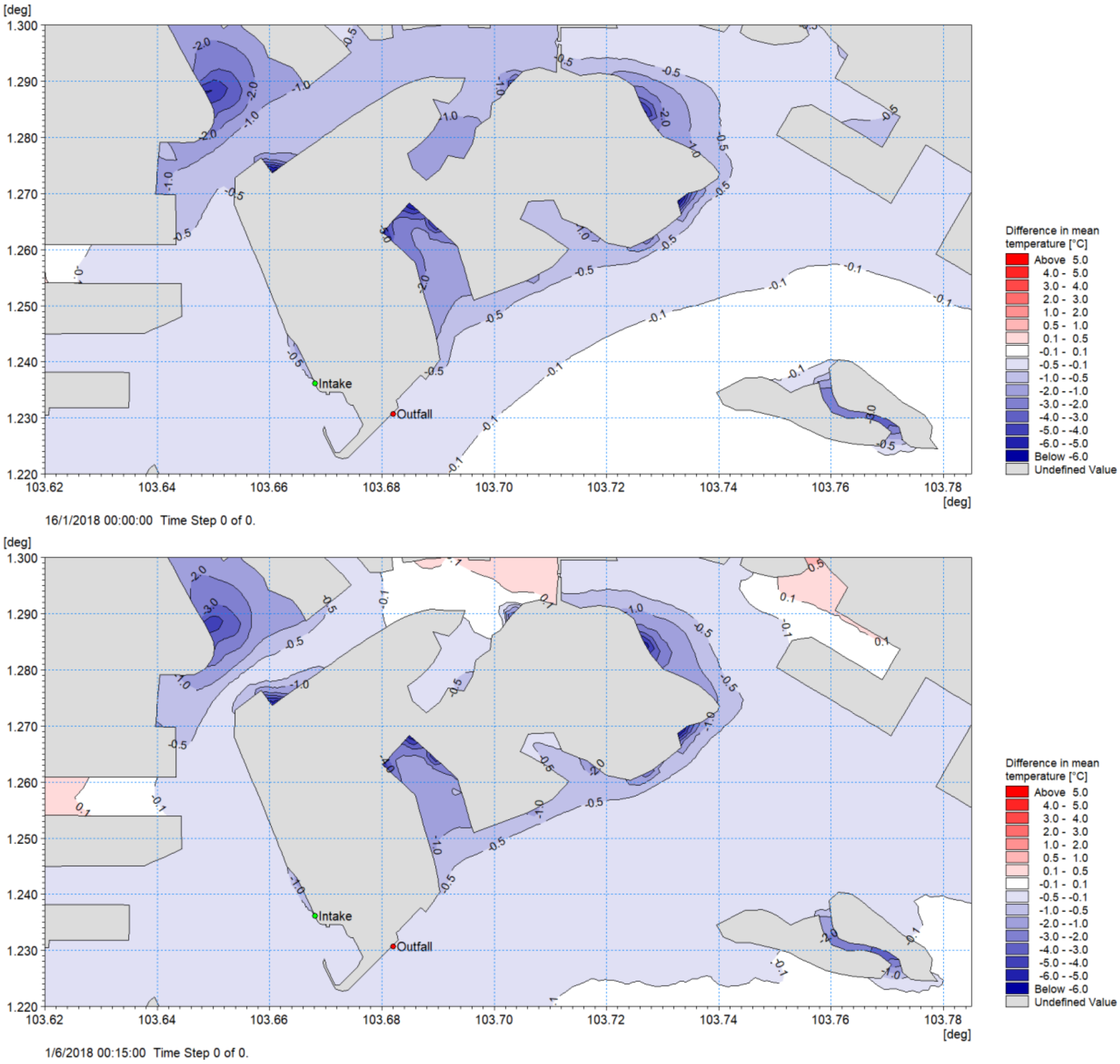


Figure A-6 2D map of statistical mean temperature difference for NE monsoon (top) and SW monsoon (bottom)[3].

[3] *Reduced statistical mean temperatures of around -0.1 to -0.5ºC are observed near the CCGT outfall when the existing outfalls withing Jurong Island are excluded. Higher mean temperature differences are generally localised near the existing outfalls.*

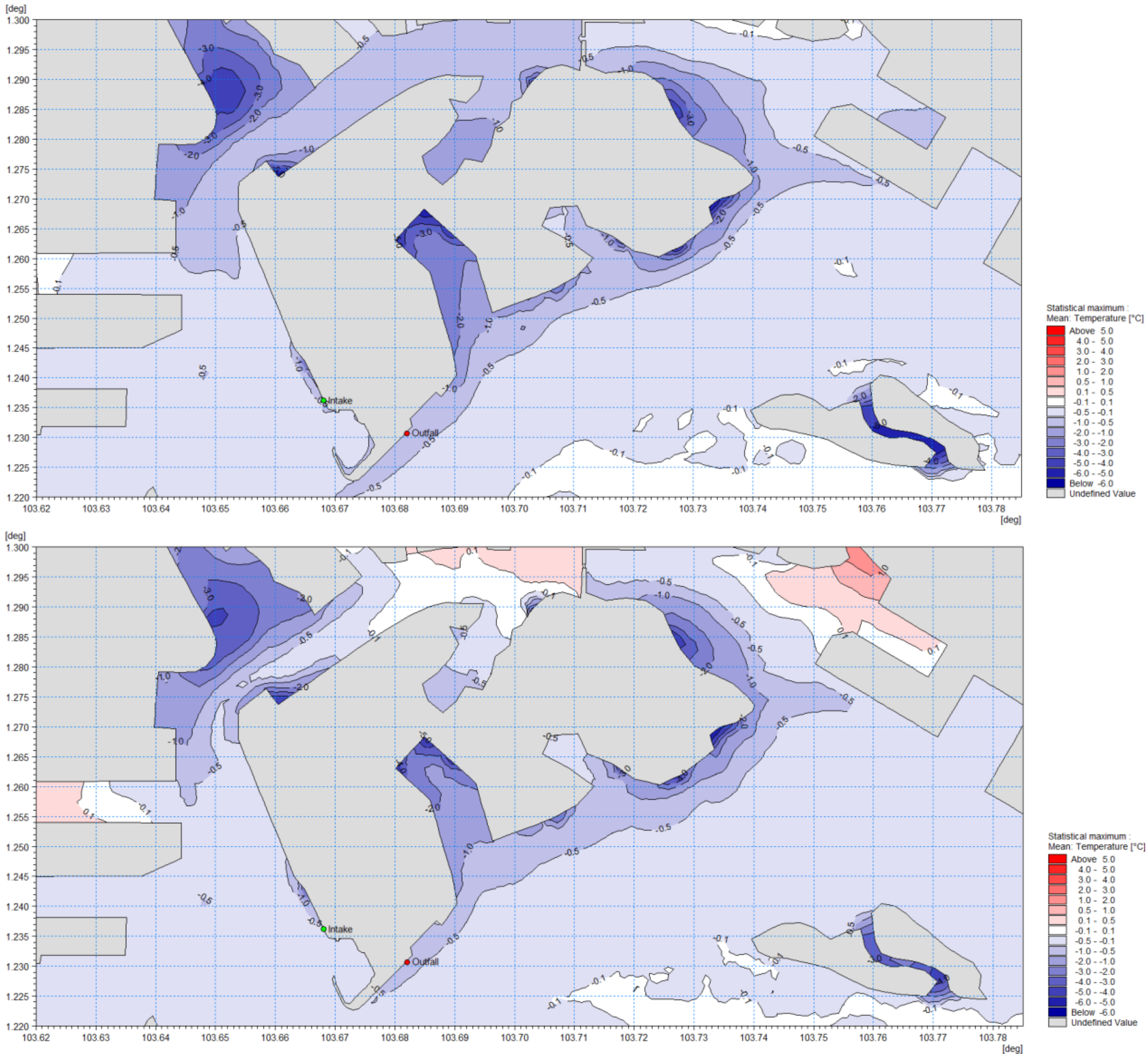


Figure A-7 2D map of statistical maximum temperature difference for NE monsoon (top) and SW monsoon (bottom)[4].

[4] *Reduced statistical maximum temperatures of around -0.5 to -1.0ºC are observed near the CCGT outfall when the existing outfalls within Jurong Island are excluded. Higher maximum temperature difference is generally localised near the existing outfalls.*

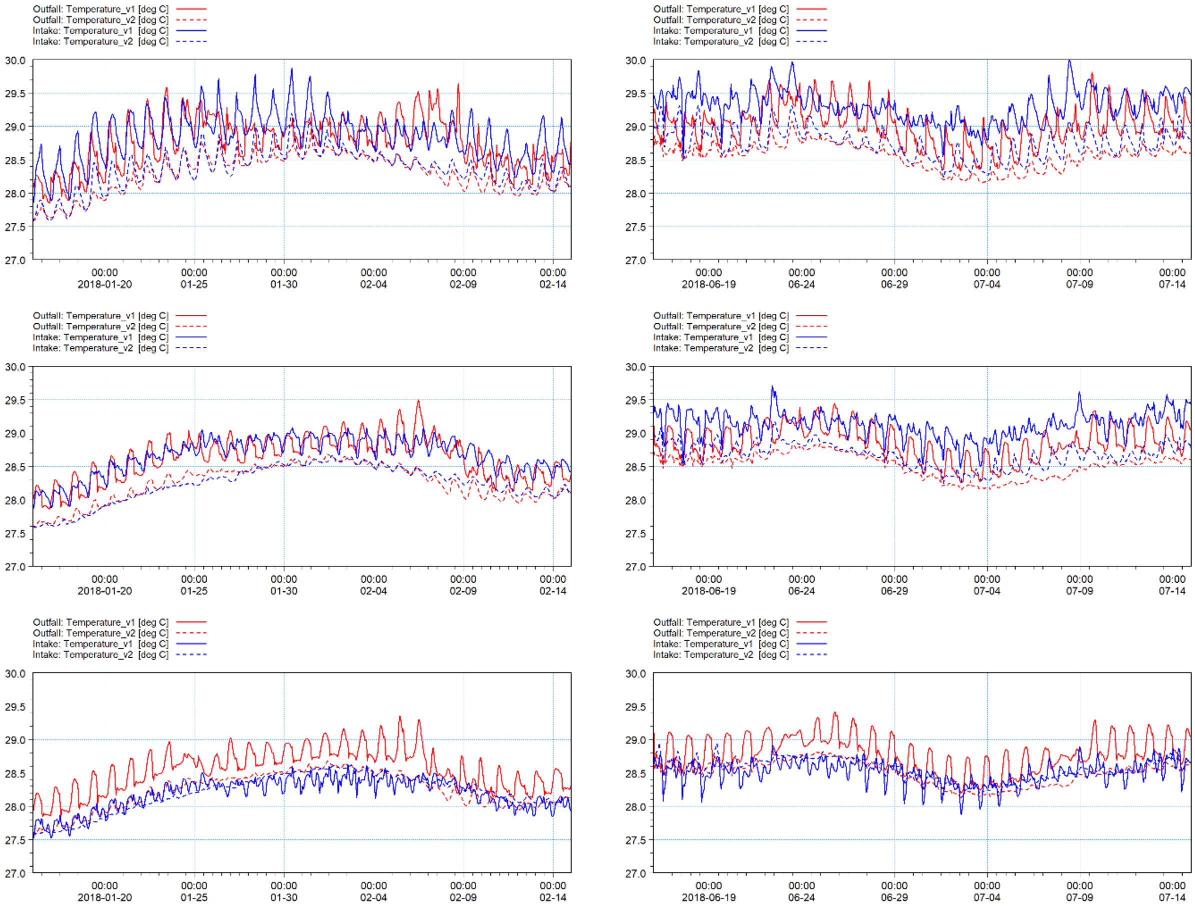


Figure A-8 Timeseries comparisons of temperature at surface, mid-depth, and bottom layers for NE monsoon (left) and SW monsoon (right). v1 refers to the results with an outfall source and v2 refers to the results without an outfall source.

Haskoning
Enhancing Society Together

A2 Hydrodynamic (HD) modelling outputs

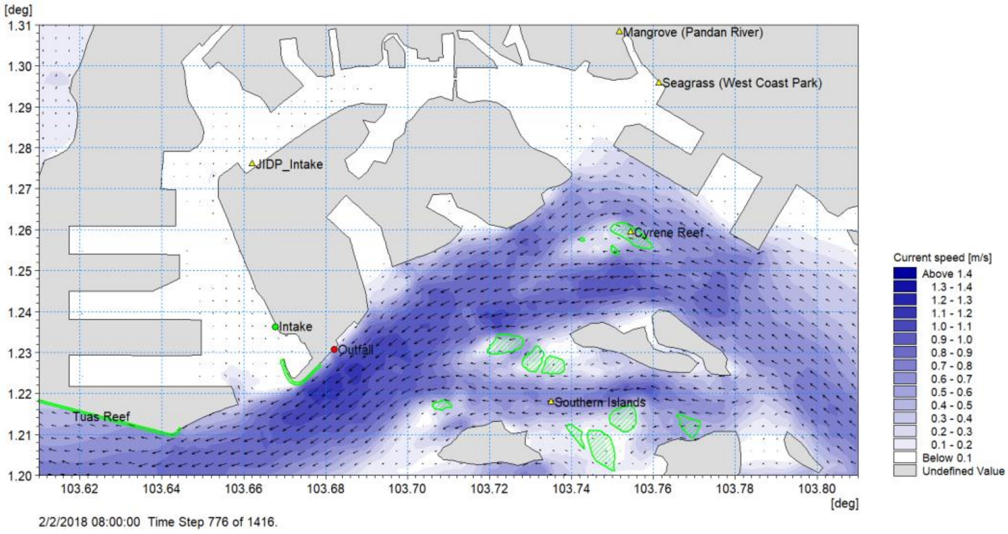
Figure Code	Season	Model	Item	Tide Condition	Phase	Layer
NE_HD_SPCS_FLO_PRE(F)_D	NE	HD	SPCS - Spontaneous current speed and direction	FLO - Peak flood	PRE(F) - Baseline, Future Profile	D - Depth averaged
NE_HD_SPCS_FLO_POS_D	NE	HD	SPCS - Spontaneous current speed and direction	FLO - Peak flood	POS - Operational	D - Depth averaged
NE_HD_SPCS_FLO_DIF(F)_D	NE	HD	SPCS - Spontaneous current speed and direction	FLO - Peak flood	DIF(F) - Difference	D - Depth averaged
NE_HD_SPCS_EBB_PRE(F)_D	NE	HD	SPCS - Spontaneous current speed and direction	EBB - Peak ebb	PRE(F) - Baseline, Future Profile	D - Depth averaged
NE_HD_SPCS_EBB_POS_D	NE	HD	SPCS - Spontaneous current speed and direction	EBB - Peak ebb	POS - Operational	D - Depth averaged
NE_HD_SPCS_EBB_DIF(F)_D	NE	HD	SPCS - Spontaneous current speed and direction	EBB - Peak ebb	DIF(F) - Difference	D - Depth averaged
NE_HD_MECS_ALL_PRE(F)_D	NE	HD	MECS - Mean current speed	ALL - For all (30 days)	PRE(F) - Baseline, Future Profile	D - Depth averaged
NE_HD_MECS_ALL_POS_D	NE	HD	MECS - Mean current speed	ALL - For all (30 days)	POS - Operational	D - Depth averaged
NE_HD_MECS_ALL_DIF(F)_D	NE	HD	MECS - Mean current speed	ALL - For all (30 days)	DIF(F) - Difference	D - Depth averaged
NE_HD_MXCS_ALL_PRE(F)_D	NE	HD	MXCS - Max current speed	ALL - For all (30 days)	PRE(F) - Baseline, Future Profile	D - Depth averaged
NE_HD_MXCS_ALL_POS_D	NE	HD	MXCS - Max current speed	ALL - For all (30 days)	POS - Operational	D - Depth averaged
NE_HD_MXCS_ALL_DIF(F)_D	NE	HD	MXCS - Max current speed	ALL - For all (30 days)	DIF(F) - Difference	D - Depth averaged
NE_HD_2.0X_ALL_PRE(F)_D	NE	HD	2.0X - Exceedance of 2 knots	ALL - For all (30 days)	PRE(F) - Baseline, Future Profile	D - Depth averaged
NE_HD_2.0X_ALL_POS_D	NE	HD	2.0X - Exceedance of 2 knots	ALL - For all (30 days)	POS - Operational	D - Depth averaged
NE_HD_2.0X_ALL_DIF(F)_D	NE	HD	2.0X - Exceedance of 2 knots	ALL - For all (30 days)	DIF(F) - Difference	D - Depth averaged
NE_HD_3.5X_ALL_PRE(F)_D	NE	HD	3.5X - Exceedance of 3.5 knots	ALL - For all (30 days)	PRE(F) - Baseline, Future Profile	D - Depth averaged

Figure Code	Season	Model	Item	Tide Condition	Phase	Layer
NE_HD_3.5X_ALL_POS_D	NE	HD	3.5X - Exceedance of 3.5 knots	ALL - For all (30 days)	POS - Operational	D - Depth averaged
NE_HD_3.5X_ALL_DIF(F)_D	NE	HD	3.5X - Exceedance of 3.5 knots	ALL - For all (30 days)	DIF(F) - Difference	D - Depth averaged
NE_HD_SLCK_ALL_PRE(F)_D	NE	HD	SLCK - Slack water time	ALL - For all (30 days)	PRE(F) - Baseline, Future Profile	D - Depth averaged
NE_HD_SLCK_ALL_POS_D	NE	HD	SLCK - Slack water time	ALL - For all (30 days)	POS - Operational	D - Depth averaged
NE_HD_SLCK_ALL_DIF(F)_D	NE	HD	SLCK - Slack water time	ALL - For all (30 days)	DIF(F) - Difference	D - Depth averaged
SW_HD_SPCS_FLO_PRE(F)_D	SW	HD	SPCS - Spontaneous current speed and direction	FLO - Peak flood	PRE(F) - Baseline, Future Profile	D - Depth averaged
SW_HD_SPCS_FLO_POS_D	SW	HD	SPCS - Spontaneous current speed and direction	FLO - Peak flood	POS - Operational	D - Depth averaged
SW_HD_SPCS_FLO_DIF(F)_D	SW	HD	SPCS - Spontaneous current speed and direction	FLO - Peak flood	DIF(F) - Difference	D - Depth averaged
SW_HD_SPCS_EBB_PRE(F)_D	SW	HD	SPCS - Spontaneous current speed and direction	EBB - Peak ebb	PRE(F) - Baseline, Future Profile	D - Depth averaged
SW_HD_SPCS_EBB_POS_D	SW	HD	SPCS - Spontaneous current speed and direction	EBB - Peak ebb	POS - Operational	D - Depth averaged
SW_HD_SPCS_EBB_DIF(F)_D	SW	HD	SPCS - Spontaneous current speed and direction	EBB - Peak ebb	DIF(F) - Difference	D - Depth averaged
SW_HD_MECS_ALL_PRE(F)_D	SW	HD	MECS - Mean current speed	ALL - For all (30 days)	PRE(F) - Baseline, Future Profile	D - Depth averaged
SW_HD_MECS_ALL_POS_D	SW	HD	MECS - Mean current speed	ALL - For all (30 days)	POS - Operational	D - Depth averaged
SW_HD_MECS_ALL_DIF(F)_D	SW	HD	MECS - Mean current speed	ALL - For all (30 days)	DIF(F) - Difference	D - Depth averaged
SW_HD_MXCS_ALL_PRE(F)_D	SW	HD	MXCS - Max current speed	ALL - For all (30 days)	PRE(F) - Baseline, Future Profile	D - Depth averaged
SW_HD_MXCS_ALL_POS_D	SW	HD	MXCS - Max current speed	ALL - For all (30 days)	POS - Operational	D - Depth averaged
SW_HD_MXCS_ALL_DIF(F)_D	SW	HD	MXCS - Max current speed	ALL - For all (30 days)	DIF(F) - Difference	D - Depth averaged

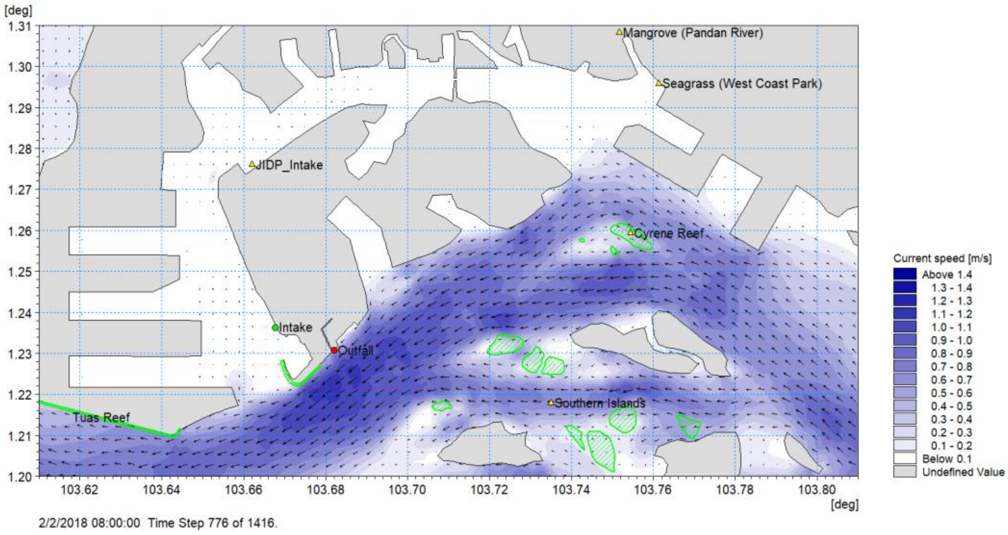
Figure Code	Season	Model	Item	Tide Condition	Phase	Layer
SW_HD_2.0X_ALL_PRE(F)_D	SW	HD	2.0X - Exceedance of 2 knots	ALL - For all (30 days)	PRE(F) - Baseline, Future Profile	D - Depth averaged
SW_HD_2.0X_ALL_POS_D	SW	HD	2.0X - Exceedance of 2 knots	ALL - For all (30 days)	POS - Operational	D - Depth averaged
SW_HD_2.0X_ALL_DIF(F)_D	SW	HD	2.0X - Exceedance of 2 knots	ALL - For all (30 days)	DIF(F) - Difference	D - Depth averaged
SW_HD_3.5X_ALL_PRE(F)_D	SW	HD	3.5X - Exceedance of 3.5 knots	ALL - For all (30 days)	PRE(F) - Baseline, Future Profile	D - Depth averaged
SW_HD_3.5X_ALL_POS_D	SW	HD	3.5X - Exceedance of 3.5 knots	ALL - For all (30 days)	POS - Operational	D - Depth averaged
SW_HD_3.5X_ALL_DIF(F)_D	SW	HD	3.5X - Exceedance of 3.5 knots	ALL - For all (30 days)	DIF(F) - Difference	D - Depth averaged
SW_HD_SLCK_ALL_PRE(F)_D	SW	HD	SLCK - Slack water time	ALL - For all (30 days)	PRE(F) - Baseline, Future Profile	D - Depth averaged
SW_HD_SLCK_ALL_POS_D	SW	HD	SLCK - Slack water time	ALL - For all (30 days)	POS - Operational	D - Depth averaged
SW_HD_SLCK_ALL_DIF(F)_D	SW	HD	SLCK - Slack water time	ALL - For all (30 days)	DIF(F) - Difference	D - Depth averaged

A2.1 NE Monsoon

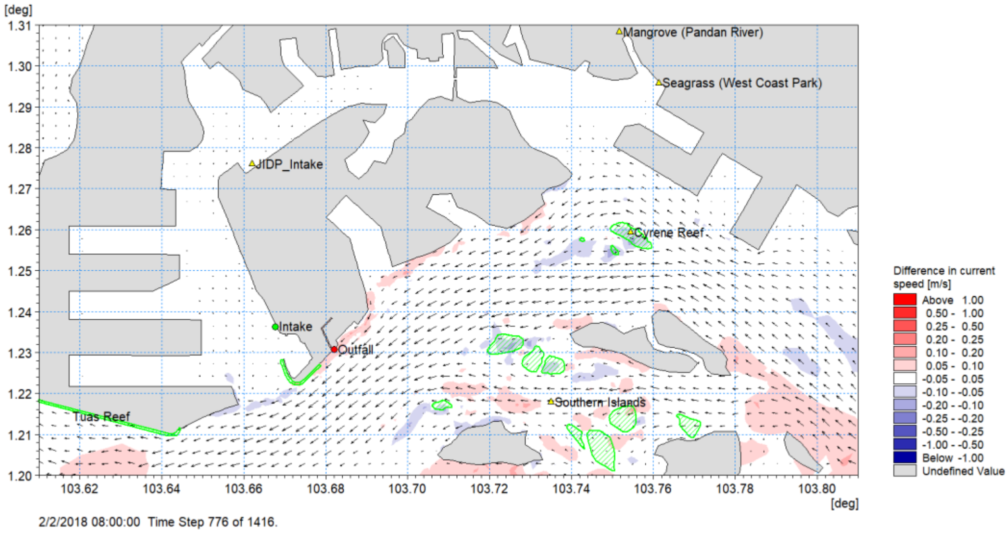
NE_HD_SPCS_FLO_PRE(F)_D



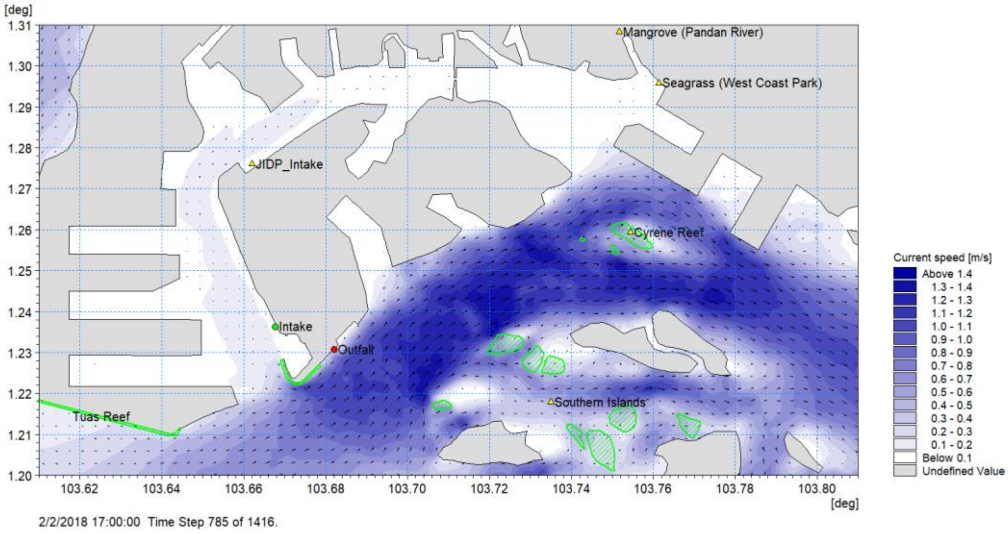
NE_HD_SPCS_FLO_POS_D



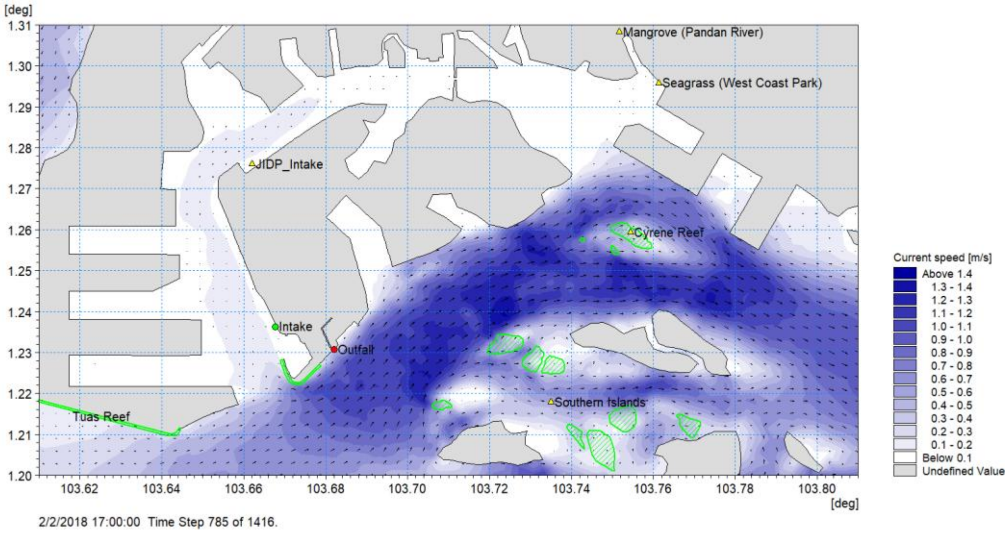
NE_HD_SPCS_FLO_DIF(F)_D



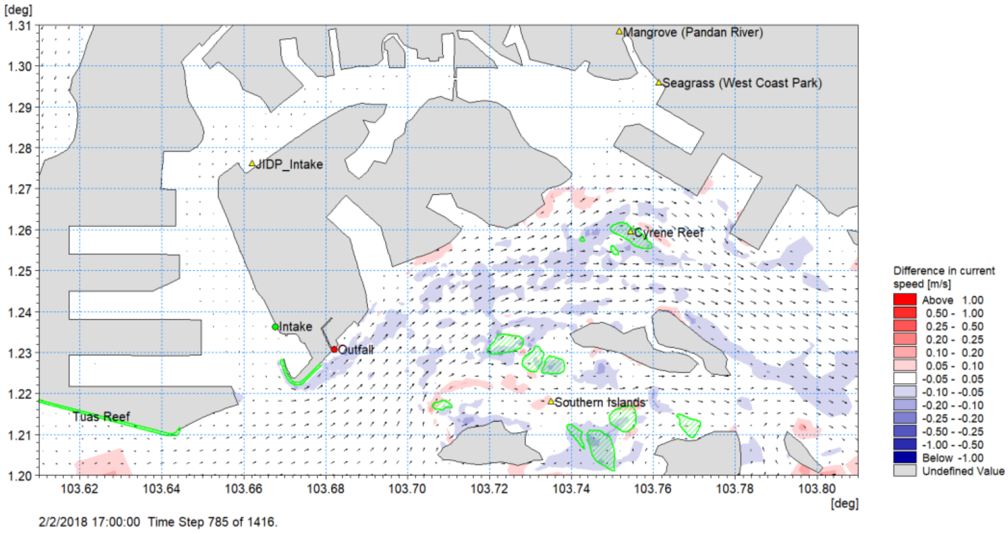
NE_HD_SPCS_EBB_PRE(F)_D



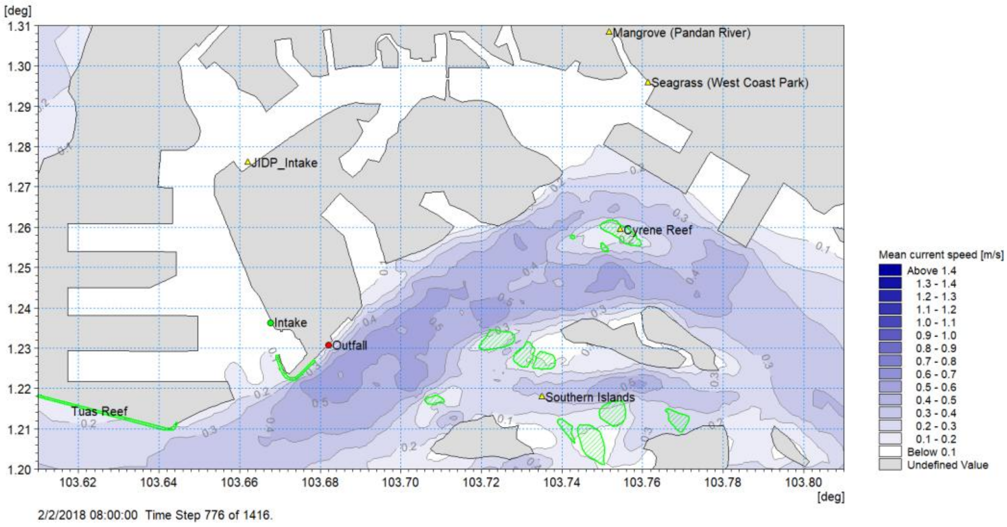
NE_HD_SPCS_EBB_POS_D



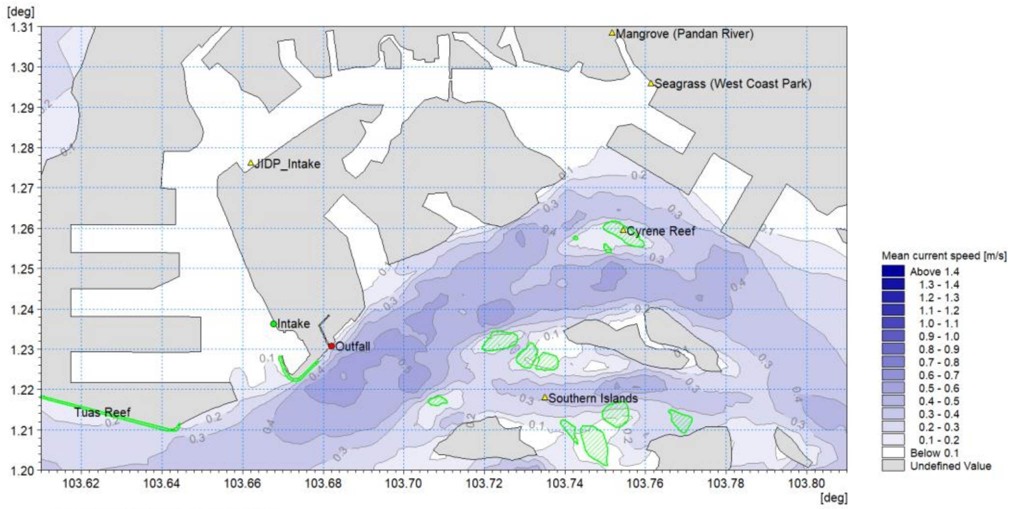
NE_HD_SPCS_EBB_DIF(F)_D



NE_HD_MECS_ALL_PRE(F)_D

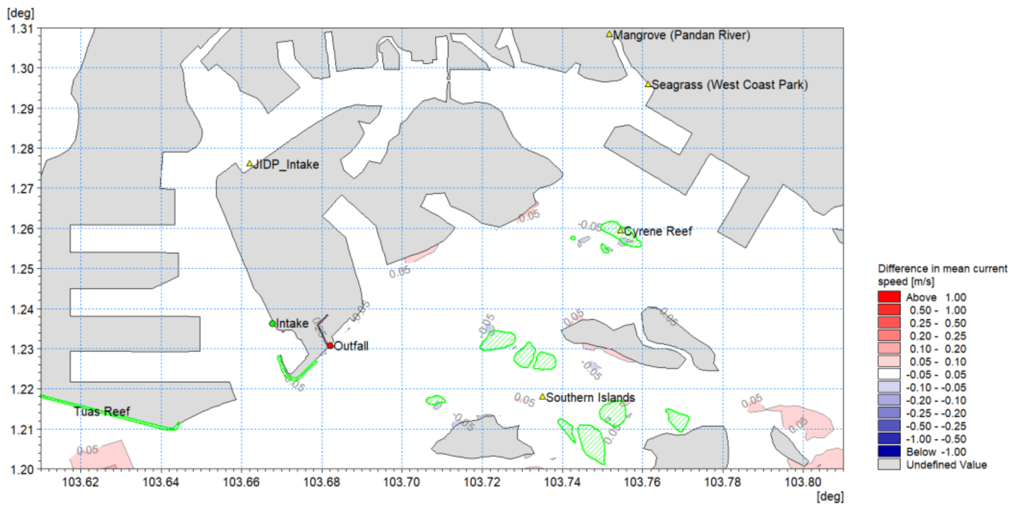


NE_HD_MECS_ALL_POS_D



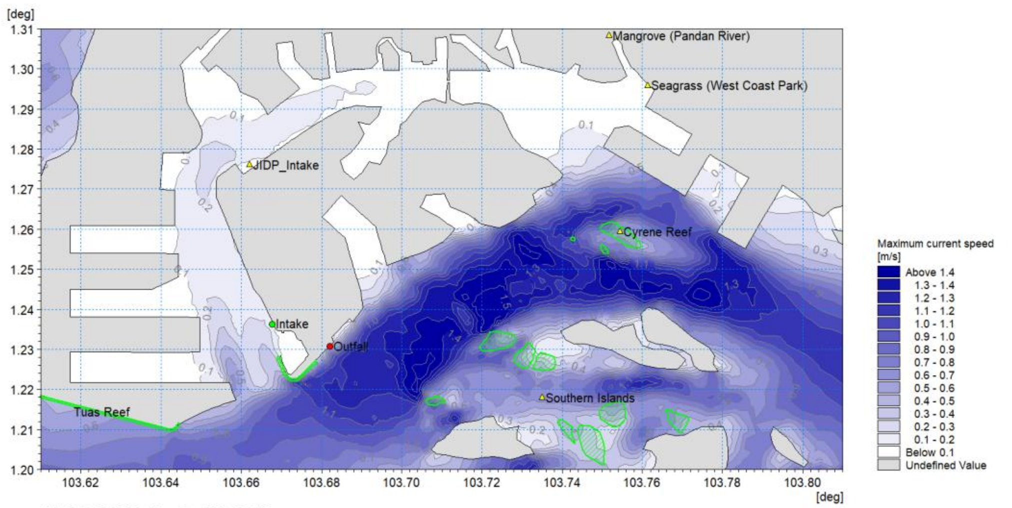
2/2/2018 08:00:00 Time Step 776 of 1416.

NE_HD_MECS_ALL_DIF(F)_D



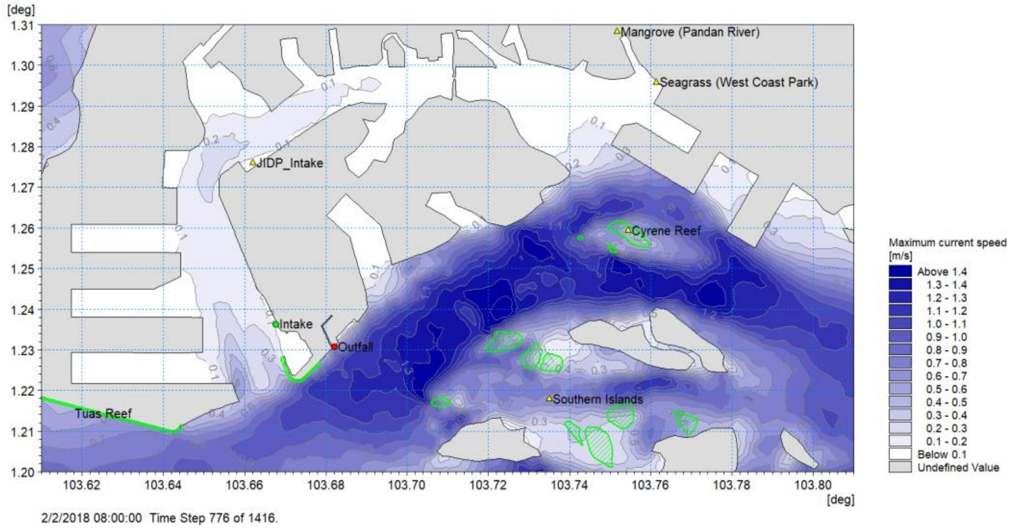
2/2/2018 08:00:00 Time Step 776 of 1416.

NE_HD_MXCS_ALL_PRE(F)_D

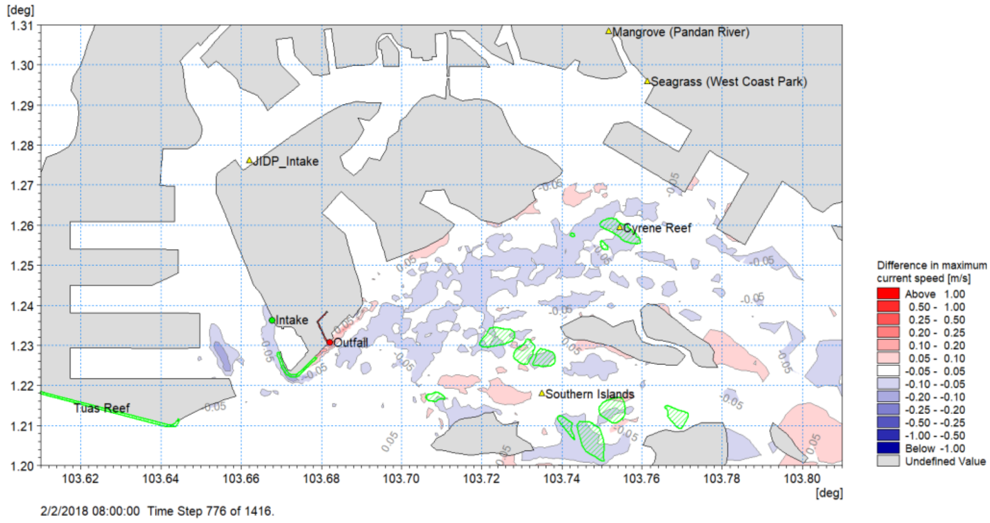


2/2/2018 08:00:00 Time Step 776 of 1416.

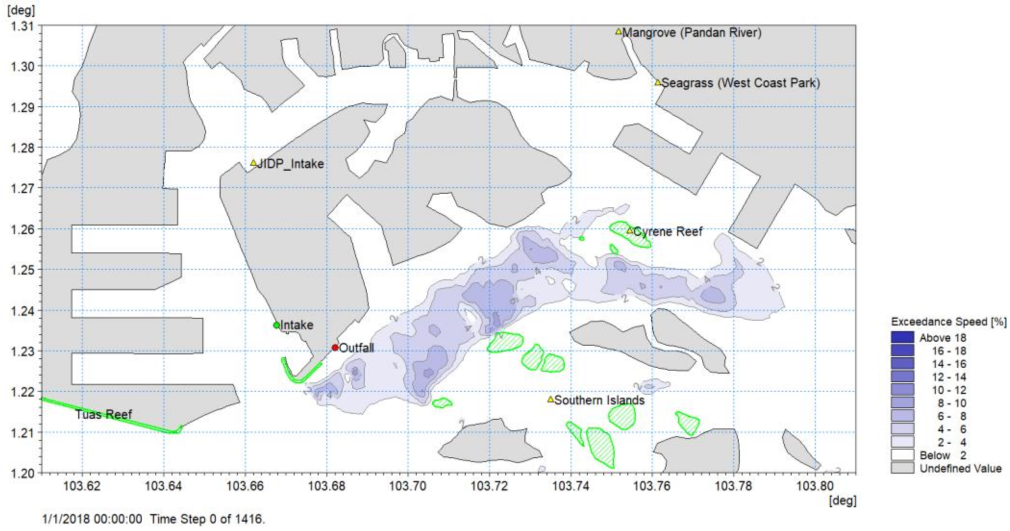
NE_HD_MXCS_ALL_POS_D



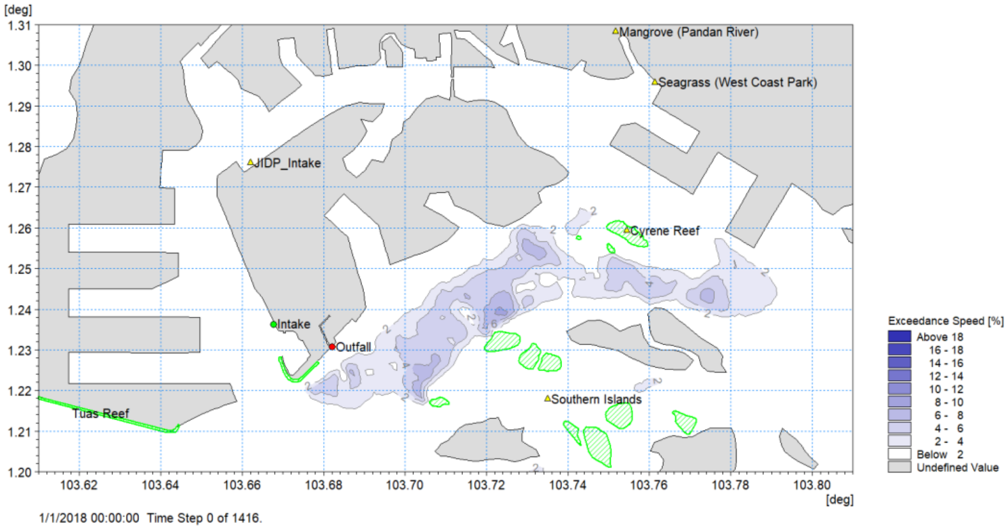
NE_HD_MXCS_ALL_DIF(F)_D



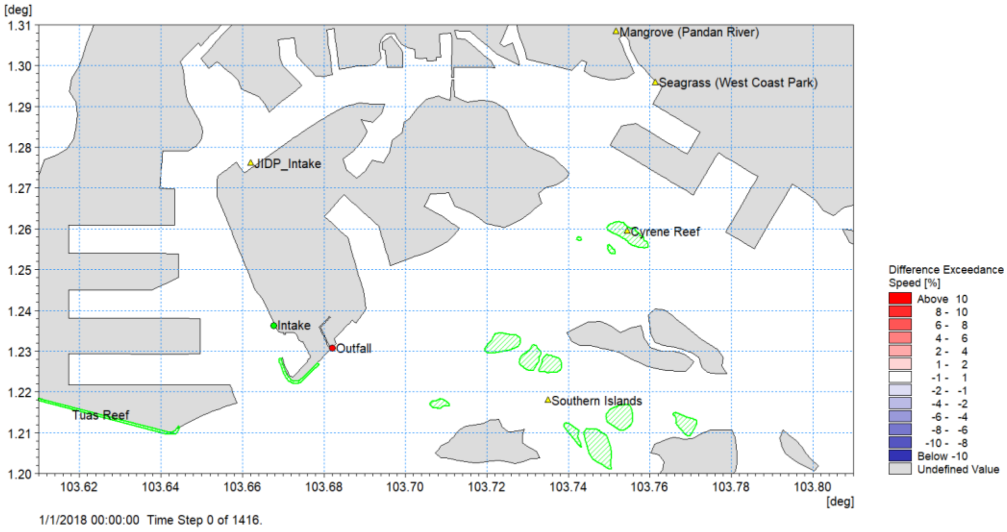
NE_HD_2.0X_ALL_PRE(F)_D



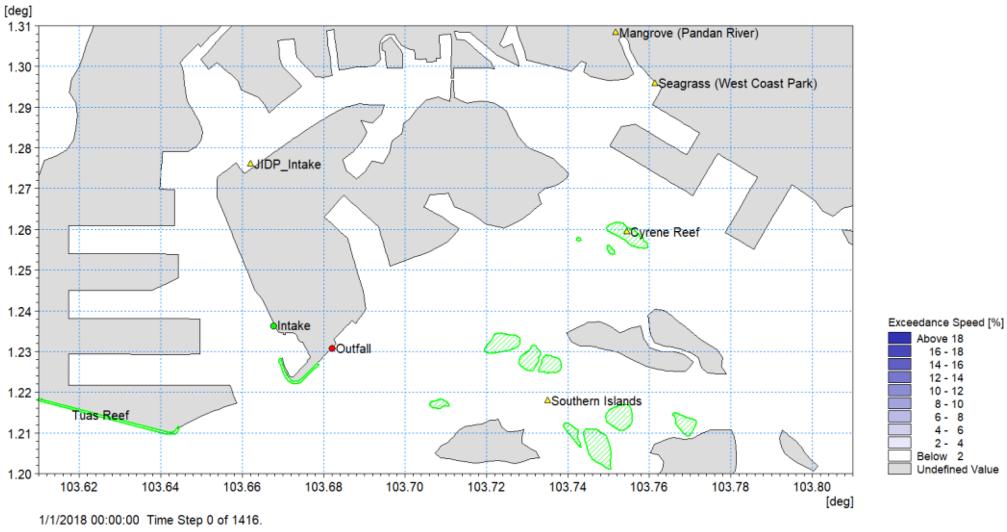
NE_HD_2.0X_ALL_POS_D



NE_HD_2.0X_ALL_DIF(F)_D

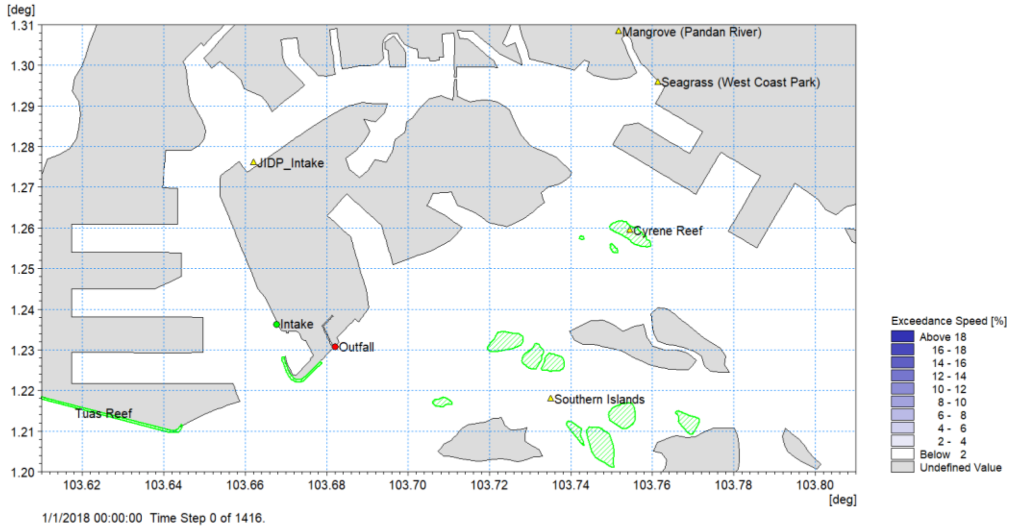


NE_HD_3.5X_ALL_PRE(F)_D

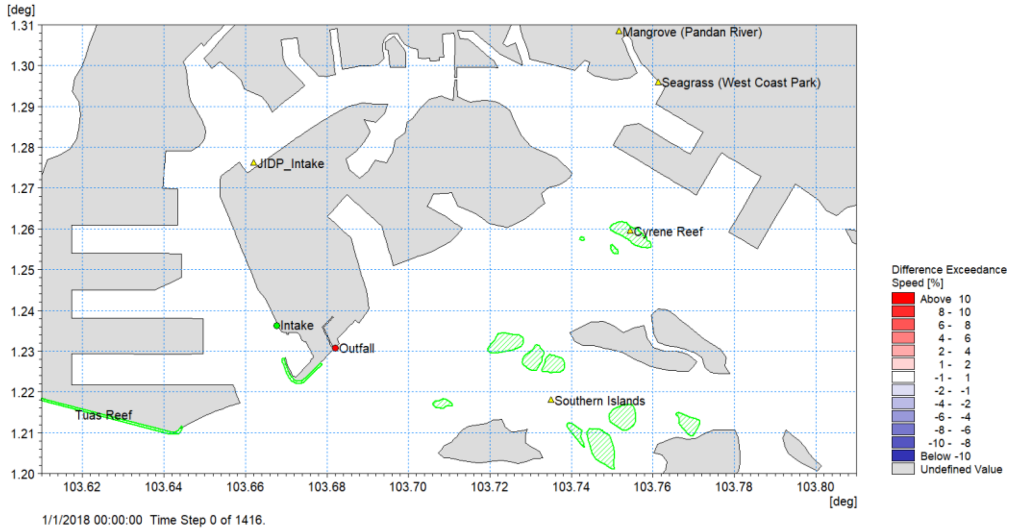


Haskoning
Enhancing Society Together

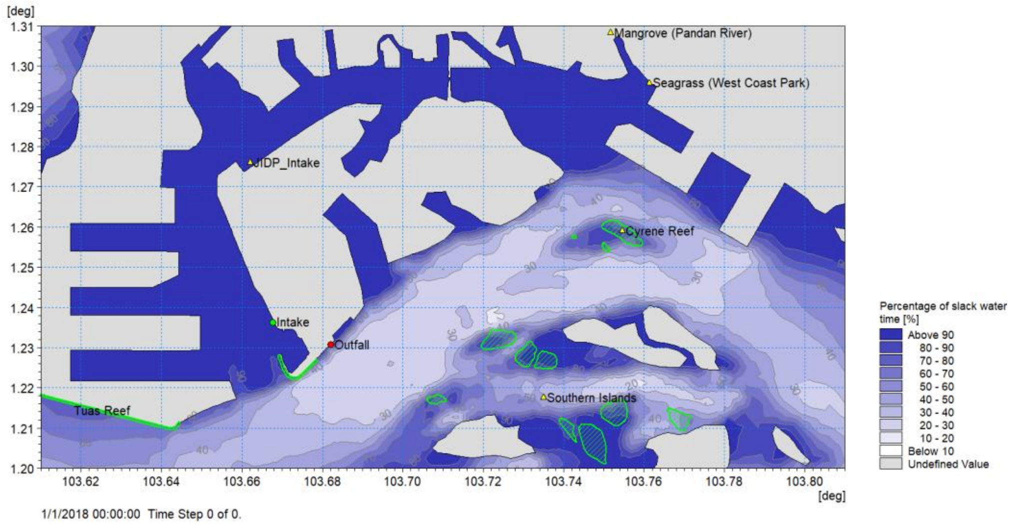
NE_HD_3.5X_ALL_POS_D



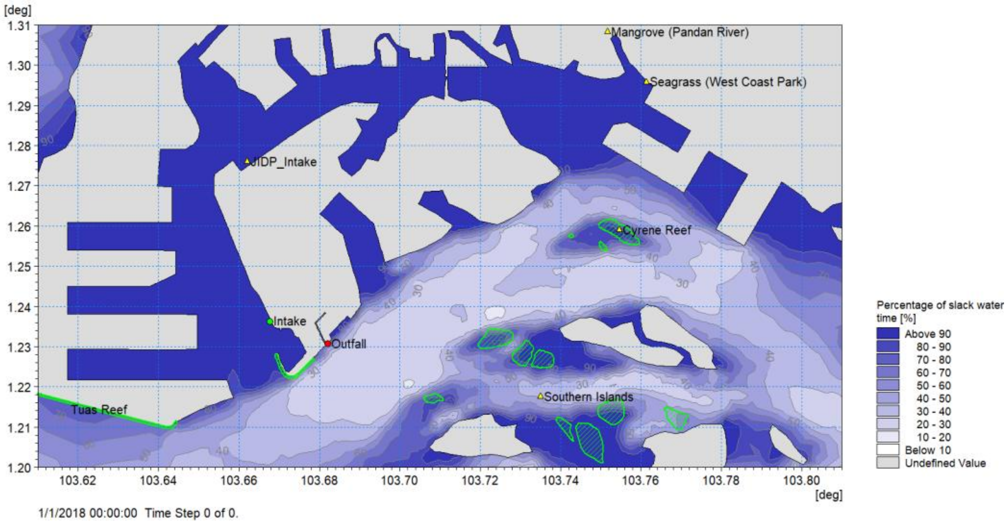
NE_HD_3.5X_ALL_DIF(F)_D



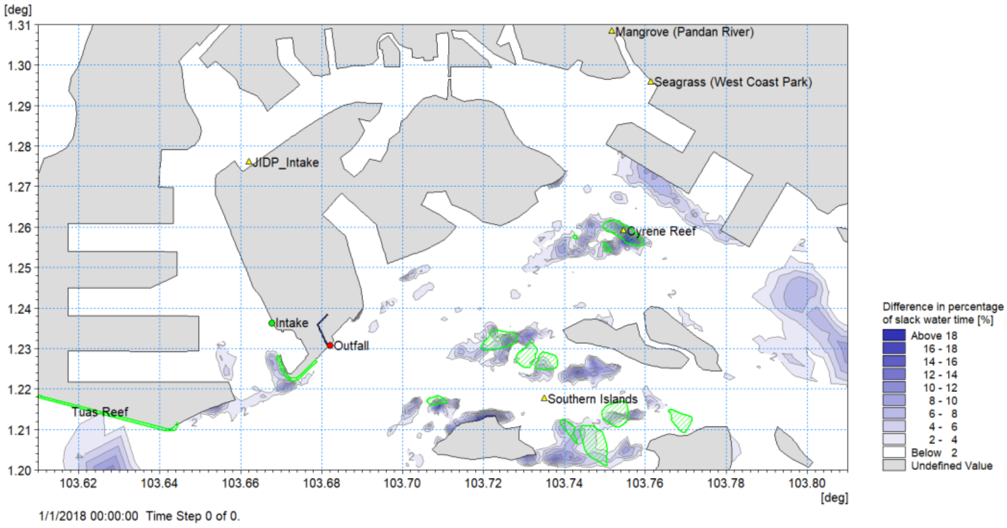
NE_HD_SLCK_ALL_PRE(F)_D



NE_HD_SLCK_ALL_POS_D

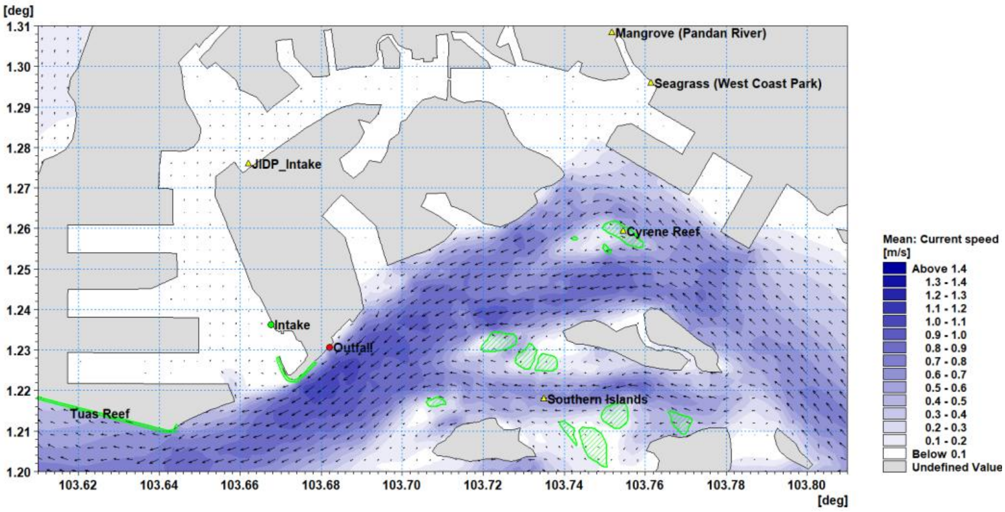


NE_HD_SLCK_ALL_DIF(F)_D

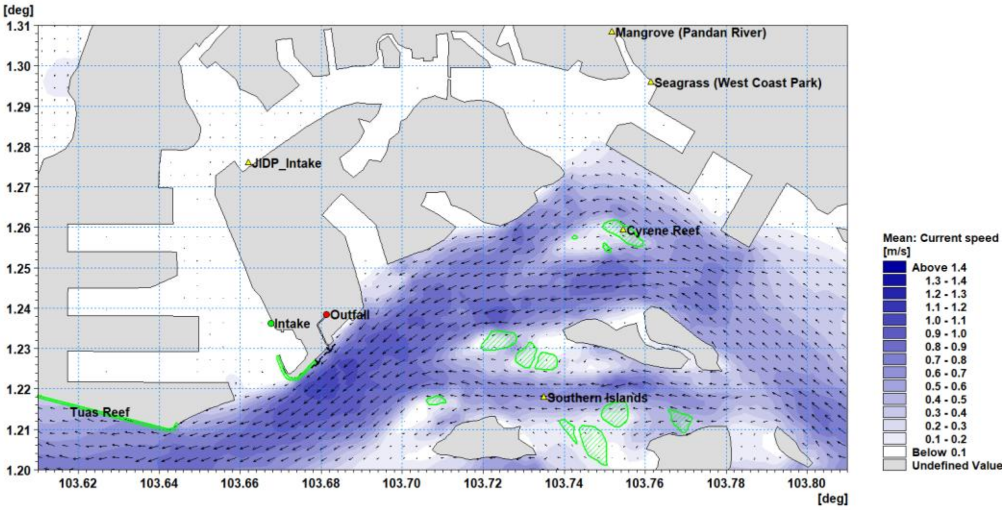


A2.2 SW Monsoon

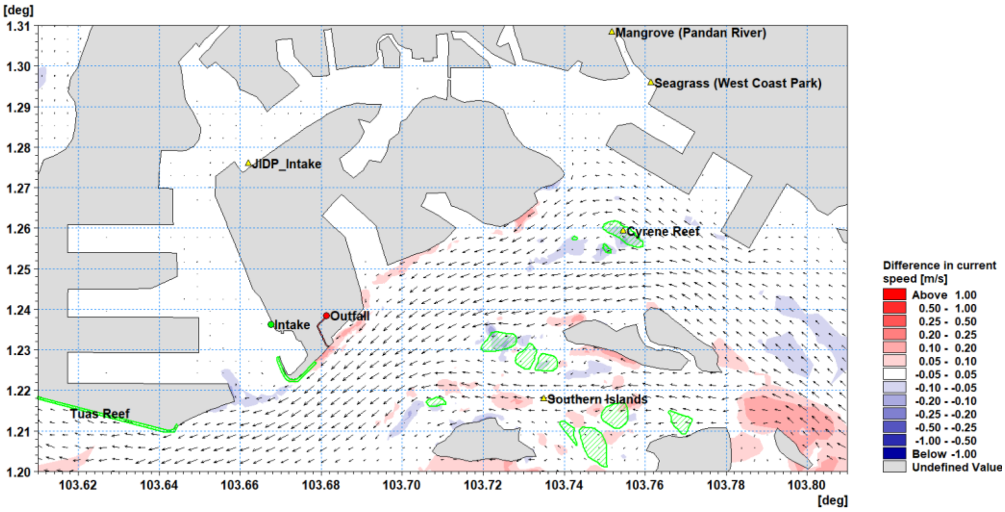
SW_HD_SPCS_FLO_PRE(F)_D



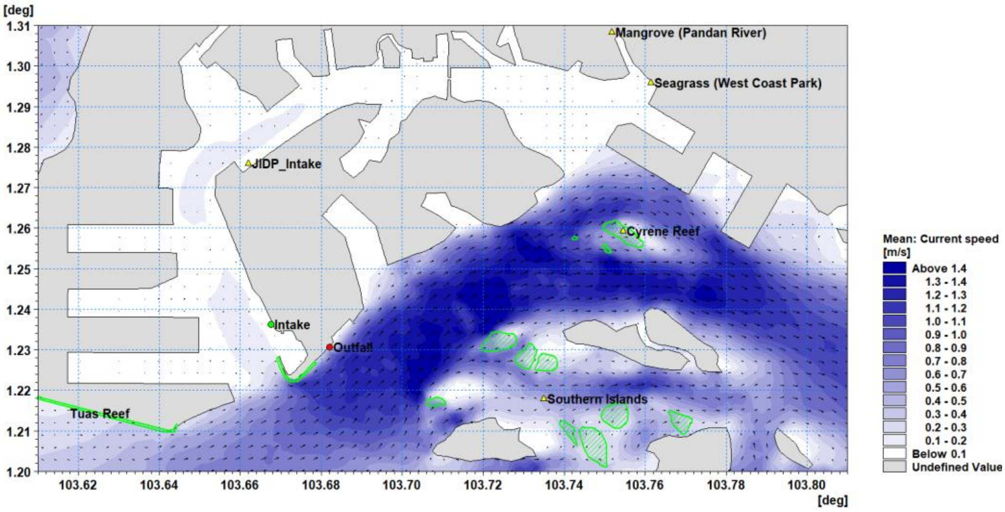
SW_HD_SPCS_FLO_POS_D



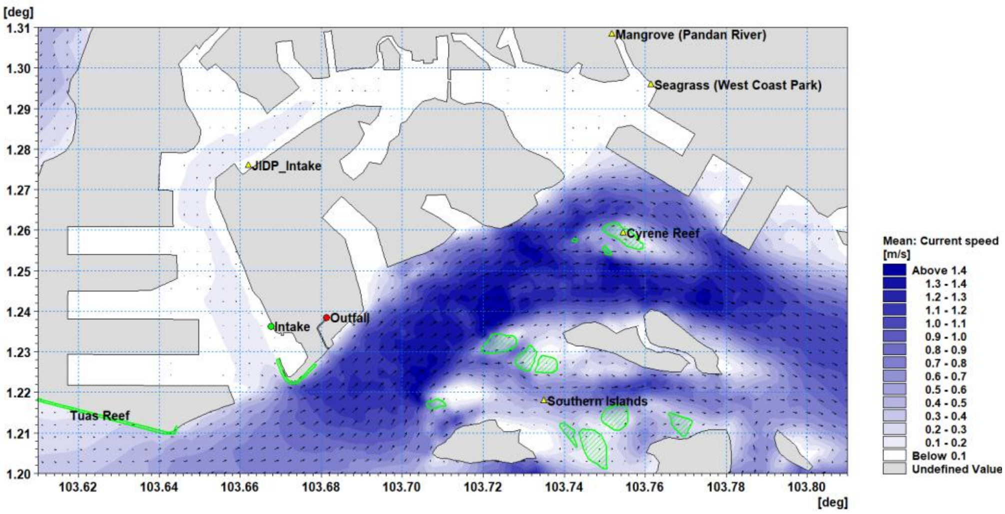
SW_HD_SPCS_FLO_DIF(F)_D



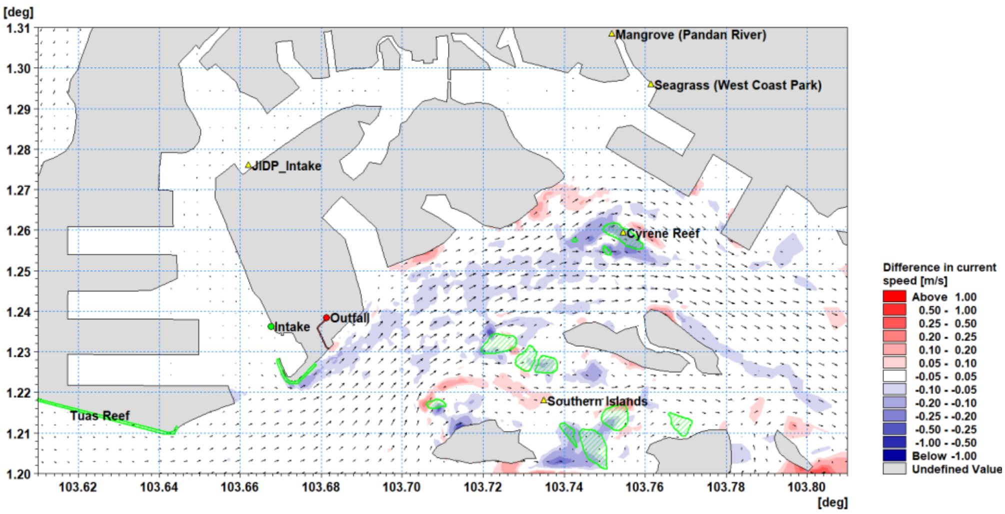
SW_HD_SPCS_EBB_PRE(F)_D



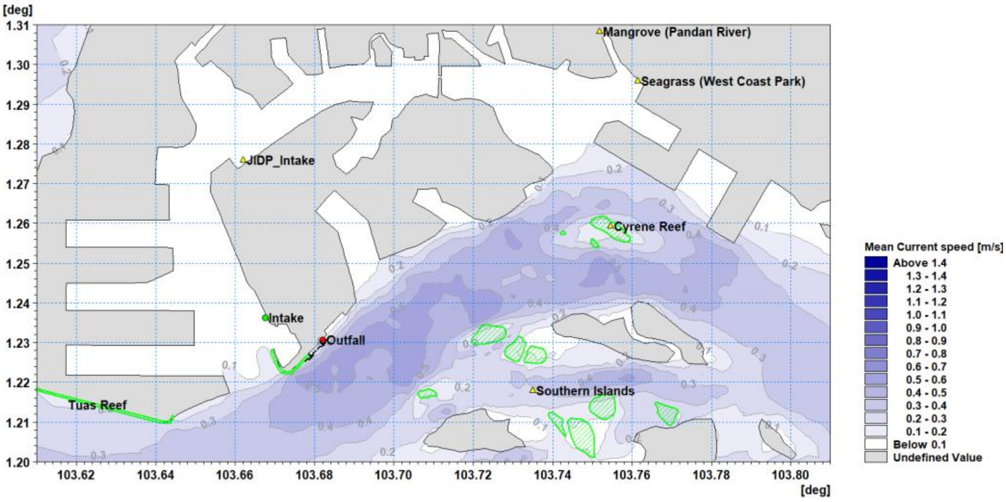
SW_HD_SPCS_EBB_POS_D



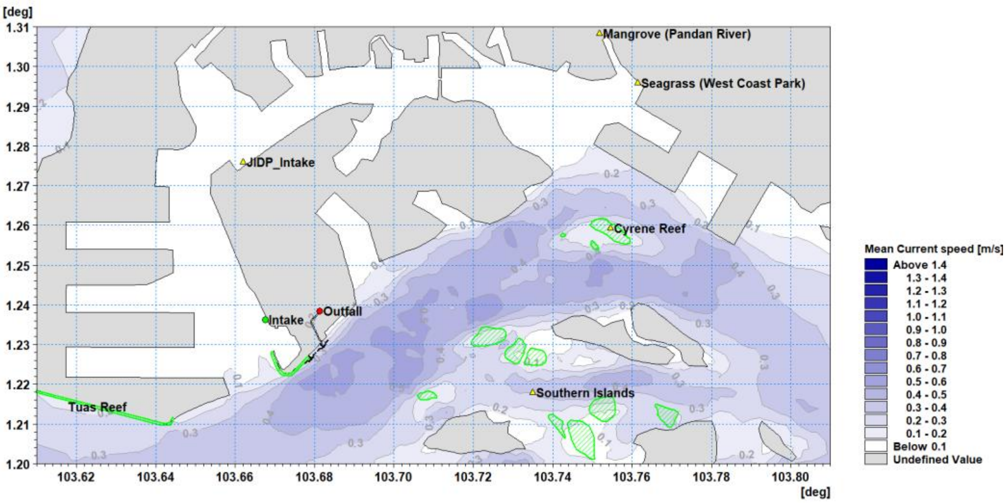
SW_HD_SPCS_EBB_DIF(F)_D



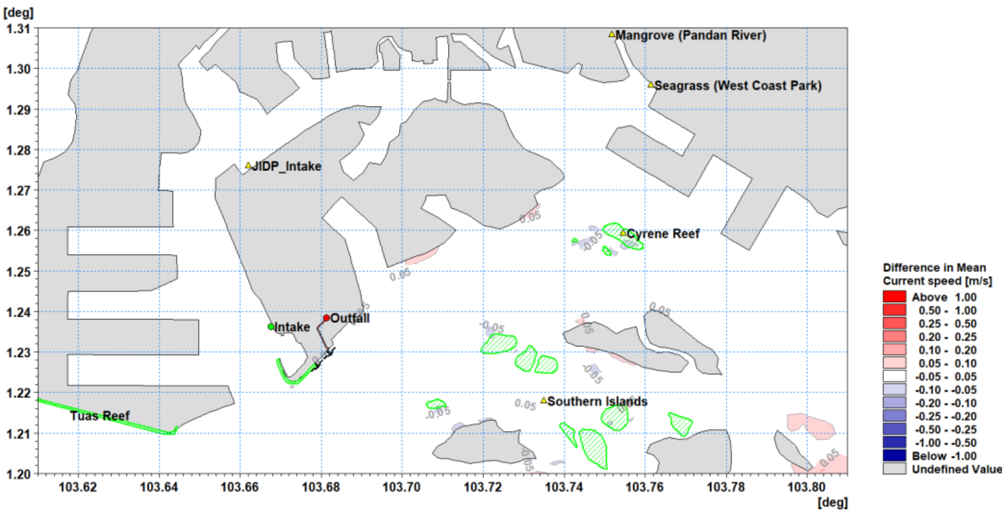
SW_HD_MECS_ALL_PRE(F)_D



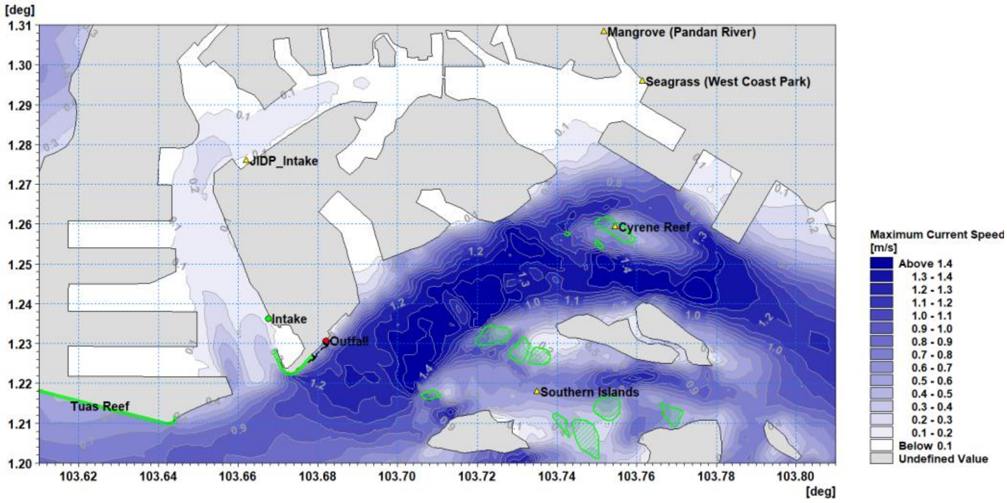
SW_HD_MECS_ALL_POS_D



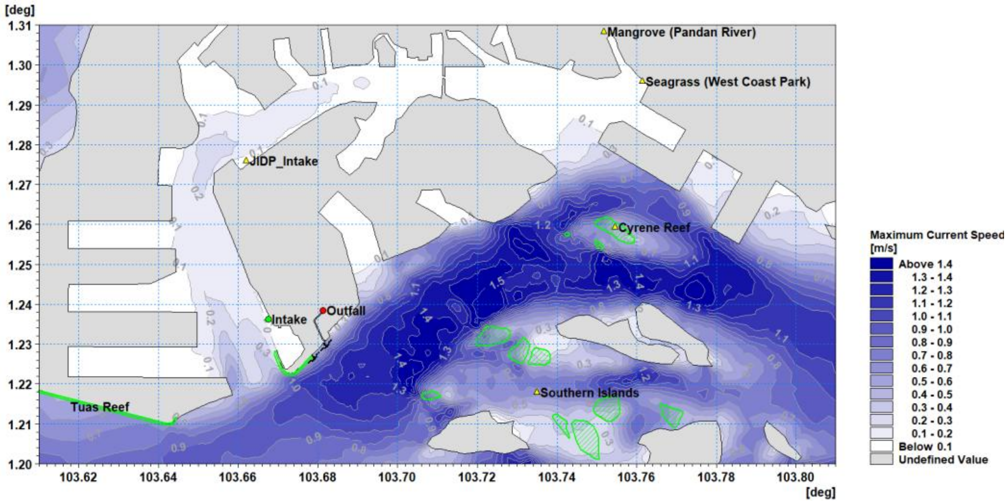
SW_HD_MECS_ALL_DIF(F)_D



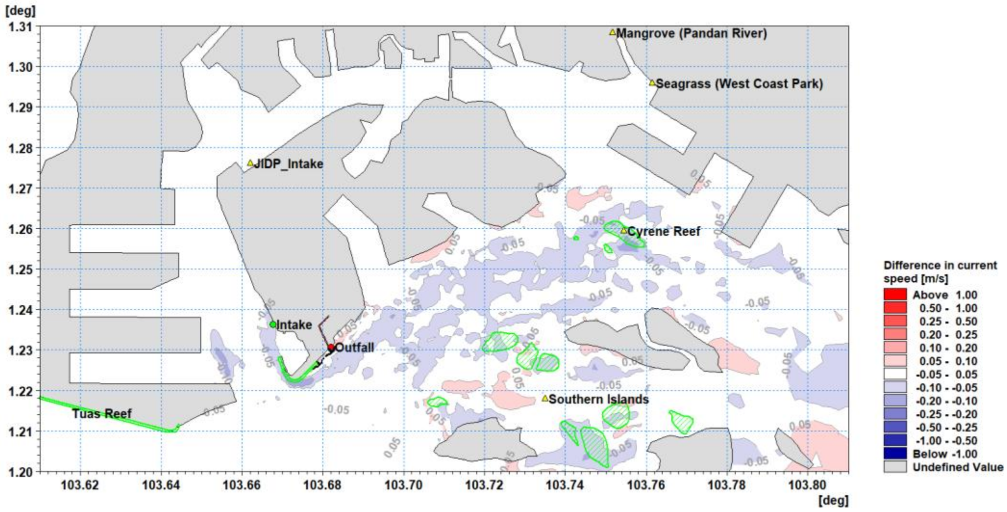
SW_HD_MXCS_ALL_PRE(F)_D



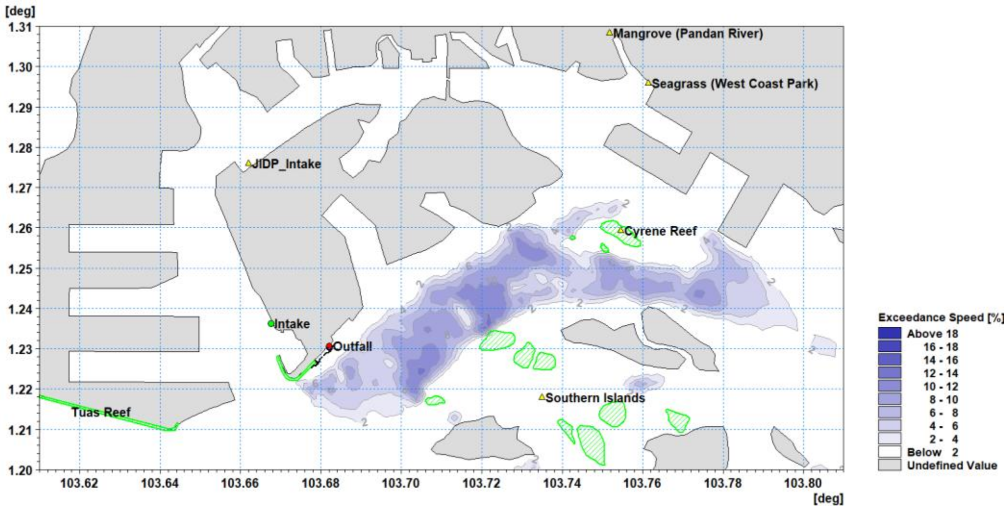
SW_HD_MXCS_ALL_POS_D



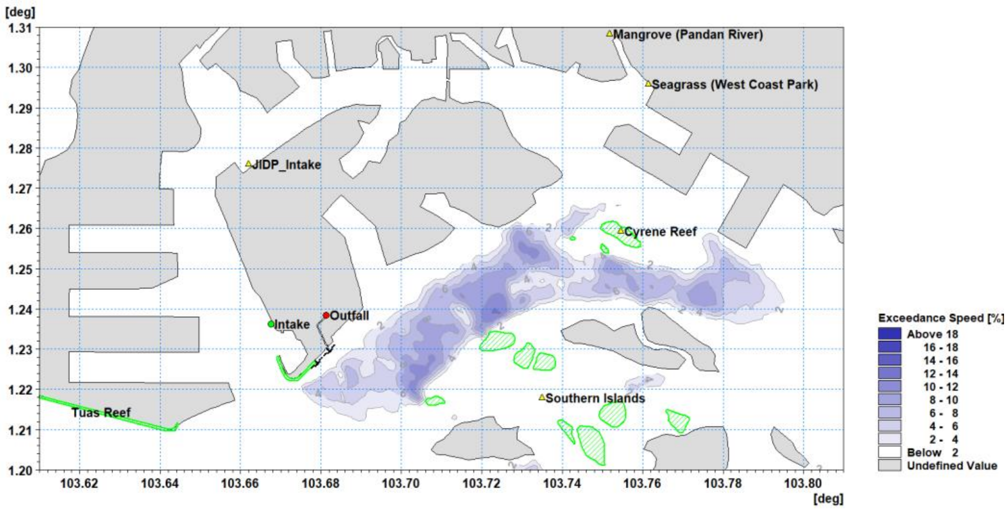
SW_HD_MXCS_ALL_DIF(F)_D



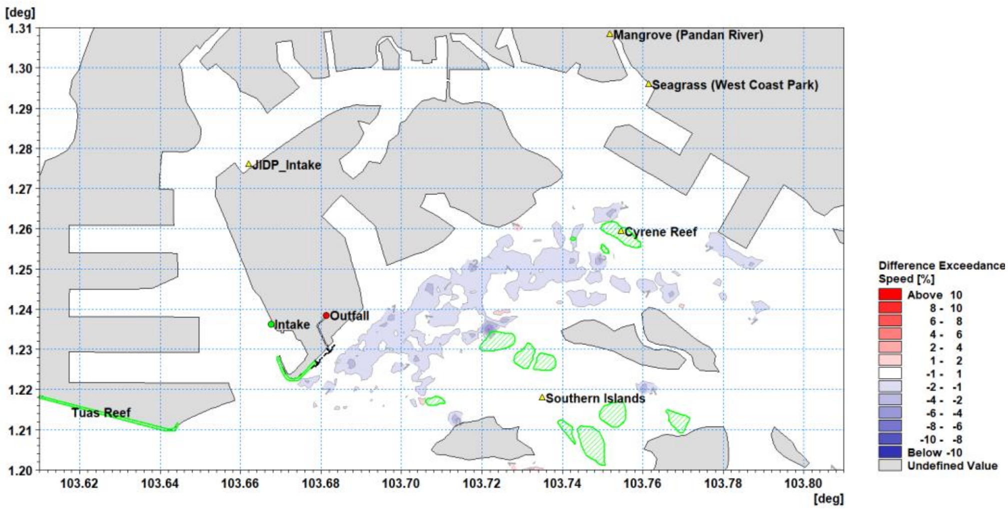
SW_HD_2.0X_ALL_PRE(F)_D



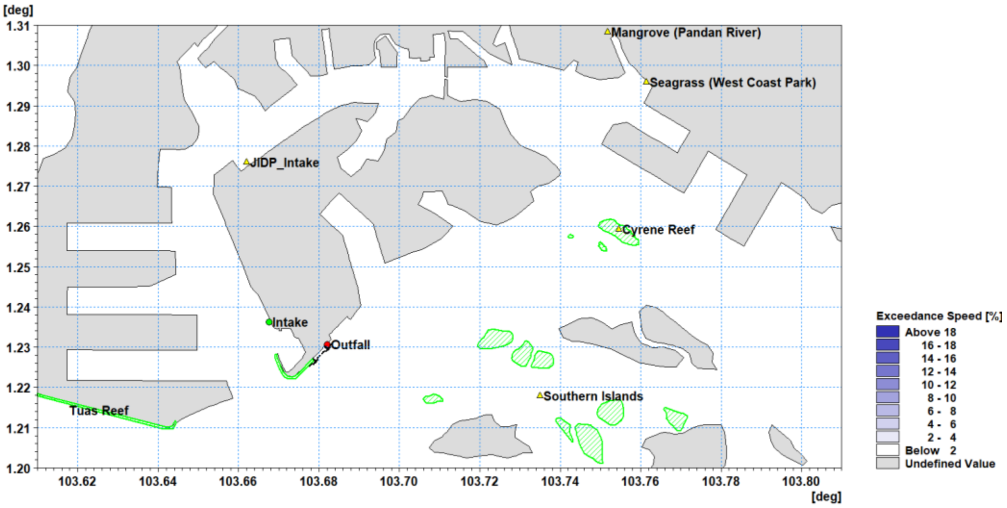
SW_HD_2.0X_ALL_POS_D



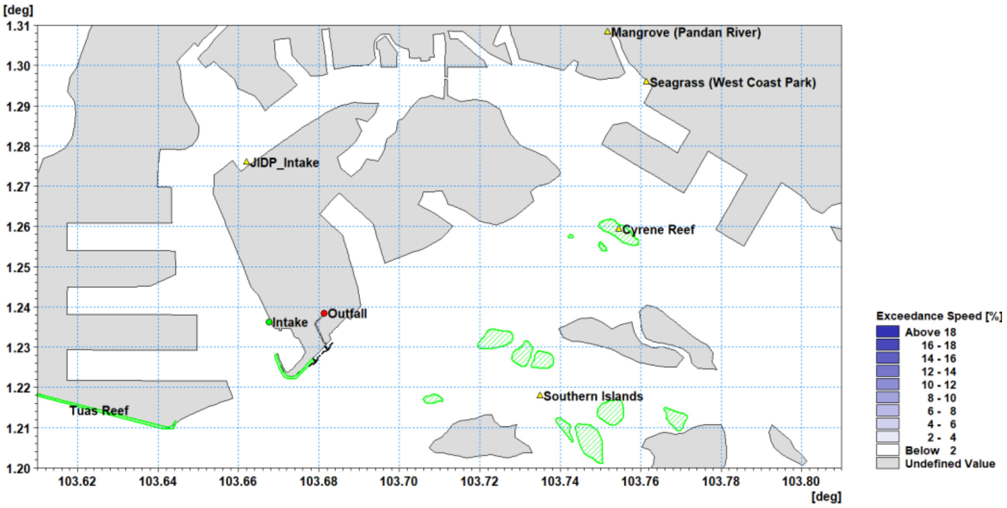
SW_HD_2.0X_ALL_DIF(F)_D



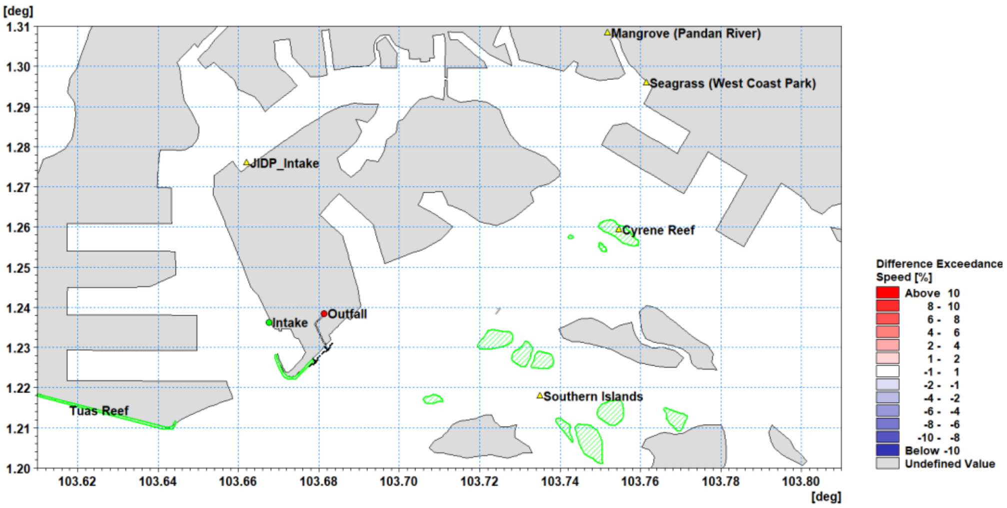
SW_HD_3.5X_ALL_PRE(F)_D



SW_HD_3.5X_ALL_POS_D

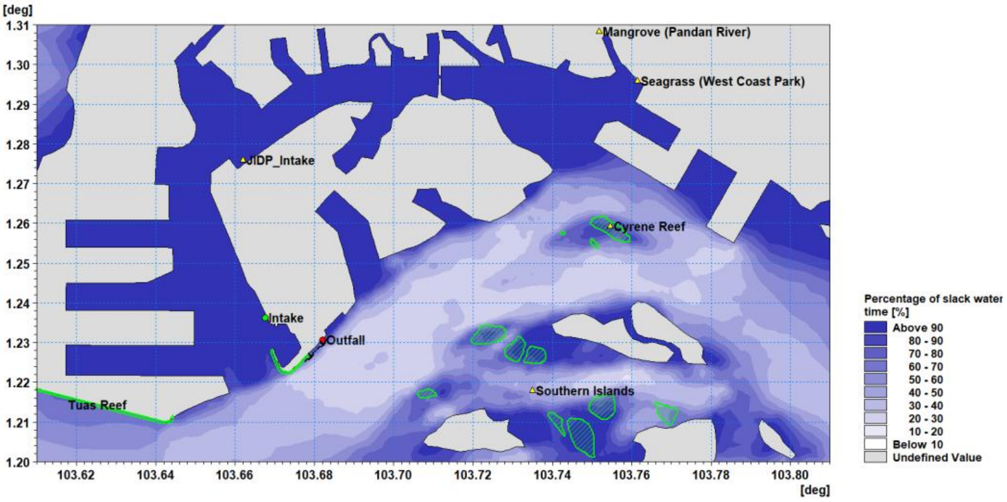


SW_HD_3.5X_ALL_DIF(F)_D

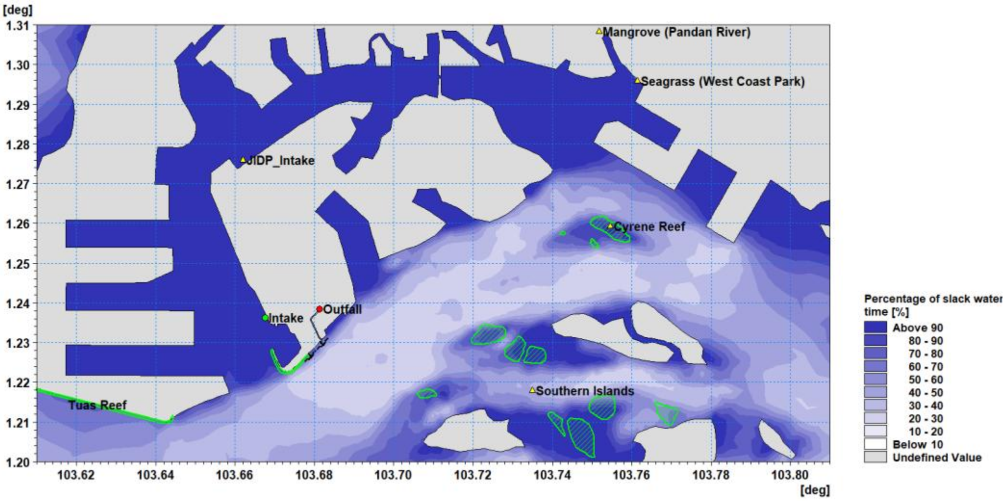


Haskoning
Enhancing Society Together

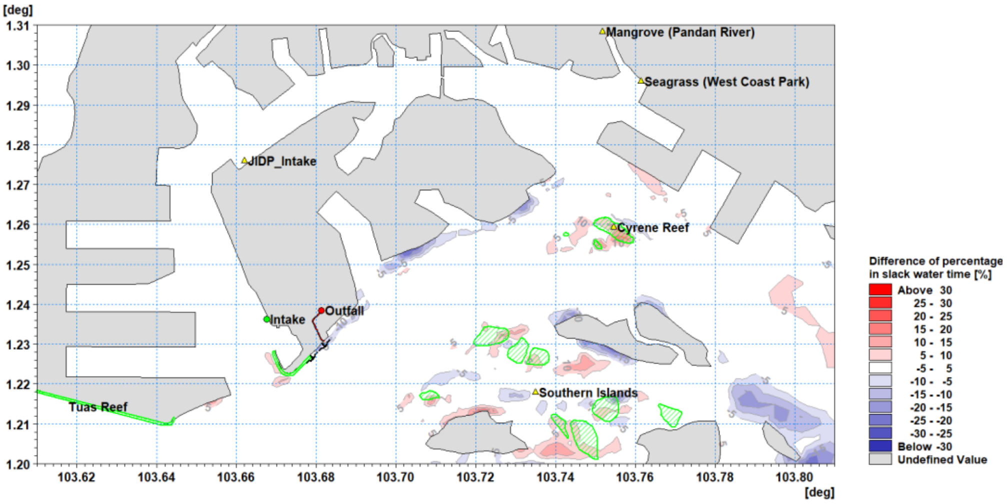
SW_HD_SLCK_ALL_PRE(F)_D



SW_HD_SLCK_ALL_POS_D



SW_HD_SLCK_ALL_DIF(F)_D

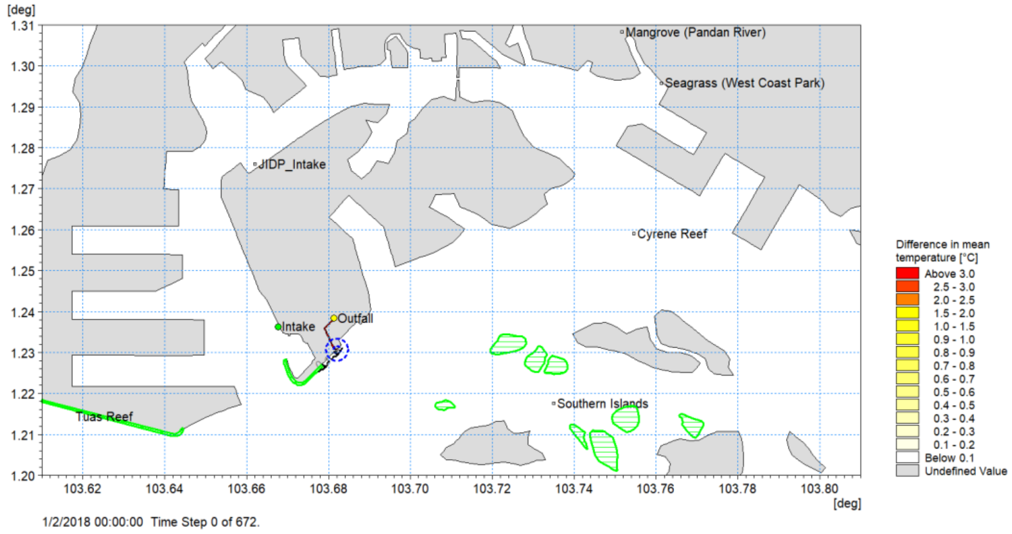


A3 Thermal Plume (TMP) modelling outputs

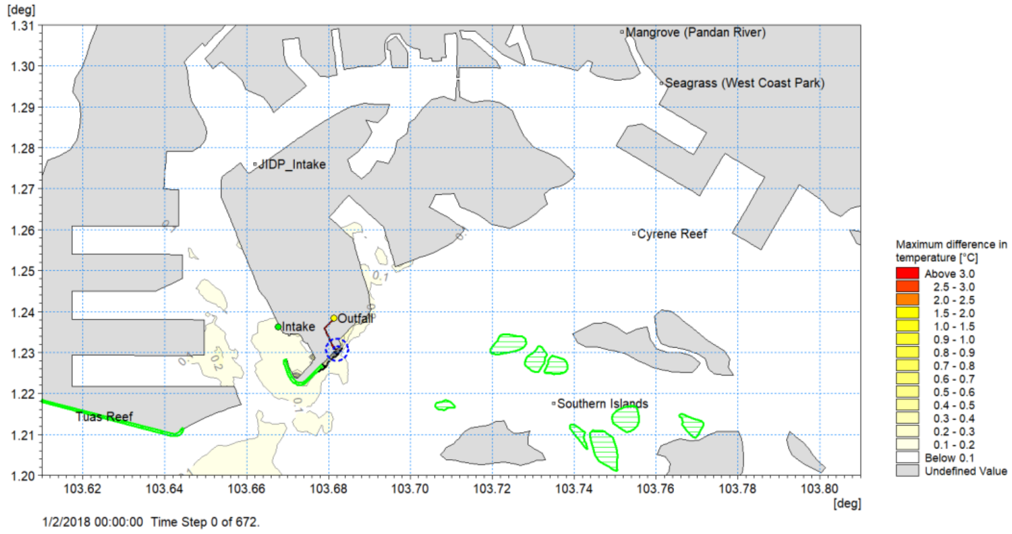
Figure Code	Season	Model	Item	Tide Condition	Phase	Layer
NE_TP_METP_ALL_DIF(F)_B	NE	TP	METP - Mean excess temperature	ALL - For all (30 days)	DIF(F) - Difference	B - Bottom
NE_TP_MXTP_ALL_DIF(F)_B	NE	TP	MXTP - Max excess temperature	ALL - For all (30 days)	DIF(F) - Difference	B - Bottom
NE_TP_METP_ALL_DIF(F)_S	NE	TP	METP - Mean excess temperature	ALL - For all (30 days)	DIF(F) - Difference	S - Surface
NE_TP_MXTP_ALL_DIF(F)_S	NE	TP	MXTP - Max excess temperature	ALL - For all (30 days)	DIF(F) - Difference	S - Surface
NE_TP_PEX2_ALL_DIF(F)_B	NE	TP	PEX2 - Percentage time of excess temperature above +2 degree C	ALL - For all (30 days)	DIF(F) - Difference	B - Bottom
NE_TP_PEX2_ALL_DIF(F)_S	NE	TP	PEX2 - Percentage time of excess temperature above +2 degree C	ALL - For all (30 days)	DIF(F) - Difference	S - Surface
SW_TP_METP_ALL_DIF(F)_B	SW	TP	METP - Mean excess temperature	ALL - For all (30 days)	DIF(F) - Difference	B - Bottom
SW_TP_MXTP_ALL_DIF(F)_B	SW	TP	MXTP - Max excess temperature	ALL - For all (30 days)	DIF(F) - Difference	B - Bottom
SW_TP_METP_ALL_DIF(F)_S	SW	TP	METP - Mean excess temperature	ALL - For all (30 days)	DIF(F) - Difference	S - Surface
SW_TP_MXTP_ALL_DIF(F)_S	SW	TP	MXTP - Max excess temperature	ALL - For all (30 days)	DIF(F) - Difference	S - Surface
SW_TP_PEX2_ALL_DIF(F)_B	SW	TP	PEX2 - Percentage time of excess temperature above +2 degree C	ALL - For all (30 days)	DIF(F) - Difference	B - Bottom
SW_TP_PEX2_ALL_DIF(F)_S	SW	TP	PEX2 - Percentage time of excess temperature above +2 degree C	ALL - For all (30 days)	DIF(F) - Difference	S - Surface

A3.1 NE Monsoon

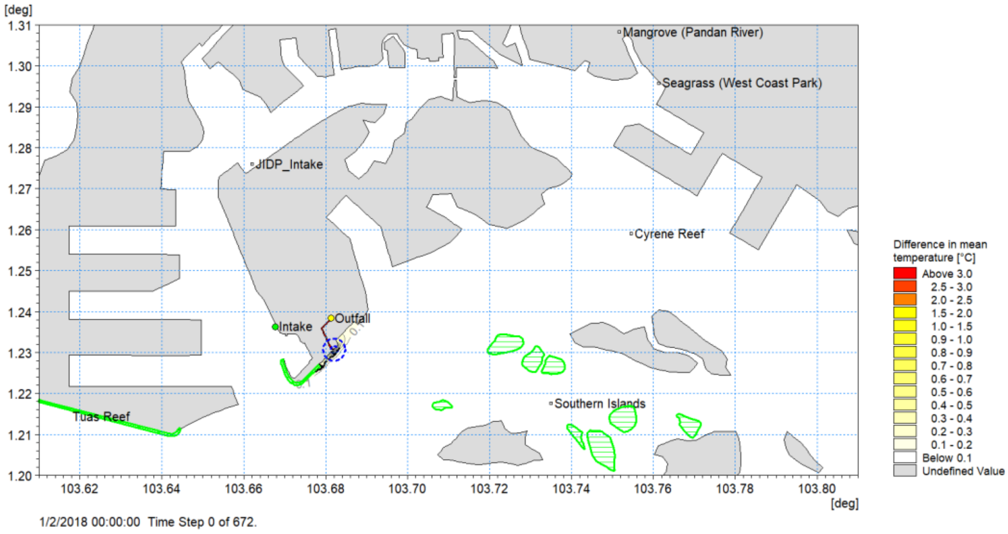
NE_TP_METP_ALL_DIF(F)_B



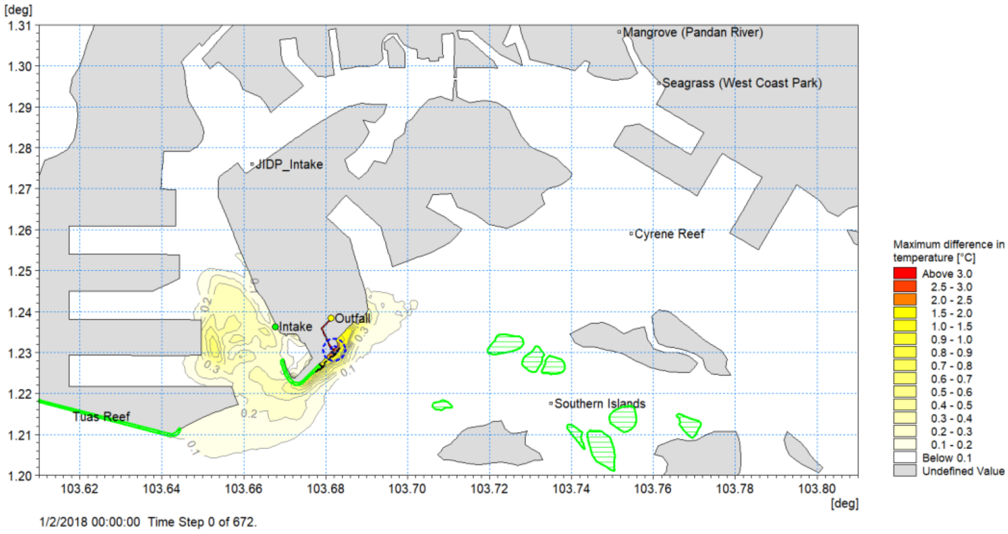
NE_TP_MXTP_ALL_DIF(F)_B



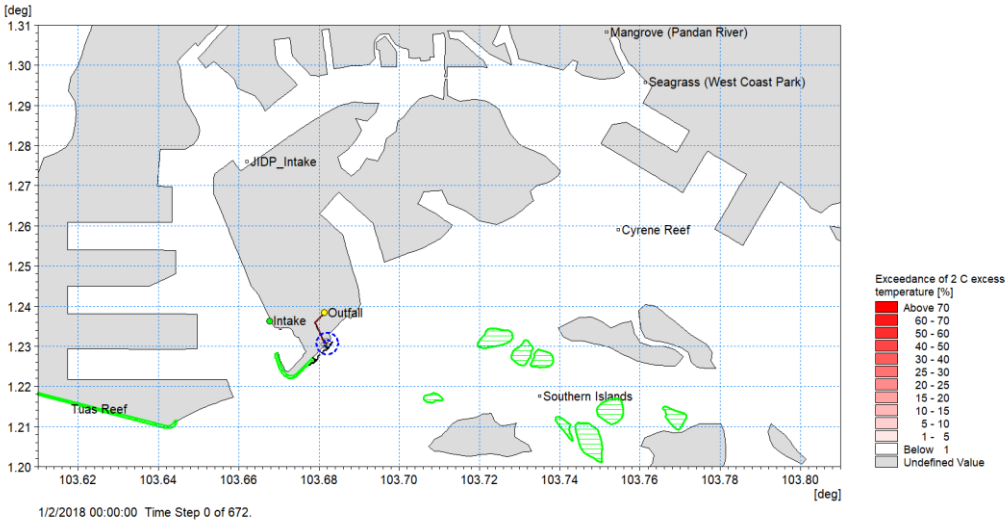
NE_TP_METP_ALL_DIF(F)_S



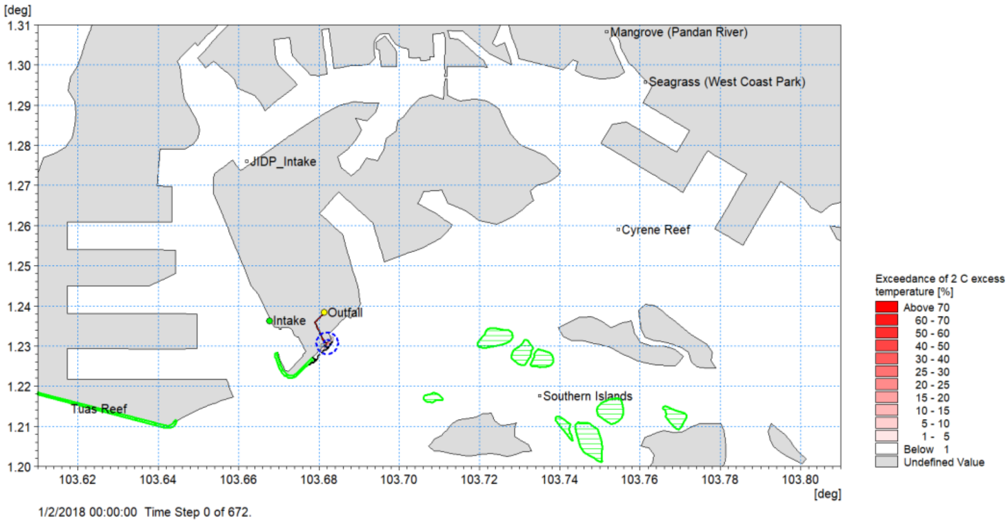
NE_TP_MXTP_ALL_DIF(F)_S



NE_TP_PEX2_ALL_DIF(F)_B

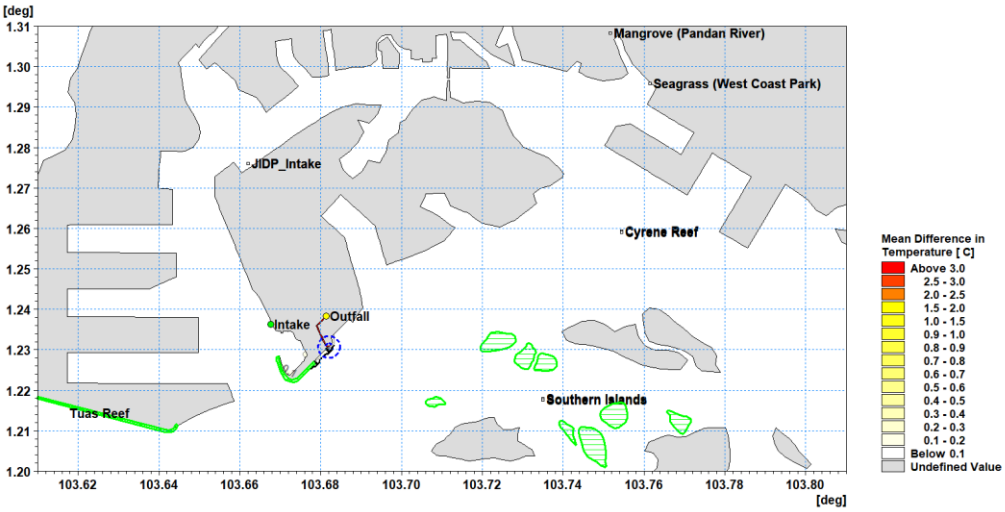


NE_TP_PEX2_ALL_DIF(F)_S

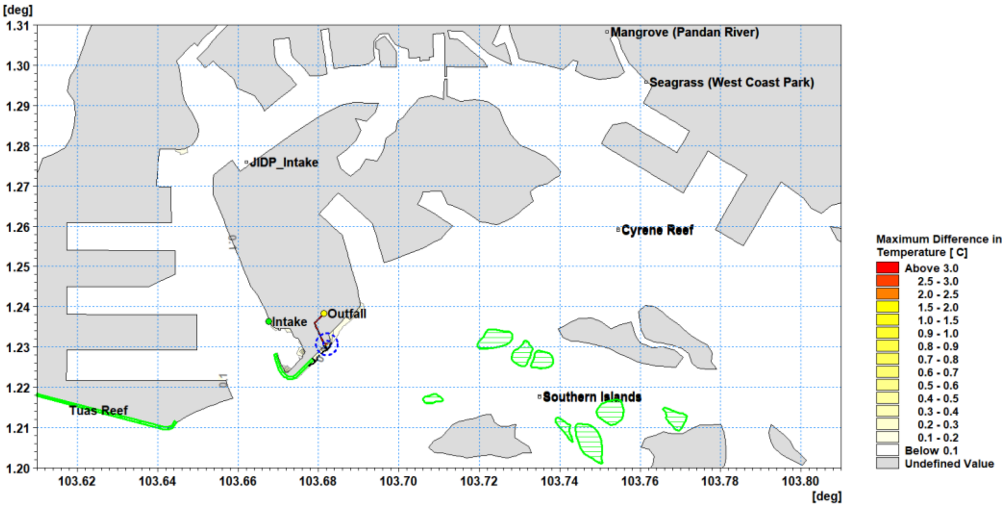


A3.2 SW Monsoon

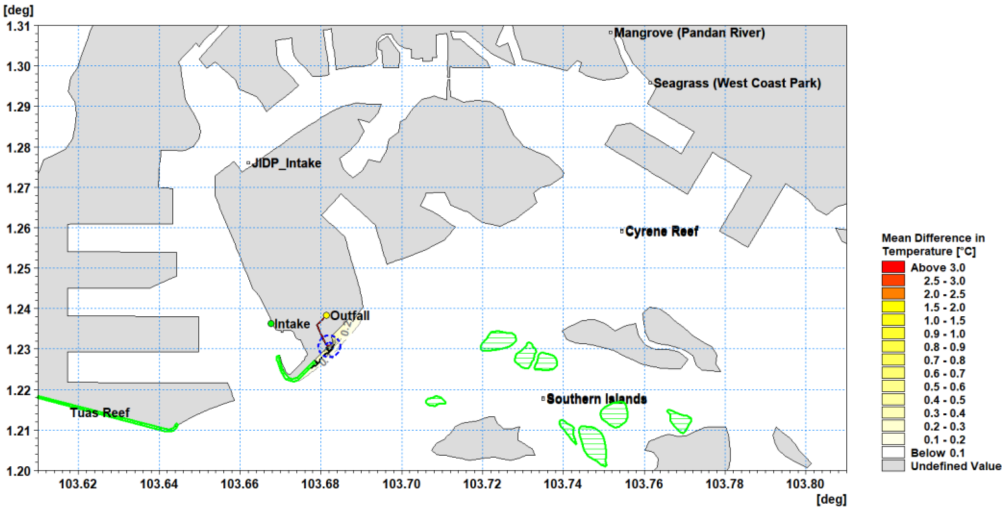
SW_TP_METP_ALL_DIF(F)_B



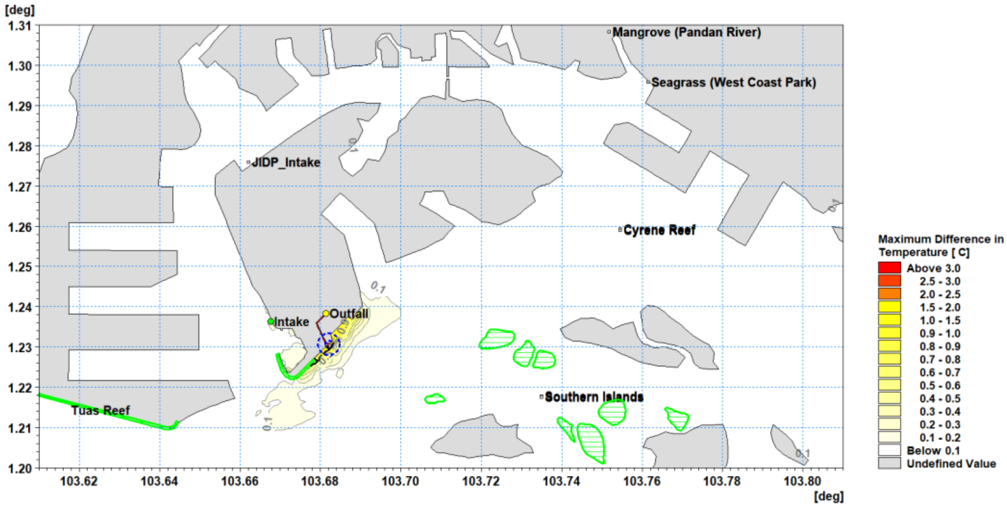
SW_TP_MXTP_ALL_DIF(F)_B



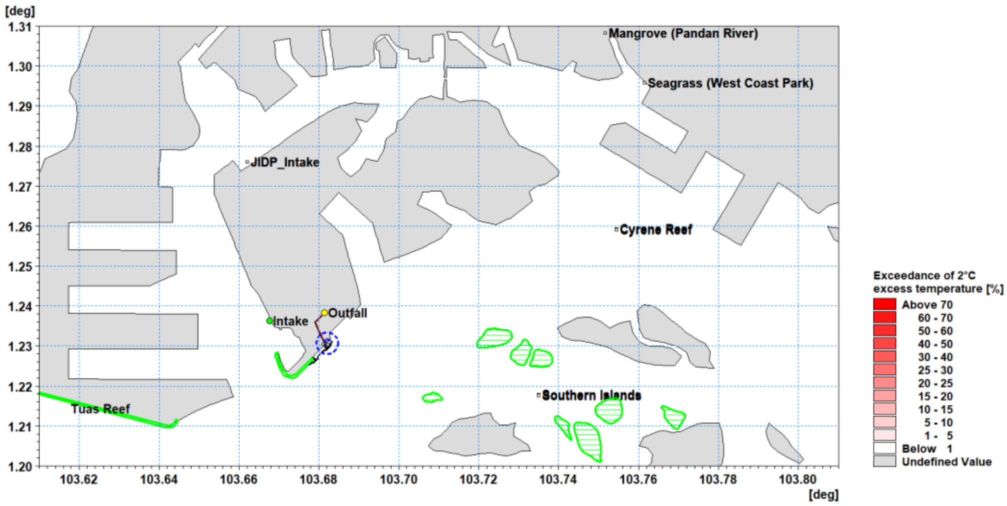
SW_TP_METP_ALL_DIF(F)_S



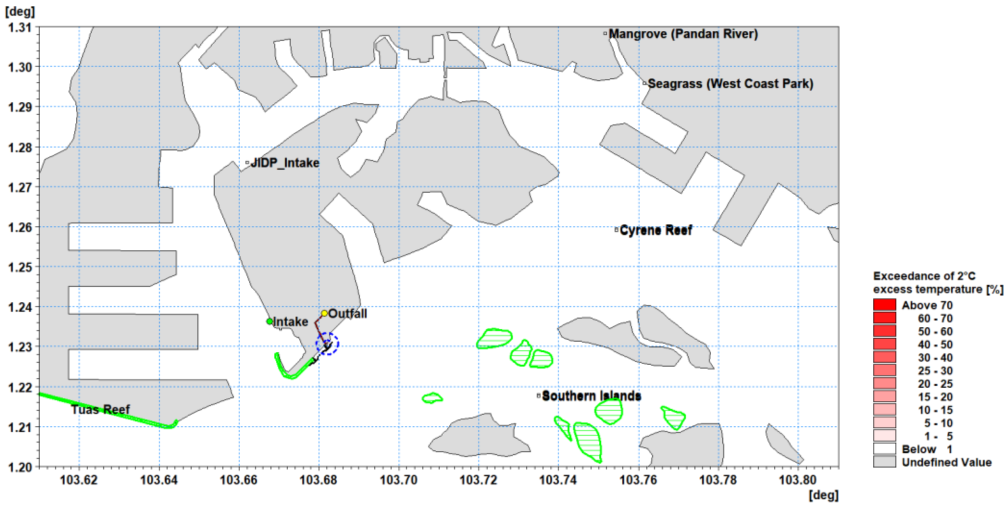
SW_TP_MXTP_ALL_DIF(F)_S



SW_TP_PEX2_ALL_DIF(F)_B



SW_TP_PEX2_ALL_DIF(F)_S

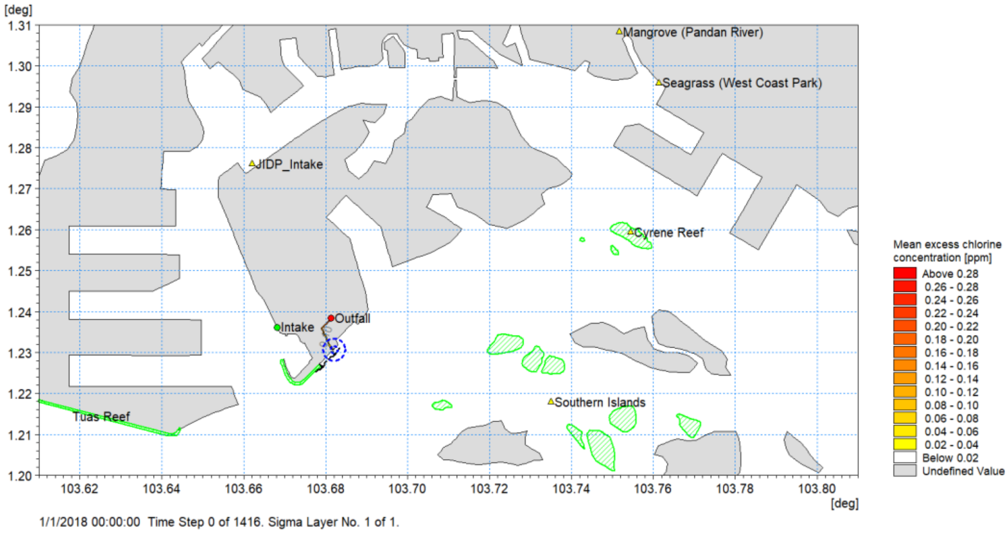


A4 Chlorine Plume (CP) modelling outputs

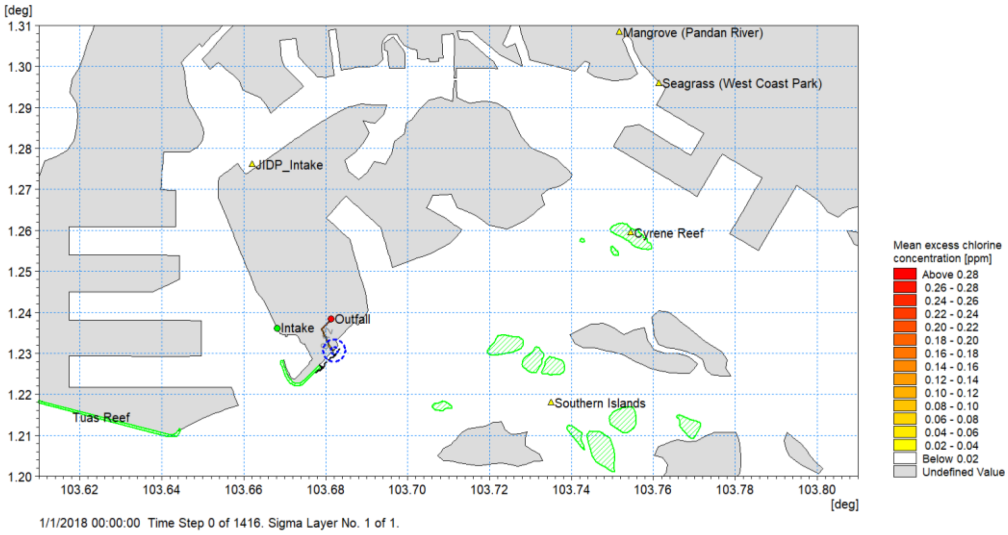
Figure Code	Season	Model	Item	Tide Condition	Phase	Layer
NE_CP_MECP_ALL_DIF_B	NE	CP	MECP - Mean excess chlorine	ALL - For all (30 days)	DIF - Difference	B - Bottom
NE_CP_MECP_ALL_DIF_S	NE	CP	MECP - Mean excess chlorine	ALL - For all (30 days)	DIF - Difference	S - Surface
NE_CP_MXCP_ALL_DIF_B	NE	CP	MXCP - Maximum excess chlorine	ALL - For all (30 days)	DIF - Difference	B - Bottom
NE_CP_MXCP_ALL_DIF_S	NE	CP	MXCP - Maximum excess chlorine	ALL - For all (30 days)	DIF - Difference	S - Surface
NE_CP_PECP_ALL_DIF_B	NE	CP	PECP- Percentage exceedance of 0.013ppm of excess chlorine	ALL - For all (30 days)	DIF - Difference	B - Bottom
NE_CP_PECP_ALL_DIF_S	NE	CP	PECP - Percentage exceedance of 0.013ppm of excess chlorine	ALL - For all (30 days)	DIF - Difference	S - Surface
SW_CP_MECP_ALL_DIF_B	SW	CP	MECP - Mean excess chlorine	ALL - For all (30 days)	DIF - Difference	B - Bottom
SW_CP_MECP_ALL_DIF_S	SW	CP	MECP - Mean excess chlorine	ALL - For all (30 days)	DIF - Difference	S - Surface
SW_CP_MXCP_ALL_DIF_B	SW	CP	MXCP - Maximum excess chlorine	ALL - For all (30 days)	DIF - Difference	B - Bottom
SW_CP_MXCP_ALL_DIF_S	SW	CP	MXCP - Maximum excess chlorine	ALL - For all (30 days)	DIF - Difference	S - Surface
SW_CP_PECP_ALL_DIF_B	SW	CP	PECP- Percentage exceedance of 0.013ppm of excess chlorine	ALL - For all (30 days)	DIF - Difference	B - Bottom
SW_CP_PECP_ALL_DIF_S	SW	CP	PECP - Percentage exceedance of 0.013ppm of excess chlorine	ALL - For all (30 days)	DIF - Difference	S - Surface

A4.1 NE Monsoon

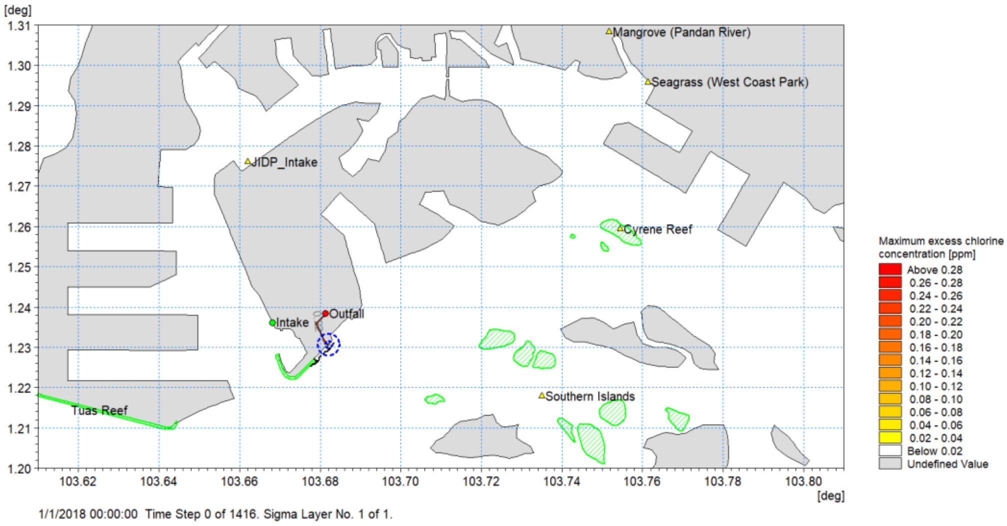
NE_CP_MECP_ALL_DIF_B



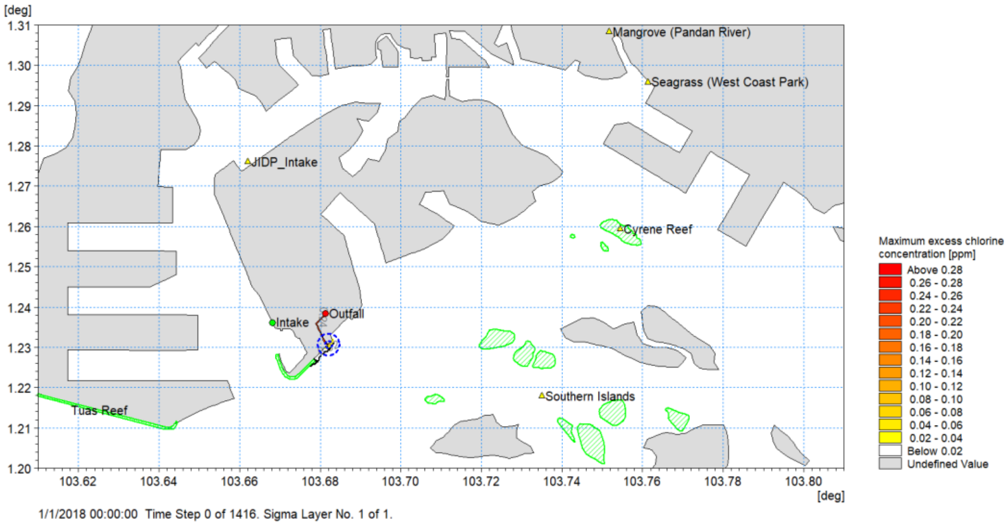
NE_CP_MECP_ALL_DIF_S



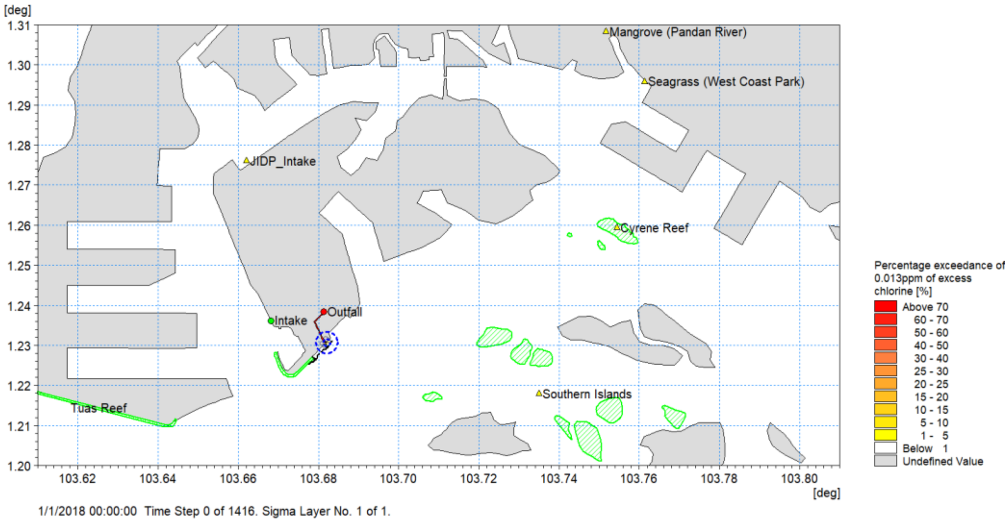
NE_CP_MXCP_ALL_DIF_B



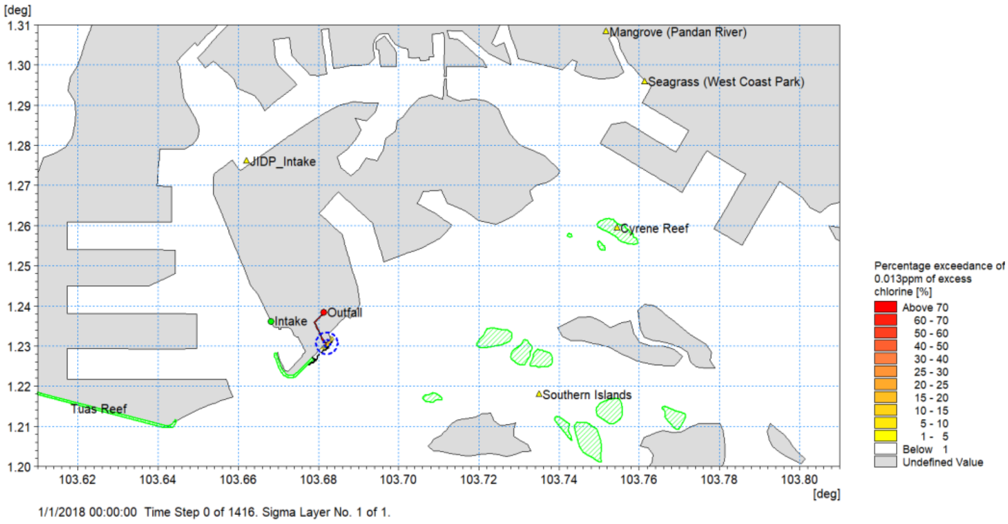
NE_CP_MXCP_ALL_DIF_S



NE_CP_PECP_ALL_DIF_B



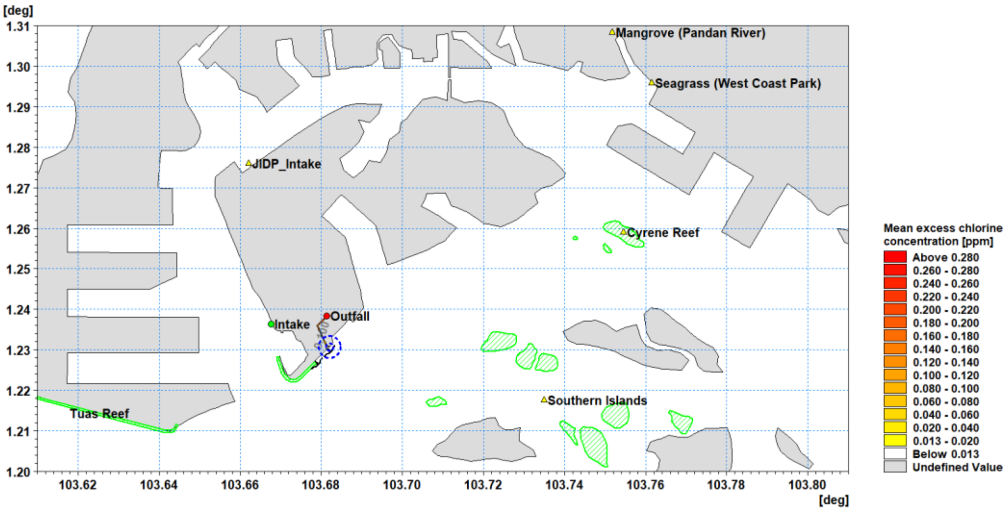
NE_CP_PECP_ALL_DIF_S



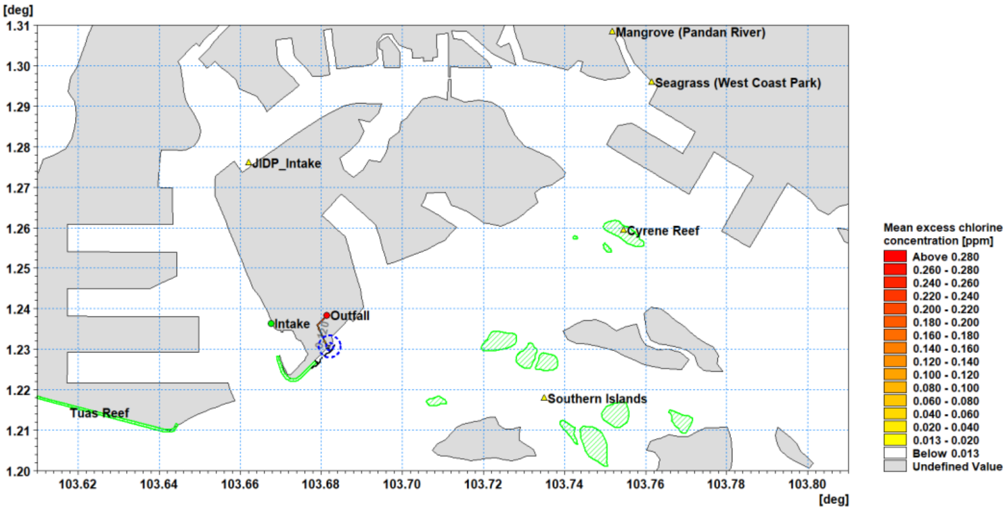
Haskoning
Enhancing Society Together

A4.2 SW Monsoon

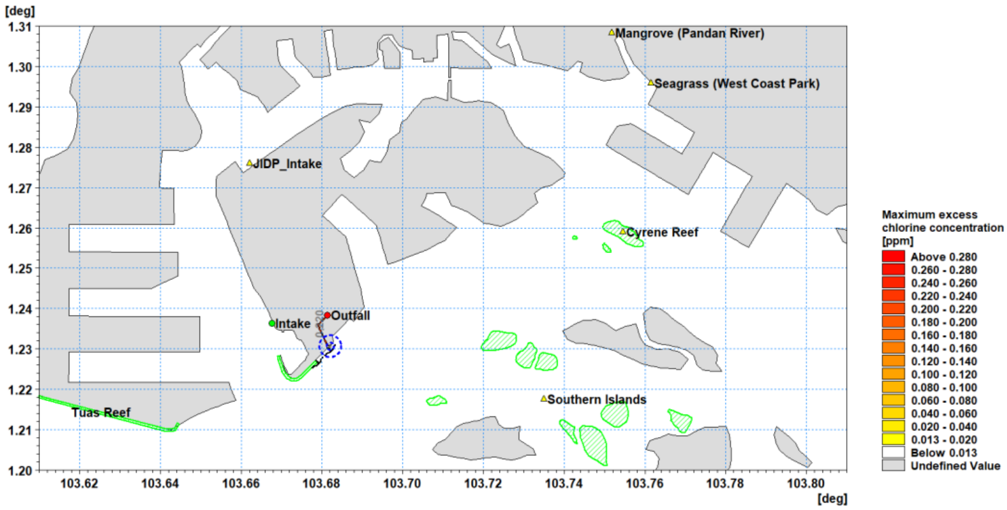
SW_CP_MECP_ALL_DIF_B



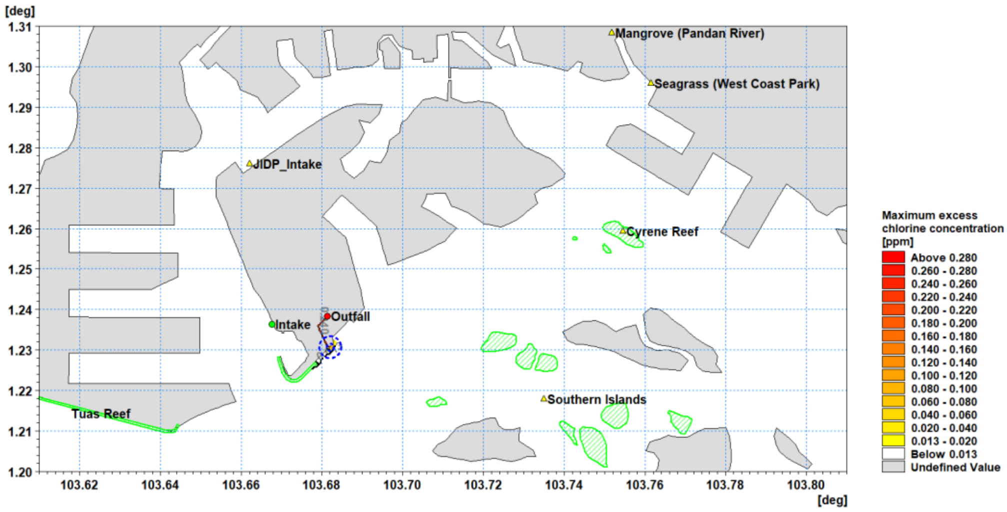
SW_CP_MECP_ALL_DIF_S



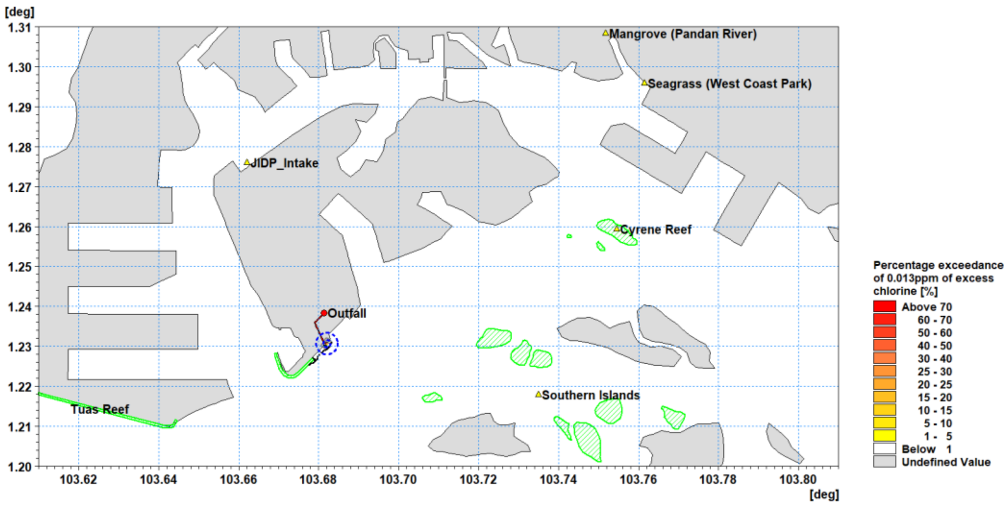
SW_CP_MXCP_ALL_DIF_B



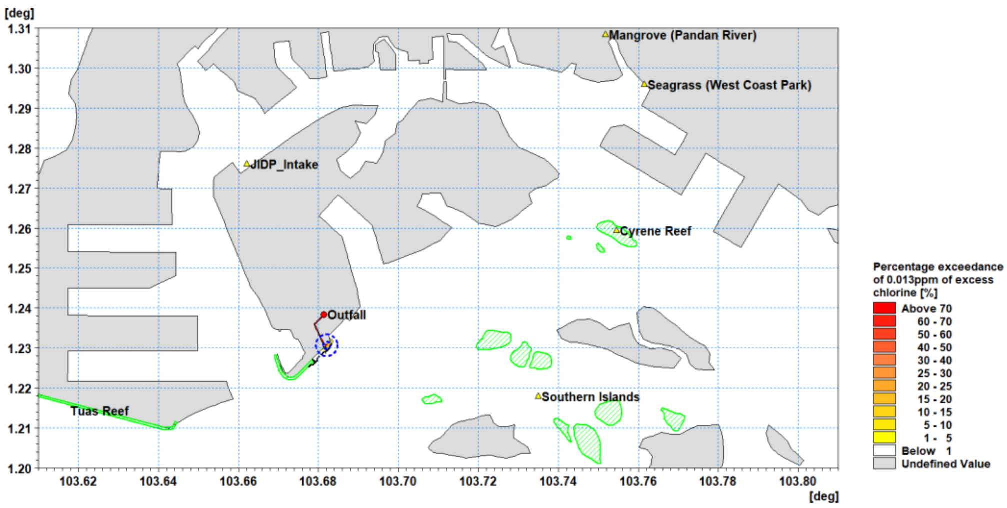
SW_CP_MXCP_ALL_DIF_S



SW_CP_PECP_ALL_DIF_B



SW_CP_PECP_ALL_DIF_S



ERM has over 160 offices across the following countries and territories worldwide

Argentina
Australia
Belgium
Brazil
Canada
Chile
China
Colombia
France
Germany
Ghana
Guyana
Hong Kong
India
Indonesia
Ireland
Italy
Japan
Kazakhstan
Kenya
Malaysia
Mexico
Mozambique
Myanmar

The Netherlands
New Zealand
Norway
Panama
Peru
Poland
Portugal
Puerto Rico
Romania
Russia
Senegal
Singapore
South Africa
South Korea
Spain
Sweden
Switzerland
Taiwan
Tanzania
Thailand
UAE
UK
US
Vietnam

ERM Singapore

20 Collyer Quay,
#15-01/02
Singapore
049319

T: +65 6324 9636

www.erm.com

Sustainability is our business

ERM