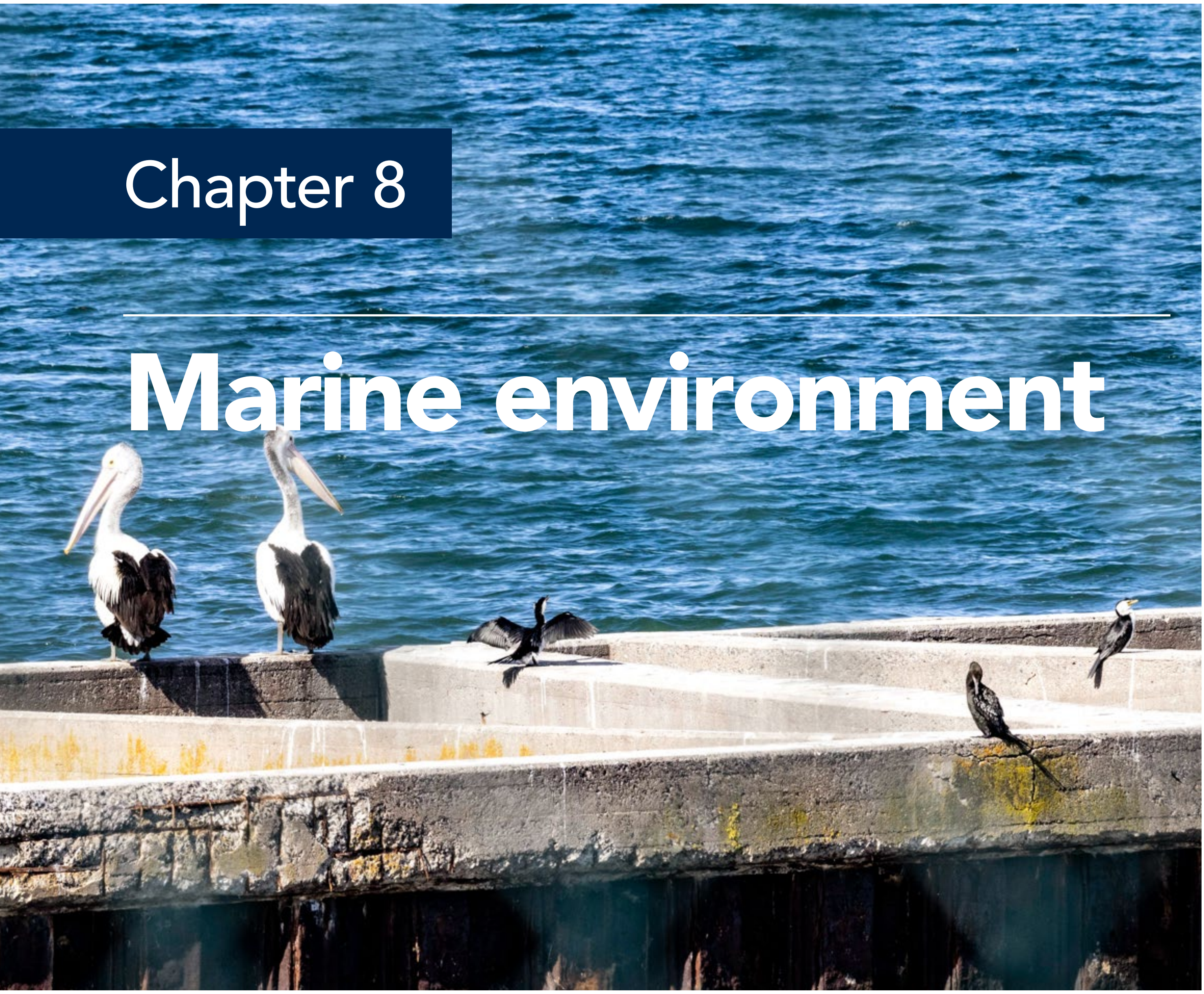
Chapter 8

Marine environment



This chapter provides an assessment of the potential impacts on marine ecology and water quality associated with the construction and operation of the Viva Energy Gas Terminal Project (the project) and summarises the outcomes of Technical Report A: *Marine ecology and water quality impact assessment.*

Potential impacts on terrestrial ecology including migratory waders and shorebirds are discussed in Chapter 10: *Land environment* and Technical Report D: *Terrestrial ecology impact assessment*.

8.1 Overview

Corio Bay is the largest internal bay within Port Phillip Bay, located in the south-western corner and covering an area of 4,300 hectares. The Point Wilson / Limeburners Bay section of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site is located approximately one kilometre to the north of the proposed location of the floating storage and regasification unit (FSRU) on the northern shore of Corio Bay. The project area does not directly intersect or overlap the Ramsar site.

Field investigations were carried out over a 12-month period to understand the baseline conditions of the marine environment. Field investigations included current, temperature and water quality monitoring, assessment of bathymetry, surveys of the seabed habitat and plankton and larvae surveys. The seabed and shoreline of Corio Bay have been substantially modified over the last 170 years with shipping channels being dredged, the western shoreline being established for industrial uses, the Port of Geelong being developed, and seawalls, marinas and jetties constructed as part of Geelong's urbanisation. Despite these developments, field investigations indicate that Corio Bay has good water quality and a diverse range of marine life that has adapted to the existing conditions of the Bay. Corio Bay has a dynamic and self-sustaining ecosystem which includes approximately 1,000 species of plants and animals.

Project activities have the potential to impact the surrounding marine environment during construction and operation of the project. The potential impacts could include direct impacts on marine biota, changes to the chemical or physical attributes of the marine environment and indirect effects on habitat conditions, biota and the ecological character of Corio Bay, including the Point Wilson / Limeburners Bay section of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site. Understanding how the project could impact the marine environment is an important step in developing effective and appropriate measures to avoid, minimise and manage potential impacts.

8.1.1 Construction

Localised dredging, excavation of a trench for installation of the seawater transfer pipe, construction of a temporary loadout facility at Lascelles Wharf and construction of the extension to Refinery Pier have the potential to cause impacts to the marine environment during the construction phase of the project. Potential impacts related to these activities, such as turbidity, light attenuation, habitat modification and underwater noise would be temporary and localised and would not result in significant impacts to nearby populations and communities. It is likely that any altered conditions (e.g., turbidity, light availability) would return to original conditions within a short period of time after the construction activity ceases.

These potential impacts would be managed through implementation of the recommended mitigation measures such as avoiding dredging during spring when marine productivity is highest; installation of a silt curtain to minimise turbidity in the water column near seagrass beds and at the refinery seawater intake; and turbidity, seabed and plankton monitoring.

8.1.2 Operation

For over 60 years, Viva Energy's Geelong Refinery has been using up to 350 megalitres (ML) per day of seawater from Corio Bay for cooling purposes. This seawater is then discharged to Corio Bay at temperatures warmer than the ambient seawater temperature and with residual levels of chlorine associated with biofouling control through four EPA licensed discharge outlets. The project would also require the use of seawater for liquified natural gas (LNG) heating purposes as part of operation of the FSRU. This provides a beneficial synergy between the project and the adjacent refinery.

The reuse of seawater from the project in the refinery during operation means there would be no change to the maximum volume of water drawn from Corio Bay (350 ML/day) and residual chlorine concentrations in the discharge would remain

the same. However, while still above the ambient seawater temperature, the reuse of the cooled water from the FSRU in the refinery would result in a reduced temperature differential in the seawater discharge back into Corio Bay.

The reuse of the FSRU water in the refinery as cooling water during project operation would result in no change to the total volume of seawater extracted from Corio Bay, no change to the volume of water discharged from the refinery, no change in residual chlorine levels and an improvement in the temperature of the discharge compared to the existing refinery discharge. As the refinery discharge has been occurring for more than 60 years, the EES studies were able to assess empirical evidence of potential effects associated with the chlorine and temperature levels.

The field surveys did not identify evidence of negative impacts on marine ecology under the existing refinery discharge plumes which have been occurring over the last 60 years. Seagrass in the vicinity of the plume was observed to be abundant and healthy; sea urchins, which are considered to be sensitive to chlorine, were abundant in the current discharge plume; and tests on mussels from the vicinity showed no detectable residual chlorine. As such, this empirical evidence provides confidence that it would be highly unlikely that there would be adverse impacts on the marine environment from operation of the FSRU and reuse in the refinery as the proposed discharge is an overall improvement when compared within the quality of the existing discharge.

An alternative discharge arrangement for the project, and assessed in the EES, would involve direct discharge of some, or all, of the cooled FSRU discharge water into Corio Bay via a diffuser located under the Refinery Pier extension. The diffuser could be used during refinery maintenance periods when the rate of FSRU discharge could exceed the refinery demand for seawater and would be used in the event that the refinery was permanently decommissioned in the future and the option for reuse of the FSRU discharge water was no longer available. As the diffuser would be designed to achieve high dilution, modelling shows that the resulting chlorine and temperature plumes on the seabed would be localised within the shipping channel and well below temperature and chlorine guideline limits.

The project would result in a slight increase to the proportion of plankton entrained in the FSRU water intake from the Ramsar site and northern and southern Corio Bay compared to the current refinery intake. However, these entrainment rates are considered low to negligible in comparison to natural predation and other losses.

Other potential impacts to the marine environment during operation such as spills of fuels and chemicals, additional light spill, vessel strikes with wildlife, vessel grounding, turbidity from tugs and imported pests were assessed and mitigation measures proposed to avoid and minimise adverse impacts to the marine environment.

8.1.3 Residual impacts and monitoring

With the adoption of proposed mitigation measures, construction and operation of the project is considered unlikely to result in significant residual impacts to the marine environs of Corio Bay, threatened marine fauna or to the ecological character of the Ramsar site. Residual impacts due to construction would include a localised reduction in primary productivity of phytoplankton for a short duration, and the loss of infauna (animals living in sediment) in the dredged area until they re-establish. Residual impacts due to operation of the FSRU are not considered to be significant given the marine discharge would remain largely the same as current refinery operations, and no adverse impacts on seagrass or marine biota have been detected from over 60 years of existing operations.

Further, monitoring would inform if contingency actions are required to avoid or respond to potential significant impacts on the marine environment. A monitoring program is proposed during dredging to monitor turbidity and light attenuation, seabed biota in the dredged area and Point Wilson dredged material ground (DMG), and plankton during and after dredging. Monitoring would also be undertaken for the rates and characteristics of all FSRU wastewater discharges, either from the refinery or directly to Corio Bay, to confirm that the discharge rate, temperature and chlorine concentration are within the values stipulated in the licence conditions of the refinery EPA Licence (held by Viva Energy Refining Pty Ltd) and the FSRU EPA Licence and, if not, provide the trigger for remedial action.

8.2 EES evaluation objective

The scoping requirements provided by the Minister for Planning for the project set out the specific environmental matters to be investigated and documented in the project's Environment Effects Statement (EES). The scoping requirements inform the extent and scope of the EES technical studies. The Minister identified marine ecology and water quality as a primary area of assessment for the EES as the project was considered to have the potential for significant adverse effects on the marine environment of Corio Bay, including marine water quality.

The following EES evaluation objectives are relevant to the marine ecology and water quality impact assessment:

Evaluation objective
Biodiversity
To avoid, minimise or offset potential adverse effects on native flora and fauna and their habitats, especially listed threatened or migratory species and listed threatened communities as well as on the marine environment, including intertidal and marine species and habitat values
Water and catchment values
To minimise adverse effects on water (in particular wetland, estuarine, intertidal and marine) quality and movement, and to the ecological character of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site.

Technical Report A: *Marine ecology and water quality impact assessment* prepared in support of the EES provides more detailed information on the investigations and impact assessments conducted in response to the EES scoping requirements.

8.3 Methodology

To determine the potential impacts on the marine environment from the project, the following approach was adopted for the marine ecology and water quality impact assessment:

- Characterisation of the existing marine environment within Corio Bay through a desktop review of relevant literature and online databases and a 12-month marine monitoring program
- A risk screening at the outset of the project using the methodology outlined in Chapter 7: *Assessment framework* to identify potential risks to the marine environment and inform the impact assessment and the level of investigation required
- Assessment of potential impacts during construction and operation of the project, including near-field and regional hydrodynamic modelling
- Development of mitigation measures (MM), discussed in **Section 8.12**, in response to identified potential impacts focused on elimination or avoidance of the potential impact where possible, or mitigation through measures incorporated into design, construction, and operation
- Evaluation of the residual environmental impacts which are those remaining once mitigation has been implemented.

8.4 Existing conditions

This section provides an overview of the existing marine environment within Corio Bay, including where the refinery has been discharging seawater used for cooling water purposes for over 60 years through four EPA licensed discharge outlets. The purpose of the section is to describe the marine environmental context for the proposed project and to describe baseline conditions that were used for the marine ecology and water quality impact assessment.

In addition to desktop assessments, a 12-month marine monitoring program was undertaken to develop an understanding of the existing conditions and inform the development, calibration and verification of the hydrodynamic models used to predict potential impacts. The marine monitoring program also enabled the collection of empirical data about the effects of temperature and chlorine discharges on Corio Bay through investigations of the marine environment at the existing refinery discharge plumes.

8.4.1 Study area

The study area for the marine ecology and water quality impact assessment considered all of Corio Bay as well as the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site (Ramsar site) with a focus on the marine environment surrounding the project site at Refinery Pier.

8.4.2 Overview of Corio Bay

Corio Bay is the largest internal bay within Port Phillip Bay, located in the south-western corner and covering an area of 4,300 hectares. The bathymetry of Corio Bay is characterised by a shallow perimeter and a deeper section over the centre of the Bay. **Figure 8-1** shows the bathymetric contours of Corio Bay.

The northern shoreline along the Ramsar site has shallow water, of less than 5 metres (m) that extends up to 900 m from the shoreline. This area has dominant seagrass beds and small rocky reefs.

A sand bar runs across the east entrance of the Bay between Point Lillias and Point Henry with water depths of 2 to 5 m. The Hopetoun Channel was first dredged in the 1850s through this sandbar from Port Phillip Bay to provide access to the piers and wharfs along the western shore that form the Port of Geelong. The channel is approximately 140 m wide and is maintained to a depth of 12.3 m. The Corio Channel extends north from the Hopetoun Channel up to Refinery Pier, and is also maintained at a depth of 12.3 m.

In the south-eastern corner of the Bay, the 5m depth contour is approximately 3 km offshore creating a large shallow area with extensive seagrass. In comparison, the south-western corner of the bay has a much steeper gradient with the 5 m depth contours only 300 m from shore. The central section of the bay is a broad and mostly flat zone with depths of 6 to 9 m. The average depth of Corio Bay is 7 m.

What is a Ramsar site?

A Ramsar site is a wetland designated to be of international importance under the Ramsar Convention, also known as 'The Convention on Wetlands of International Importance' signed in Ramsar, Iran on 2 February 1971.

Wetlands are a critical part of our natural environment. They protect our shores from wave action, reduce the impacts of floods, absorb pollutants and improve water quality. They provide habitat for animals and plants and many contain a wide diversity of life, supporting plants and animals that are found nowhere else. Ramsar wetlands are those that are representative, rare or unique wetlands, or are important for conserving biological diversity.

Australia has 66 Ramsar sites that cover more than 8.3 million hectares. The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site is located approximately one kilometre to the north of the project.

What is bathymetry?

Bathymetry is essentially the underwater equivalent to mapping topography on land. It is the study of the sea floor and underwater depth of oceans, seas or lakes. It involves the measuring of ocean or water depth.

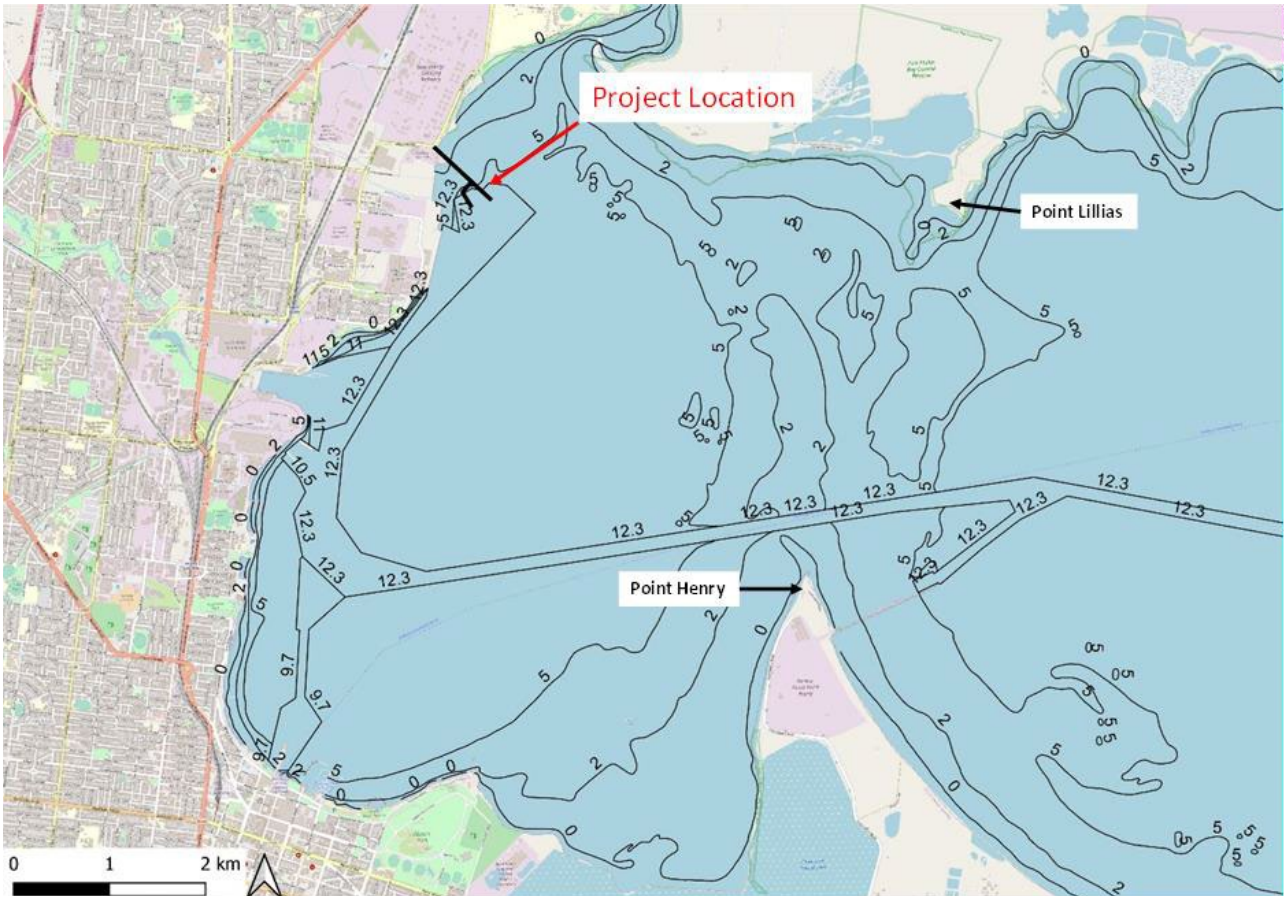


Figure 8-1 Corio Bay bathymetry

Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site

The Ramsar site is located on the western shoreline of Port Phillip Bay between Melbourne and Geelong and on the Bellarine Peninsula, as shown in **Figure 8-2**. The Ramsar site covers 22,650 hectares and comprises six distinct areas, with the Point Wilson/ Limeburners Bay section located within Corio Bay approximately 1.3 kilometres to the north of the proposed FSRU and Refinery Pier extension. Limeburners Bay is approximately 1.6 kilometres to the north of the FSRU.

The criteria under which a Ramsar site can be designated have gone through a series of changes. The most recent assessment of the Ramsar site against the criteria indicated that, at the time of listing in 1982, the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site would have met 6 of the 9 criteria including:

- Criterion 2: supports vulnerable, endangered, or critically endangered species or threatened ecological communities
- Criterion 3: supports populations of plant and/ or animal species important for maintaining the biological diversity of a particular biogeographic region
- Criterion 4: supports plant and/or animal species at a critical stage in their lifecycles or provides refuge during adverse conditions
- Criterion 5: regularly supports 20,000 or more waterbirds
- Criterion 6: regularly supports 1% of the individuals in a population of one species or subspecies of waterbird
- Criterion 8: an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

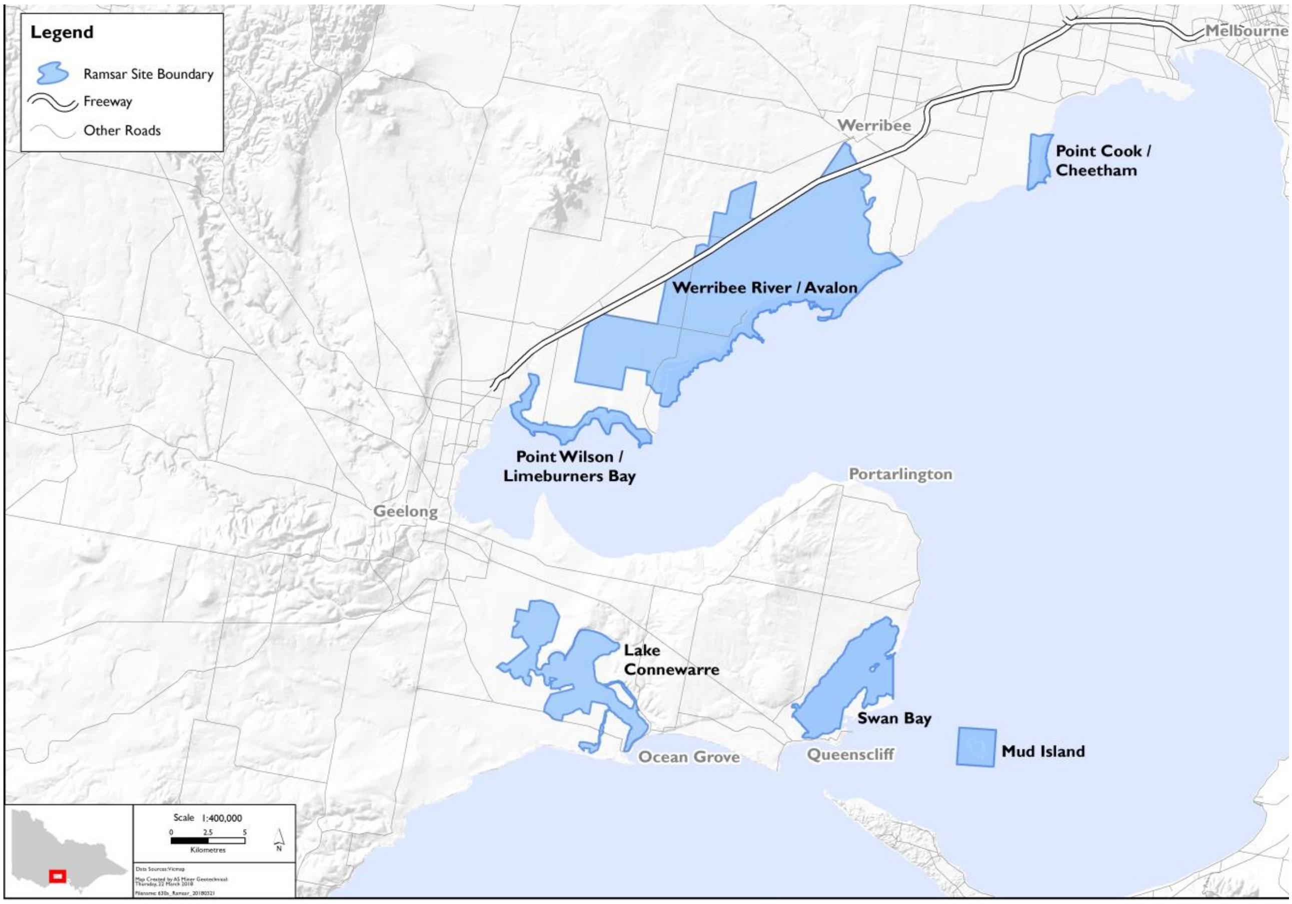


Figure 8-2 Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site)

The Ecological Character Description for the Ramsar site has identified a number of components, processes and services (CPS) that are considered critical to the ecological character of the site. These are briefly described below.

Hydrology

There are two aspects to the hydrology in the Ramsar site that are considered critical to ecological character: the interactions between freshwater flows and tidal exchange in the Lake Connewarre Complex and the artificial water regimes of the Western Treatment Plant and the Cheetham Wetlands. The hydrology of the Point Wilson/ Limeburners Bay area is comprised of tides and river flows as it is a coastal/marine area, with Hovells Creek also forming part of this area of the Ramsar site.

Saltmarsh

Each of the six areas that form the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site contain coastal saltmarsh, with a total area of 1,225 hectares within the Ramsar site boundary (Boon *et al.*, 2011 in DELWP, 2018). Saltmarsh occupies the area of the site between seagrass and terrestrial vegetation at higher elevation.

Coastal saltmarsh is listed as a vulnerable ecological community under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and is important habitat for fish when inundated as well as for feeding and roosting waterbirds when tides are low.

The Ramsar site contains a small area of saltmarsh in Limeburners Bay.

Seagrass

Seagrass is an important component of the ecological character of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site at three areas: Point Wilson / Limeburners Bay; Swan Bay and Mud Islands. Around the time of listing, there was approximately 2,500 hectares of seagrass. There are 3 species of seagrass in Port Phillip Bay which are a feature within the Ramsar site:

- *Zostera nigricaulis* – occurs only in subtidal areas where exposure to air is limited.
- *Zostera muelleri* – generally occurs in the intertidal zone, requiring periods of exposure to maintain health and growth
- *Halophila ovalis* – occurs generally in deeper water with patches around Point Wilson, but there are few deep water areas within the Ramsar boundary.

Mangroves

The mangrove areas of Port Phillip Bay comprise a single species, *Avicennia marina* and there are small areas of this mangrove species in Limeburners Bay (4 hectares). The inundated roots and pneumatophores of mangroves provide good habitat for fish and invertebrates and play a role in stabilising the soft sediments in the site.

Fish diversity and abundance

The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site provides a variety of habitats for fish ranging from freshwater species as well as estuarine and marine species in seagrass and saltmarsh habitats. Over 60 species of marine and estuarine fish have been recorded in saltmarsh and seagrass habitats of the Ramsar site. The seagrass areas are home to a large number of pipefish (which are listed as marine under the EPBC Act, the most common of which is the spotted pipefish (*Stigmatopora argus*).

Waterbird diversity and abundance

A total of 154 waterbird species have been recorded within the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site and the site regularly supports 20 species of waders from the East Asian-Australasian Flyway listed under the international migratory bird agreements Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA). The Ramsar site supports very large numbers of shorebirds across all six areas. In addition to shorebirds, the site provides habitat for a variety of waterbird groups or guilds including ducks and swans; grebes; large wading birds such as herons, ibis and spoonbills; gulls and fish-eating birds such as cormorants, pelicans and terns.

Waterbird breeding

The Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site is important for waterbird breeding for a wide variety of species. The most significant waterbird breeding location in the site is Mud Islands which is not within the project study area.

Breeding has been recorded for at least 49 species of wetland dependent birds. Beach nesting species (red-capped plover, Australian pied oyster catchers) breed at Cheetham Wetlands and on Mud Islands. A number of waterfowl and an established colonial nesting colony dominated by pied cormorants are supported at the Western Treatment Plant. Mud Islands also supports very large numbers of colonial nesting species with combined totals of greater than 100,000 nests.

8.4.3 Tides of Corio Bay

The astronomical tides in Corio Bay are semi-diurnal with a diurnal inequality meaning there are approximately two tidal cycles each day with one having a larger range than the other. Corio Bay has a small tidal range, particularly for neap tides.

The tides at Corio Bay range from 0.58m below mean sea level (MSL) at the lowest astronomical tide (LAT) to 0.66m above MSL at the highest astronomical tide (HAT). **Table 8-1** shows the tidal level at Corio Bay from the Australian National Tide Tables (2008). There is a large difference between the spring and neap tide ranges, with the spring tide range at 1.0m, and the neap tide range is only 0.2m.

Table 8-1 Tide ranges at Port of Geelong

<table>
<tr><th>Tide level</th><th colspan="3">Height (m)</th></tr>
<tr><td>Highest astronomical tide (HAT)</td><td>0.66</td><td></td><td></td></tr>
<tr><td>Mean high water spring (MHWS)</td><td>0.5</td><td rowspan="5">Spring tide = 1.0m</td><td></td></tr>
<tr><td>Mean high water neap (MHWN)</td><td>0.1</td><td rowspan="3">Neap Tide = 0.2m</td></tr>
<tr><td>Mean sea level (MSL)</td><td>0.0</td></tr>
<tr><td>Mean low water neap (MLWN)</td><td>- 0.1</td></tr>
<tr><td>Mean low water spring (MLWS)</td><td>-0.5</td><td></td></tr>
<tr><td>Lowest astronomical tide (LAT)</td><td>-0.58</td><td></td><td></td></tr>
</table>

Astronomical tides

Semidiurnal tides have a cycle of approximately half of one tidal day (about 12.5 hours). Semidiurnal tides usually have two high and two low tides each day.

Spring tides occur during full moon and new moon phases, when the moon and sun are aligned. This causes higher high tides and lower low tides than what are usually seen throughout the month. Spring tides occur twice a month.

Neap tides occur seven days after a spring tide, when the sun and moon are at right angles to each other. This causes moderate tides, where high tides a little lower and low tides are a little higher than average. Neap tides occur during the first and third quarter moon phases.

The seawater volume entering and leaving Corio Bay on a spring tide is 43 million m^3 which is about 14% of the volume of seawater in Corio Bay. Therefore, there is a significant daily exchange of water through the shipping channel between Corio Bay and the Outer Harbour on the western side of Port Phillip Bay.

The tidal water movement generates turbulence which causes mixing over the depth and horizontally. This allows species to spread throughout the bay, even though they have a very limited ability to swim. The daily rise and fall of the tides refresh the marine flora and fauna in the intertidal zone.

Due to the distance from Bass Strait, the seawater in Corio Bay stays more than a year within the Bay on average before it is replaced by new ocean seawater. As a result, the aquatic marine ecosystems in Corio Bay are largely self-contained with an emphasis on recycling nutrients within the Bay.

Understanding tidal characteristics of Corio Bay is an important consideration in establishing the hydrodynamic models required to assess the potential impacts of the project.

8.4.4 Currents in Corio Bay

Tidal currents in Corio Bay are small because of the small dimensions of the Bay and the small tidal range meaning the seawater does not have far to travel between high and low tide. The average tidal current is approximately 4 cm/s, however, stronger currents are experienced in shipping channels during spring tides, and weaker currents in shallow areas and during neap tides.

As part of the marine ecology and water quality impact assessment, two current meter deployments were undertaken to measure currents in proximity to the project area as shown in **Figure 8-3**. The summer deployment was undertaken between December and February 2020, with current speed and direction recorded every 15 minutes in 0.2 m increments above the seabed. This meter was installed north of Refinery Pier in Corio Bay 100 m offshore from the existing refinery seawater intake. The autumn deployment was undertaken between April and May 2021 at a deeper site near Refinery Pier, approximately 5m deep at mean sea level, to obtain current records in a different season.

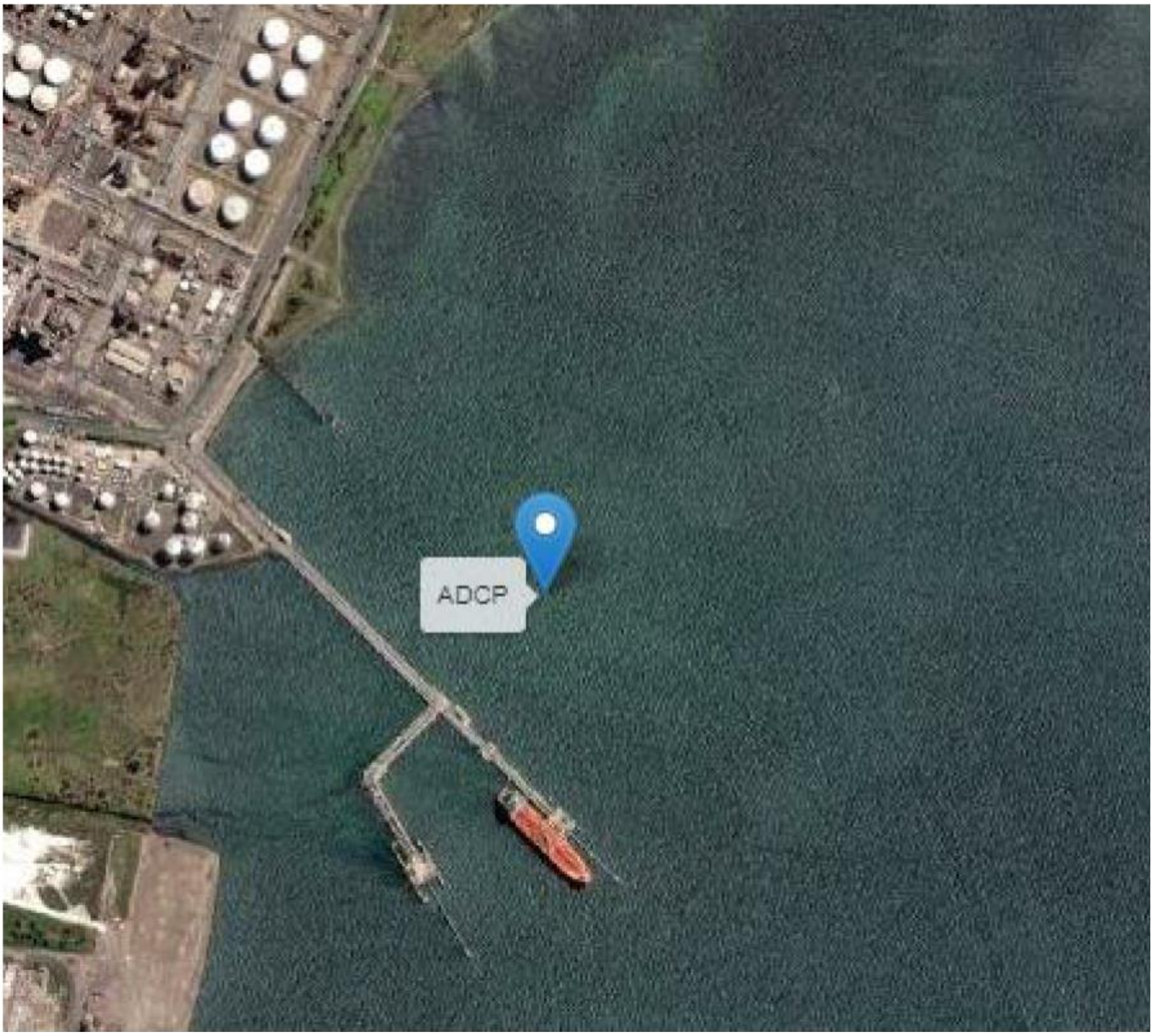


Figure 8-3 Location of deployed current meter

The two main hydrodynamic processes influencing currents in Corio Bay are tides and wind. The Spring and Neap tide cycle occurs over 28 days and therefore the full tidal pattern can be captured and understood over 28 days. As such, the data collected over the months described above was sufficient to calibrate the hydrodynamic model (discussed in **Section 8.6**) and 12 months of current data was not required.

Summer currents

At 0.6m above the seabed, the recorded currents are dominated by south-west to west currents with very little flow to the east. Currents to the north were more frequent than currents to the south. The median current speed was 0.044 m/s and the highest current speed recorded was 0.16 m/s to the south-west.

At 2.2 m above the seabed, the current directions are mostly to the south-west or west which is towards shore at the current meter location. It is possible that the current directions were influenced by the inflow of seawater into the nearby refinery intake, which could explain the consistent flow to the west. The median current speed was 0.045 m/s and the highest current speed recorded was 0.18 m/s to the south-west.

Water movement

Figure 8-4 shows the daily east-west water movement calculated from the summer current speed and direction readings. The current meter was located about 120 m offshore from the refinery inlet, and the daily water movement at this site was mostly to the west (into the intake).

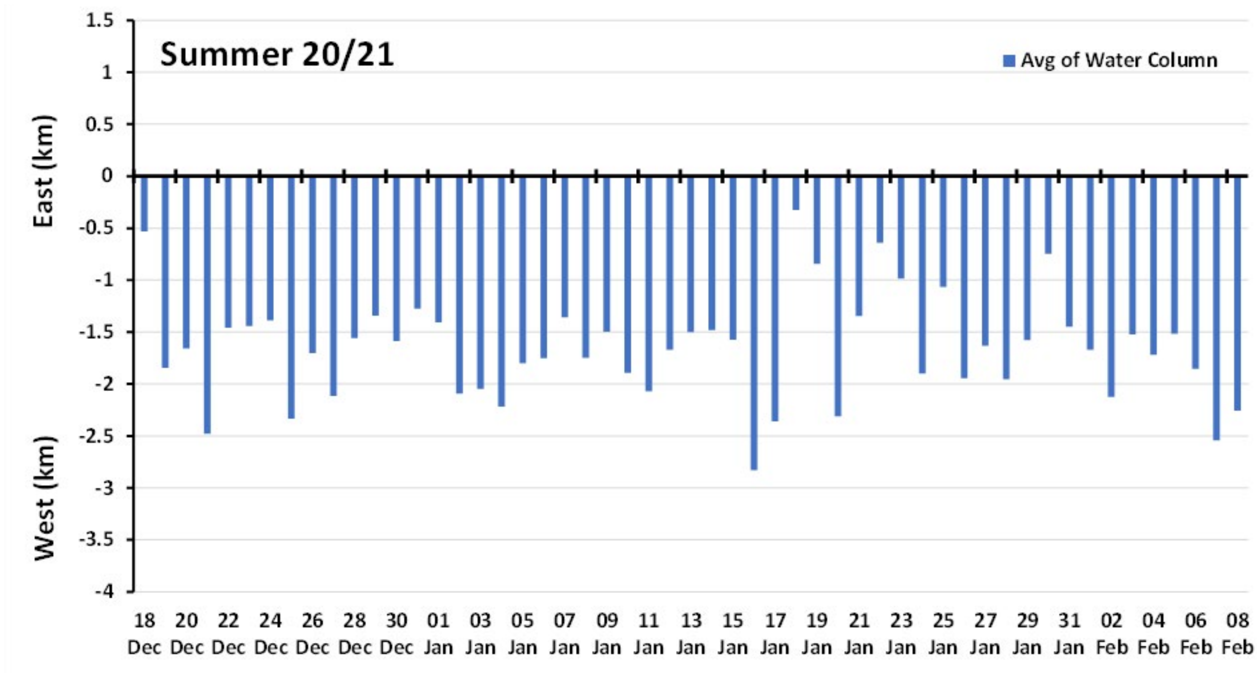


Figure 8-4 Corio bay east-west water movement

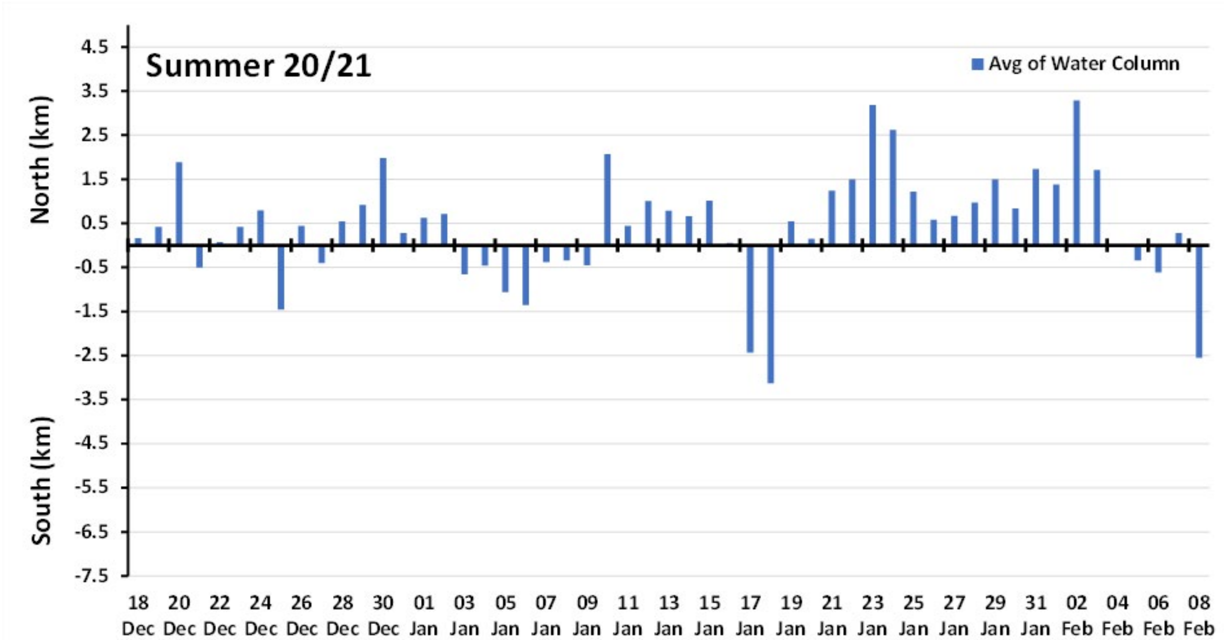


Figure 8-5 Corio Bay north-south water movement

Daily water movement to the west was 1.5 to 2.5 km/d (corresponding to an average current of 2 to 3 cm/s).

Figure 8-5 shows the daily north-south water movement calculated from the current speed and direction readings. The plot shows both north and south water movement, data is split north and south, although there is an overall movement to the north.

The periods of larger water travel correspond to prolonged winds in particular directions. The overall average water movement in a day was 0.4 km to the north, corresponding to less than 1 cm/s.

Autumn currents

Data collected from the autumn current metering near the seabed showed weaker and more variable currents, while the data collected near the surface showed stronger currents and the effects of wave-induced currents and wind shear. The data also shows a regular tidal pattern with periodic ebb and flood tidal currents, and occasional bursts of stronger currents at times of strong winds.

Figure 8-6 shows a time series of the current speed at 2 m above the seabed over a seven-day period in April 2021. The plot shows the current speed increasing and decreasing during the tide cycles, with the lowest speeds occurring at slack water between the tides.

Current measurements at 2 m and 3 m above sea level were analysed in detail, and showed a similar pattern with low speeds of 0.01 m/s, median speeds of 0.04 m/s and maximum current speeds of 0.14 m/s. This demonstrates that Corio Bay has weak current speeds most of the time. Therefore, water movement will be relatively small each day and discharged plumes would tend to mix in the locality of the point of discharge before being carried away in the net water movement.

The most frequent currents for the mid-water layer at 2 m above the seabed are from the north and north-east while there are also frequent currents from the south and south-west. Only a small percentage of the currents are from the east to south-east. At 3 m above the seabed, currents are more frequent from the north and are less frequent from the south.

Water movements

Figure 8-7 shows the daily east-west water movement calculated from the autumn current speed and direction readings in the two layers and is a projection of the water movement based on the current speed and direction at the point of measurement. Positive values on the plot indicate movement to the east while negative values represent movement to the west. This plot shows daily water movement was mostly to the east, at up to 0.5 km/d, but with an average of 0.18 km/day. This small distance of 180 m indicates that there is not a large net current but mostly a regular back and forth movement of water with the tides, interspersed by larger water travel in periods with strong winds.

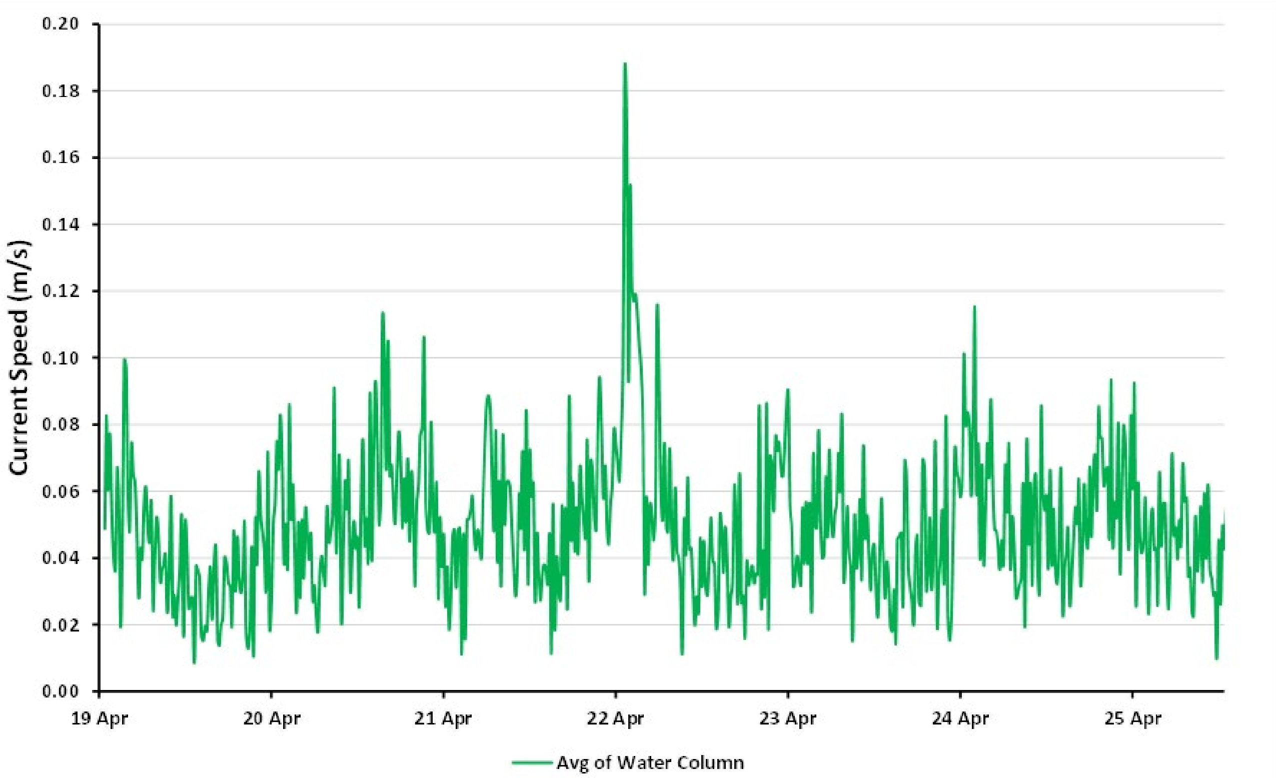


Figure 8-6 Current speed vs time during autumn current metering

The north section of Corio Bay generally has a clockwise circulation driven by regular winds from the south-west and the inflow of water in the shipping channel (MMBW, 1973). The clockwise circulation in Corio Bay mimics the clockwise circulation in Port Phillip Bay (CSIRO, 1996).

Figure 8-8 shows the daily north-south movement of water which is a projection of water movement based on the current speed and direction at the point of measurement. The movement is dominated by northerly currents which support the clockwise current circulation in Corio Bay where water enters through the deep channels, such as the Hopetoun Channel, and then circulates in a clockwise fashion to return to Port Phillip Bay in the north-east of the Corio Bay, near Point Lillias. The plot shows that water can move up to 1 km north in a day, but typically only moves a smaller distance.

Understanding currents and water movement in Corio Bay is an important consideration when establishing the hydrodynamic models required to assess the potential impacts of the project including marine discharges and potential sediment movements associated with short term dredging.

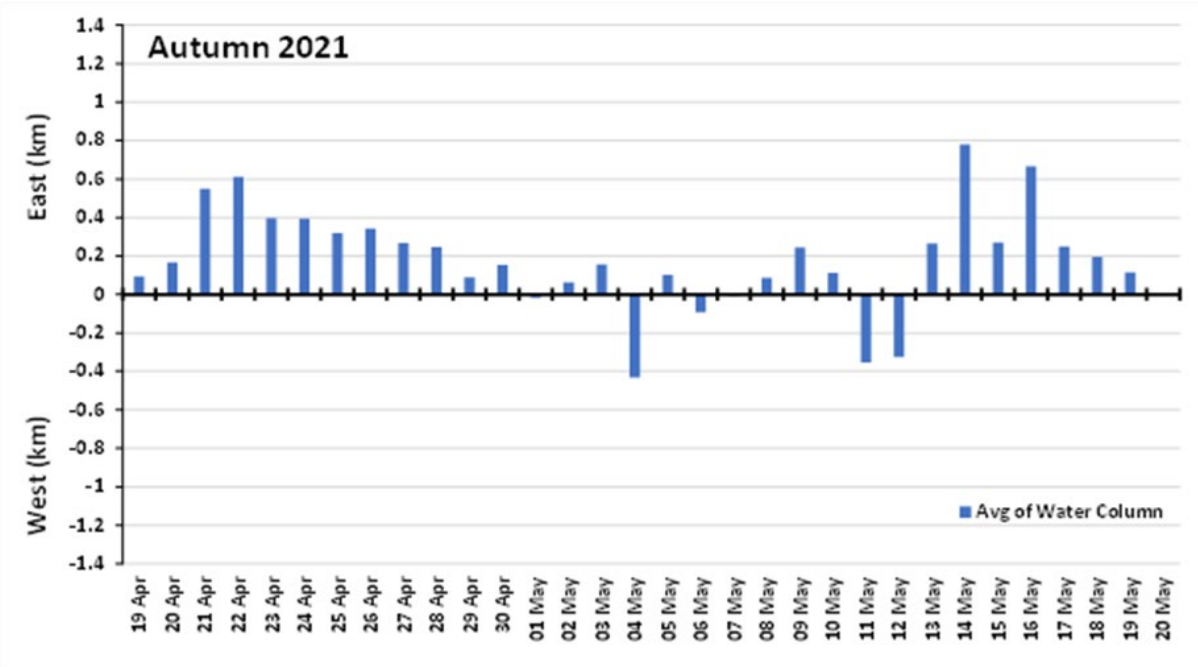


Figure 8-7 Net east-west water movement during autumn

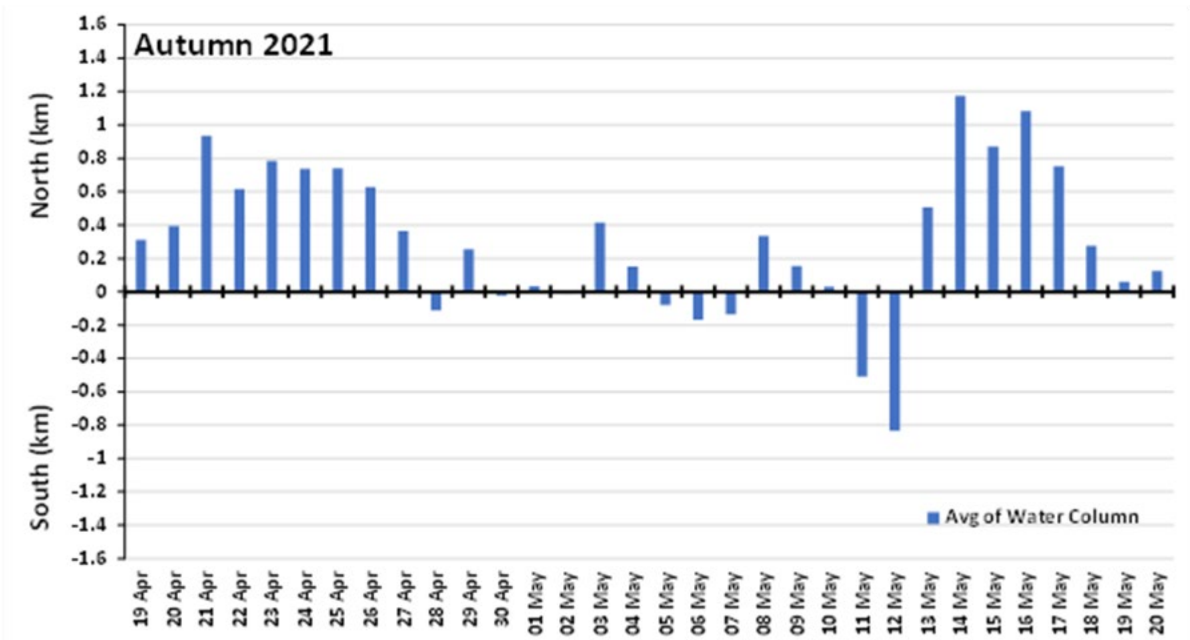


Figure 8-8 Net north-south-west water movement during autumn

8.4.5 Water Quality

Water quality is sampled by the Environment Protection Authority (EPA) at several points throughout Port Phillip Bay on a monthly basis, including Corio Bay.

EPA Victoria releases annual report cards which summarises environmental water quality using key indicators. The most recent annual report card for Port Phillip Bay was compiled for June 2019 to June 2020 for 6 monitoring sites in Port Phillip Bay and one in Corio Bay. The overall water quality index (WQI) for Port Phillip Bay in the 2019/20 period was rated as good. Above average rainfall that year resulted in increased runoff and river flows which caused an increased discharge of pollutants to the Bay, including nutrients, sediments and heavy metals.

Figure 8-9 shows the 2019-20 WQI results. The figure shows the overall WQI as well as the individual indicators which contribute to it. The Bay was rated very good in terms of dissolved oxygen and algae, good in terms of salinity, but only fair in terms of nutrients and water clarity.

Understanding water quality in Corio Bay is important in establishing baseline conditions for the assessment of potential impacts of the project, particularly from marine discharges.

Toxicants

The Port Phillip Bay Environmental Study (CSIRO, 1996) reported that most of the sediments of Port Phillip Bay contain metal concentrations well below hazardous levels. The study reported that "results show that the overall toxicant levels are continuing to decline, and that the toxicants entering Port Phillip Bay are largely locked up in the sediments".

Cores taken in the 1992-1996 study in Corio Bay showed surface enrichment with copper, lead, zinc and cadmium due to anthropogenic input. The distribution of organic toxicants was similar to that of metals. Cadmium contamination in Corio Bay was traced to an industrial effluent which was closed. After that, cadmium levels in Corio Bay mussels decreased to below the National Health and Medical Research Council limits.

Sediment sampling conducted in Corio Bay as part of the EES for this project to inform development of a dredged spoil disposal strategy (Coffey, 2020) and (AECOM, 2021) indicated that, with a small number of exceptions, contaminant levels were below guideline limits.

Salinity

Salinity data from the EPA monitoring site in Corio Bay over a 10-year period from 2010 to 2020 indicates that salinity has been consistent over the decade, with an average salinity of 37 practical salinity units (psu) and a range from around 35 to 38 psu. These salinities are typical of seawater and are within the water quality objective from the EPA Environment Reference Standard (ERS) for Geelong Arm of a 25th – 75th percentile range of 35 to 38 psu. The data also shows that salinity is consistent throughout the water column. There is a seasonal variation in salinity with higher salinity from December to March and lower salinity from July to August. This variation reflects the balance of rainfall, runoff and evaporation.

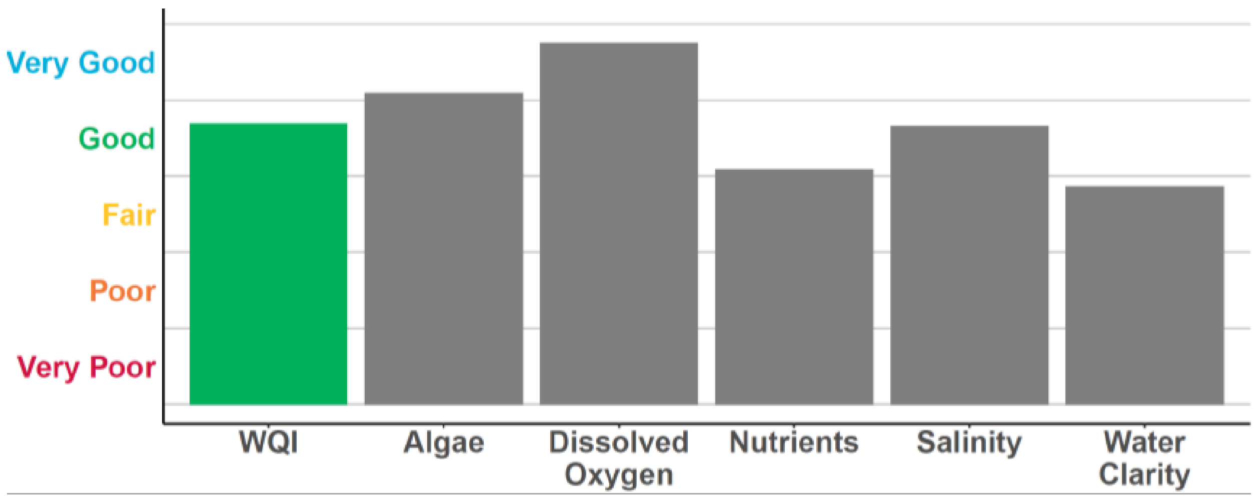


Figure 8-9 Water quality index for Pot Phillip Bay 2019/20

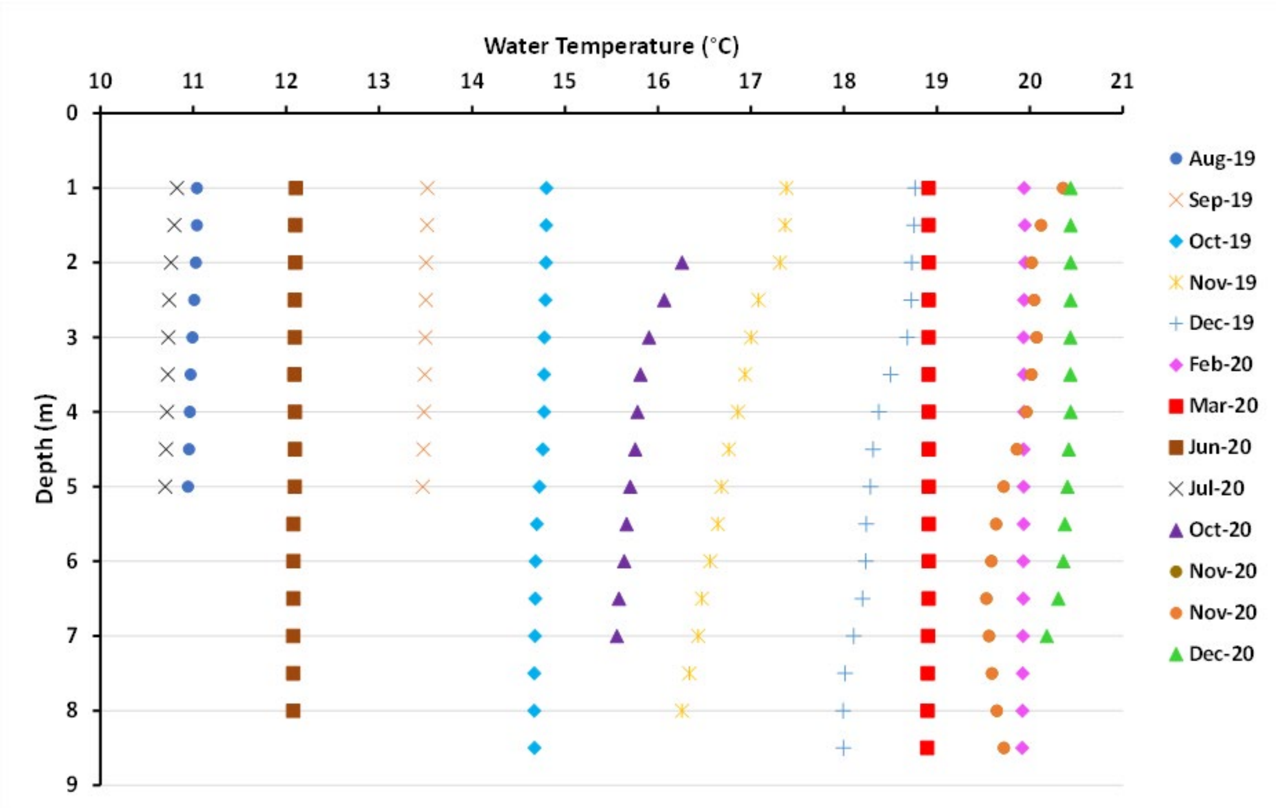


Figure 8-10 Corio Bay water temperature profiles (2019-2020)

Suspended solids

The suspended solids (SS) data for Corio Bay over the 10-year period from 2010 to 2020 indicates that there were higher SS concentrations from 2014 to 2018 with the concentration reaching 14mg/L. This is above the EPA water quality objective for SS of a 75th percentile concentration of 5mg/L. For the other years, the SS concentration has been consistently below 4mg/L. The EPA report does not provide an explanation for the high SS values from 2014 to 2018.

Dissolved oxygen

The dissolved oxygen data for Corio Bay from 2010 to 2020, indicates that dissolved oxygen is at very satisfactory levels, generally between 90 and 110% saturation with no events of low dissolved oxygen. This meets the water quality objective for dissolved oxygen in the Geelong Arm set out in the ERS.

Temperature

Monitoring data from March 2015 to August 2020 shows the average monthly temperature in Corio Bay and Port Phillip Bay was 16°C. However, Corio Bay has a slightly larger temperature range than the central segment of Port Phillip Bay with a summer maximum about 0.6°C higher and a winter minimum about 1°C lower. The larger range reflects the limited water movement in Corio Bay compared to Port Phillip Bay.

The EPA monitoring site in Corio Bay is in 9m water depth. There will be larger monthly temperature variations in shallower water. In intertidal zones, the organisms experience the water temperature at high tide and the air temperature at low tide. Over a day, the variation in temperature in the intertidal zone can range from around 14°C to 24°C depending on the season.

Figure 8-10 shows average monthly temperature data from August 2019 to December 2020 throughout the water column. There is a large seasonal variation in water temperature – from around 11°C in July to around 20.5°C in December 2020. The water temperature is generally consistent through the water column to 9 m depth although a small thermocline is apparent in October to December in some years.

For the EES, a water temperature monitoring program was conducted with the aim of assessing temperature variations in shallow and mid depths. This involved use of HOBO U24-002-C loggers which were permanently placed in a protective housing. The loggers recorded a single point water temperature reading every 10 minutes and the data was collected monthly. One logger was positioned at the refinery inlet at a depth of around 2 m and a second logger was placed off Refinery Pier in water of a depth of around 5 m as shown in **Figure 8-11**.

Figure 8-12 shows measured records of seawater temperature at two sites in Corio Bay from November 2020 to mid-June 2021. The blue line (refinery inlet) shows the temperature for the logger in the refinery inlet which was positioned in water around 1 – 2 m in depth, which is typical of water in the intertidal zone of the shallow Bay. This logger showed a larger degree of variation compared with the logger at the pier (orange line) which was positioned at a depth of around 5 m. The inlet had daily variations of up to 5°C and a median of 2.85°C, due to the large amount of heating and cooling by solar radiation. Due to greater depth, the logger at Refinery Pier had less variation with a maximum variation of 4.5°C and a median variation of 0.6°C.

Nutrients

The total nitrogen (TN) and total phosphorus (TP) data over the 10-year period of 2010 to 2020 is shown in **Figure 8-13**. This shows that TN has a wide range – from 150 µg/L to 300 µg/L with no particular seasonal pattern. Between 2010 and 2016, TN averaged of 204 µg/L. However, the average increases to 225 µg/L with the inclusion of 2016 to 2020 data.

TP has a more consistent concentration over the decade in the range of 60 to 100 µg/L. There is a seasonal pattern with lower TP in spring and higher TP in autumn. Over the decade, the average TP was 80 µg/L. There is no trend of increasing TP concentration.

Plant growth in Port Phillip Bay is nitrogen-limited. Nitrogen, as ammonia and nitrate are the most critical nutrients. Phosphorus is of less interest because it is present in excess in Port Phillip Bay compared to inorganic nitrogen. The TN to TP ratio is low at only 3:1, which indicates that nitrogen is usually the limiting nutrient for algal growth.

Figure 8-11 Location of water temperature loggers

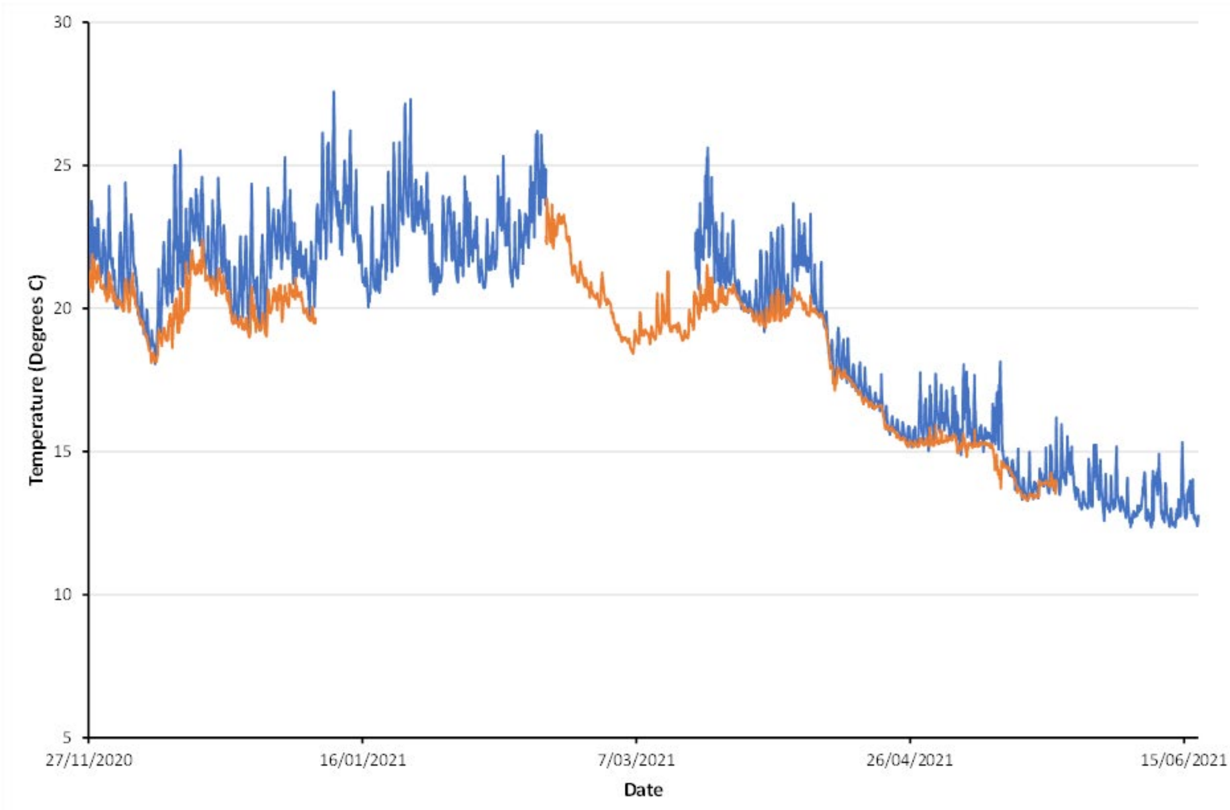


Figure 8-12 Recorded seawater temperature near Refinery Pier

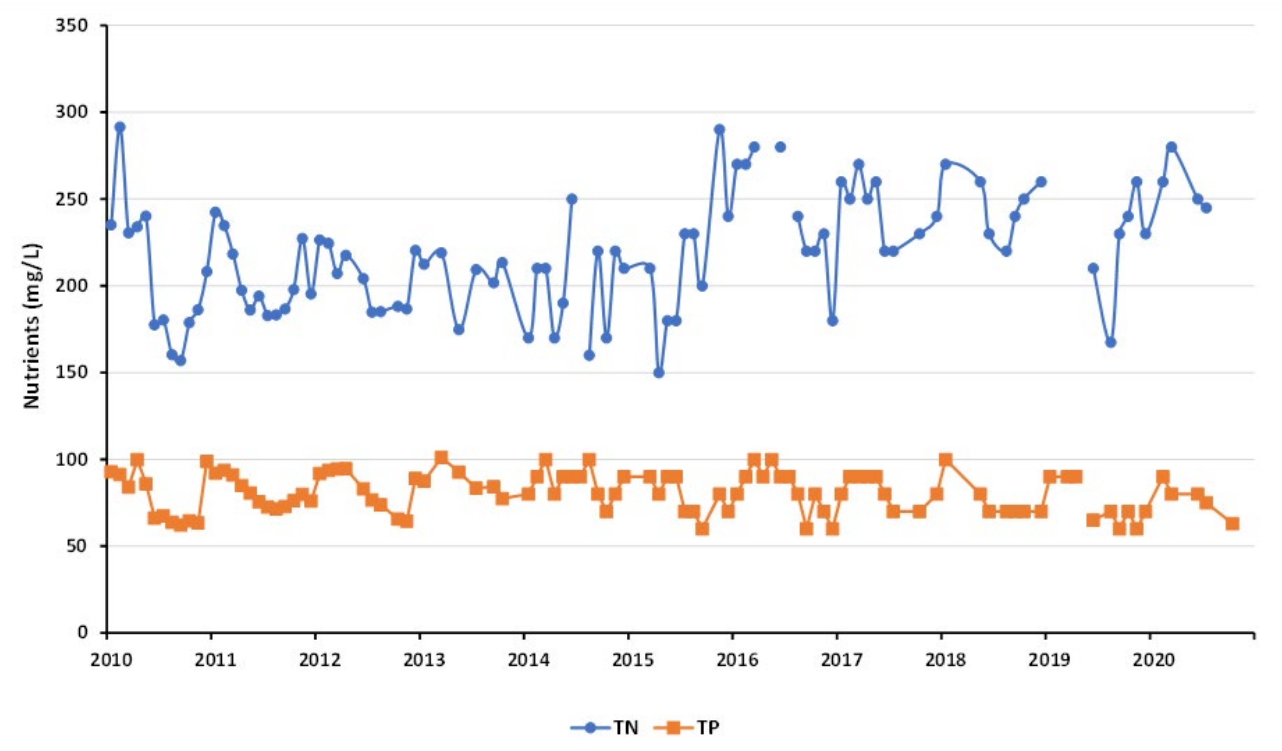


Figure 8-13 Corio Bay nutrients (2010-2020)

Chlorophyll-a

Chlorophyll-a concentrations in Corio Bay were measured by the EPA from 2000 to 2020. There was an increase in chlorophyll-a from 2003, reaching a peak in the summer of 2012. After that, the concentration decreased, mostly to less than 1 µg/L with occasional spikes. This meets the water quality objective for chlorophyll-a in the Geelong Arm set out in the ERS.

Seasonal variations in chlorophyll-a from 2000 to 2020 showed the highest concentrations in summer and autumn, with lower concentrations in winter and spring. The seasonal cycle involves an increase in phytoplankton populations commencing in spring and reaching a peak in summer and early autumn when there is warmer water and longer days – both favourable to phytoplankton growth. There is a decline in late autumn and winter, with cooler water and shorter days, so the cycle can start again into the next summer.

Turbidity

Turbidity is a measure of water clarity. High turbidity results in lower clarity and less transmission of light. Alternatively, low turbidity results in better clarity and more transmission of light through the water column. The growth of seagrass and seaweeds on the seabed in Corio Bay requires sufficient light to reach the plants to enable growth.

Turbidity has been measured by the EPA at one site in mid-Corio Bay and several sites in Port Phillip Bay since 2014. **Figure 8-14** shows the measured turbidity in Corio Bay and the Werribee site in Port Phillip Bay from January 2014 to December 2020. Over this period, the turbidity has averaged around 1 Nephelometric Turbidity Units (NTU) at both sites, with a recorded peak of 8.5NTU in Corio Bay. Turbidity peaks can result from storms or from phytoplankton blooms. The combination of fine sediments and wave action can at times generate high turbidity, particularly in coastal waters which will limit seagrass growth.

There is no limit for turbidity listed for Port Phillip Bay in the ERS, however, there is a limit for turbidity of 75% < 10 NTU for other estuaries. Using this as a guideline, the turbidity in Corio Bay is low and satisfactory. This means that there usually is sufficient light reaching the seabed of Corio Bay to enable the growth of seagrasses and seaweeds in the seabed over a range of depths.

The waters near the seabed in Corio Bay are much more turbid than the surface waters in the upper water column. This is a result of marine organic detritus and fine silts sinking to the seabed, forming a soft layer on the seabed about 10 to 20 mm deep. Re-suspension of the fine silts and clays that make up the surface sediments and the organic material causes a high turbidity near the seabed. **Figure 8-15** shows the turbidity readings for the period from 19 December 2019 to 3 January 2020. The turbidity was variable and ranged from around 4 NTU to 40 NTU. The median turbidity near the seabed was 12 NTU.

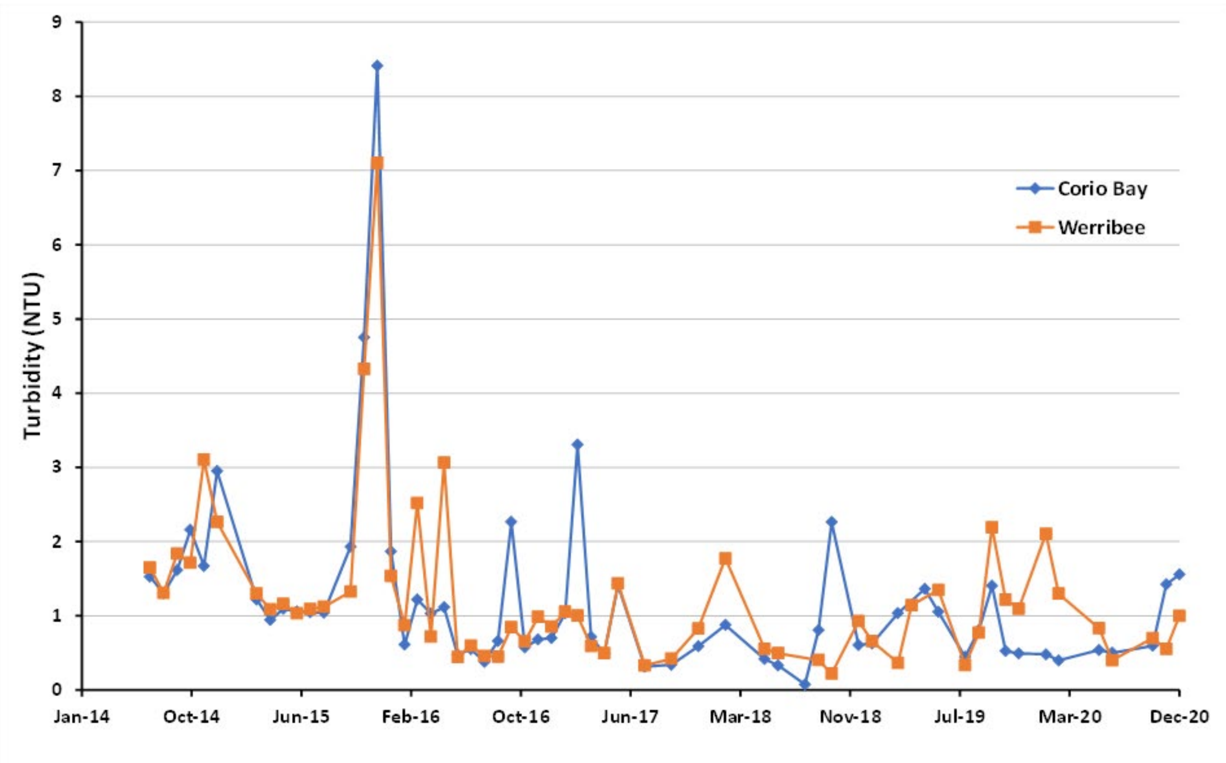


Figure 8-14 Turbidity in Corio Bay (2014-2020)

Light attenuation

Light attenuation was measured in Corio Bay with sensors at two depths near the Ramsar site in water which was 7 m deep. The two sensors were attached 2.3m apart at depths of 4 m and 6.3 m, at MSL. **Figure 8-16** shows a plot of the calculated average light attenuation from 20 May 2021 to 6 June 2021.

The average k_d (diffuse attenuation coefficient which is a measure of how light dissipates with depth in water) in north Corio Bay for the period was approximately 0.75 m^{-1}. The average kd value of 0.75 m^{-1} in north Corio Bay corresponds to a total suspended solids concentration of 5 mg SS/L.

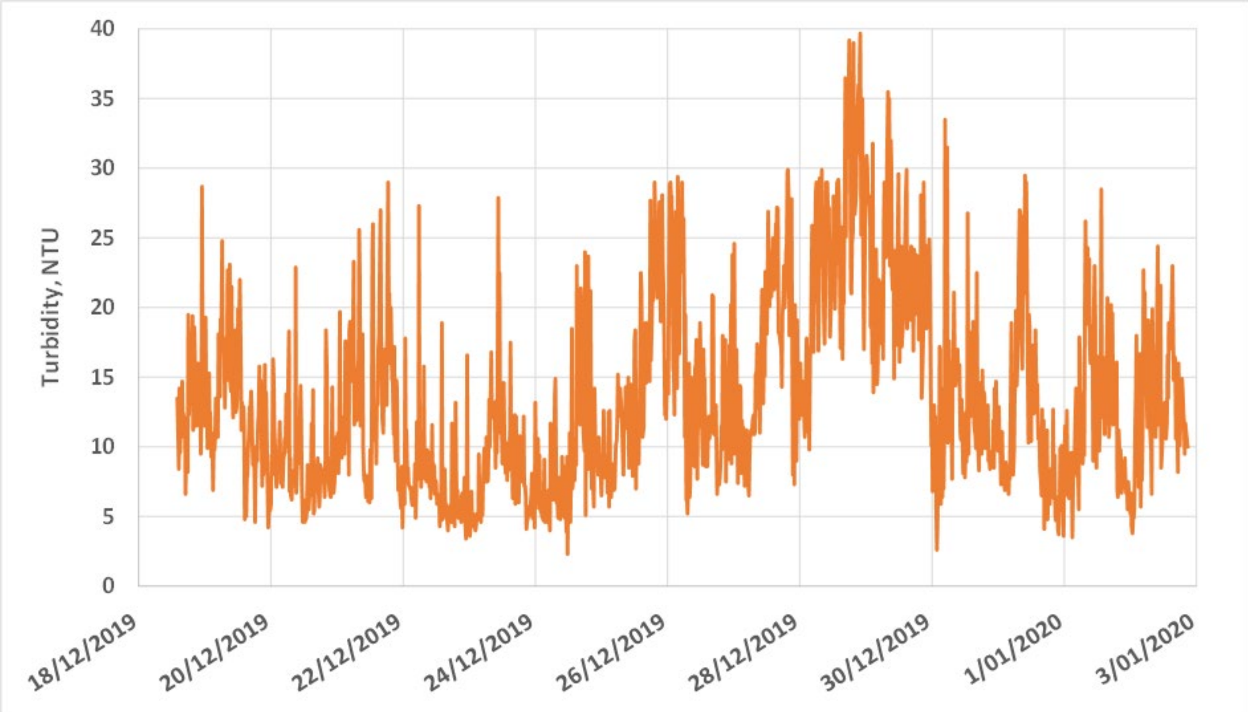


Figure 8-15 Turbidity near the seabed in Corio Bay (2019-2020

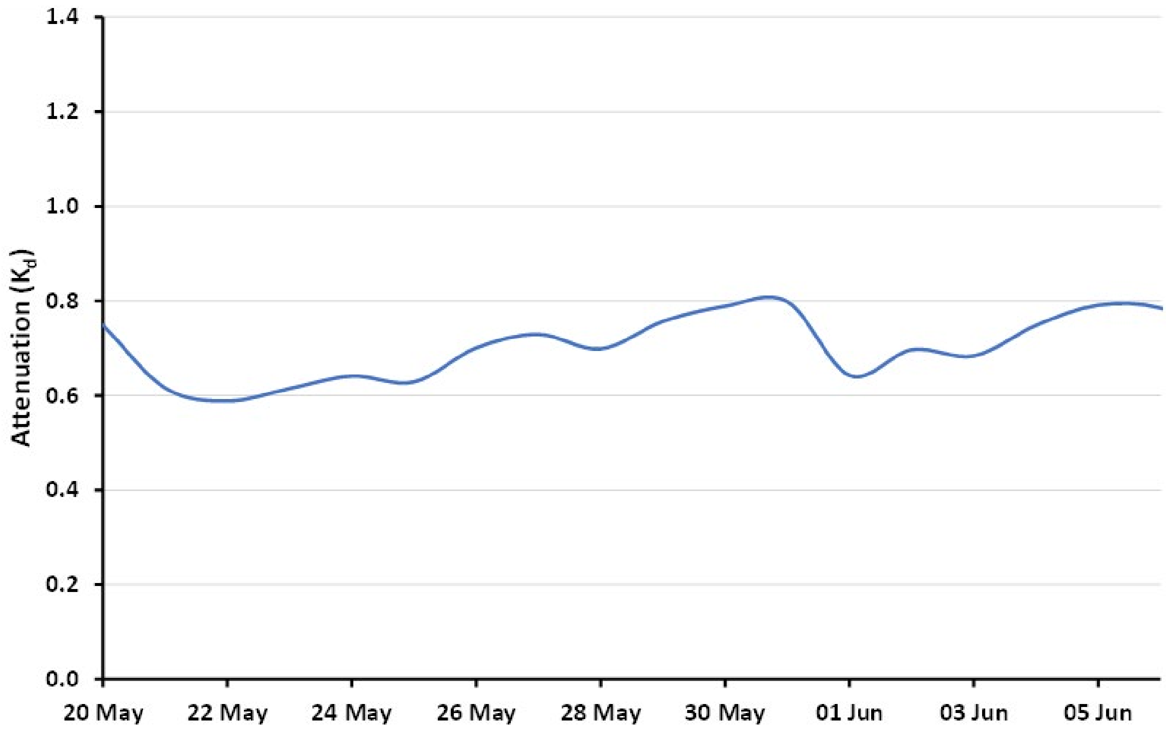


Figure 8-16 Light attenuation in Corio Bay (k_d)

8.4.6 Aquatic plants

All marine plants use light energy from the sun to transform carbon dioxide, water and nutrients into organic matter, while releasing oxygen (the process of photosynthesis). There are four main groups of aquatic plants living in Corio Bay: phytoplankton, seagrasses, macroalgae and microphytobenthos.

Phytoplankton are tiny single-cell algae that live in the water and are moved about by currents. Corio Bay contains more than 300 species of phytoplankton, ranging in size from a few thousandths to a few tenths of a millimetre across. The two main categories are diatoms and dinoflagellates. Diatoms have an intricate silica skeleton and try to keep close to the surface and are usually most numerous in summer. Dinoflagellates have two flagella, or threads, which can be used to steer them through the water. They have a versatile lifestyle, some being able to live on organic matter dissolved in water, while others are carnivorous and eat smaller algae, bacteria and protozoa.

Seagrasses are marine flowering plants that reproduce by vegetative growth or from seed fertilised by pollen. They usually grow on sandy or muddy surfaces, using rhizomes and roots for anchorage. Seagrasses obtain some nutrients from the sediment through their roots, while the leaves take up nutrients directly from the water. Seagrass beds are areas of high biological productivity and provide food and shelter for many marine animals. Most of the seagrasses in Corio Bay occur in intertidal and shallow waters less than 5m deep. There are extensive seagrass beds along the shoreline in front of the refinery, and along the northern coast in the Ramsar site. Intertidal seagrass is dominated by *Zostera muelleri* while the subtidal seagrass is dominated by *Zostera nigricaulis*. Deeper areas of the Inner Harbour have a sedimentary substrate but significant cover of the seagrass *Halophila australis* at intermediate depths where there is sufficient light penetration.

Macroalgae are large marine plants commonly known as "seaweeds". Some grow on rocks, shells or firm sand and are anchored by roots while others drift around the Bay with the currents. Over 60 species of green algae, approximately 100 species of brown algae and approximately 260 species of red algae have been recorded in Port Phillip Bay, and most of them would be present in Corio Bay. Macroalgae obtain nutrients from the water through their fronds and stems. They need light to survive, so they can only grow in shallow water where there is sufficient sunlight. The densest stands occur in the shallower waters of Corio Bay, mainly between 2 and 8m water depth.

Microphytobenthos are microscopic algae that live in a thin layer on the seafloor. They are also referred to as benthic algal mats because the algae grow on the surface of the sediment. There are dense mats in southern Corio Bay and moderately dense patches in the entrance to the Geelong Arm. They convert organic matter falling to the seabed and grow at a slow rate (as they exist in low light levels).

Understanding aquatic plants in Corio Bay is important in establishing baseline conditions for the assessment of potential impacts of the project, particularly from marine discharges.

8.4.7 Plankton monitoring in Corio Bay

EPA monitoring

Phytoplankton abundance has been monitored by EPA at several sites in Port Phillip Bay and one site in Corio Bay in 2008-09 (*Baywide Water Quality Monitoring Program - Milestone Report No.5*, EPA March 2010) and then on a monthly basis since 2012.

Phytoplankton is the most significant primary producer in Port Phillip Bay, accounting for the majority of net primary production. Phytoplankton monitoring shows a similar number and abundance of species at all monitoring sites throughout Port Phillip Bay, including Corio Bay, but a large variation in abundance at particular sites through the year due to short blooms of a few species. EPA phytoplankton counts from 2012 to 2020 show that the median number of phytoplankton cells in Corio Bay (330,000 cells/L) were essentially the same as in central Port Phillip Bay (360,000 cells/L), but lower than near Werribee (430,000 cells/L) and higher than at Popes Eye, near the entrance of Port Phillip Bay (195,000 cells/L).

Figure 8-17 shows the total phytoplankton abundance in Corio Bay from 2012 to 2020. Over this time the number of phytoplankton cells in Corio Bay averaged 643,000 cells/L with periodic large spikes, due to higher abundances of phytoplankton in summer. Over this period, the typical or geometric mean number of phytoplankton cells was 354,000 cells/L.

The EPA phytoplankton data shows that Corio Bay has an active plankton community that is usually more abundant than in some areas of Port Phillip Bay (such as the central region or Popes Eye, near the Entrance), but less abundant than in Port Phillip Bay near Werribee (due to the input of nutrients from the Western Treatment Plant).

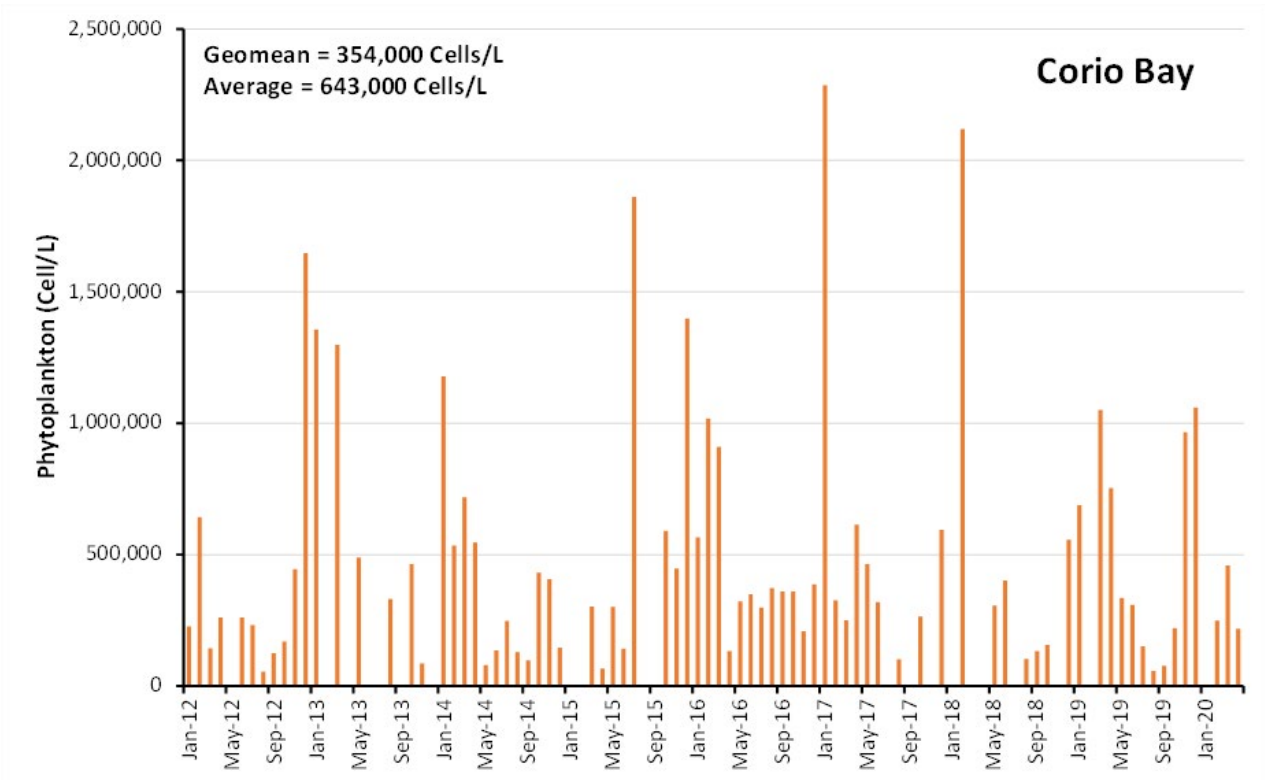


Figure 8-17 Phytoplankton in Corio Bay (2012-2020)

Project monitoring

A detailed survey of plankton in Corio Bay was conducted as part of the EES marine ecology and water quality impact assessment from November 2020 to November 2021 to assess the spatial distribution of plankton in Corio Bay and the effects of the circulation patterns, channel deepening and refinery use of seawater for cooling. The sampling included collection and identification of phytoplankton, zooplankton and ichthyoplankton at up to ten sites in Corio Bay. One sampling site was in the existing refinery seawater inlet, with the other nine sites distributed around Corio Bay and the Geelong Arm of Port Phillip Bay.

More intensive sampling was conducted in the refinery seawater inlet which began in October 2020 and proceeded weekly until the end of the month. Through November and December 2020, the inlet was sampled fortnightly before transitioning to monthly from January 2021. For a better comparison with the continued monthly sampling in 2021, the weekly and fortnightly results have been standardised into monthly results which are outlined in Section 8.4.8 below. The location of the inlet sampling location is shown in Figure 8-18. The nine sites used in the offshore sampling, are shown in Figure 8-19. The distribution of sites aimed to cover the different habitats in Corio Bay and the adjacent waters of Port Phillip Bay. Six of the sites are located within Corio Bay; one near Refinery Pier, one to the north, one at the EPA monitoring site in Corio Bay, and three in the south of the Bay. Three of the sites are in the Geelong Arm of Port Phillip Bay which were reference sites to compare the phytoplankton communities in Corio Bay with those in Port Phillip Bay.

Plankton samples were collected at all sites over summer, from November 2020 until January 2021.

Figure 8-18 Inlet plankton sampling location

Figure 8-19 Offshore plankton sampling sites

An analysis of the results show that the plankton distribution was well mixed throughout the Bay with no significant difference detected between plankton in North Corio, South Corio and the Geelong Arm. Therefore, the monthly sampling in Corio Bay was reduced to the three offshore sites in Corio North, Refinery Pier, Point Abeona and the EPA monitoring site.

The plankton communities that were sampled in Corio Bay comprise:

- Phytoplankton, which are the microscopic plants that can photosynthesize and one of the key sources of primary production in Corio Bay
- Zooplankton, which are the small animals of various feeding groups that provide a source of food for other filter feeding animals including other plankton, invertebrates on the seabed, jellyfish, larval fish and small fish
- Ichthyoplankton which are fish eggs and fish larvae.

The results from the inlet and offshore sampling undertaken for the marine ecology and water quality study are outlined below in **Sections 8.4.8**, **8.4.9** and **8.4.10**.

8.4.8 Phytoplankton

Phytoplankton are the microscopic plants that photosynthesise and are responsible for about half the primary production in Corio Bay. Most phytoplankton obtain their energy through photosynthesis (they are autotrophs), although some species of phytoplankton can obtain energy by also consuming other phytoplankton or bacteria (heterotrophs). Phytoplankton are grazed on by zooplankton, the next level in the marine food chain, but are also eaten by a range of larval fish and benthic filter-feeding organisms.

Phytoplankton have a limited capacity to swim in the water column. However, due to their very small size, their ability to maintain position in tidal currents with vertical mixing is very limited so they drift with prevailing currents and mixing processes. Phytoplankton typically have rapid life cycles (only hours to a few days) and can respond quickly to changes in the availability of light and nutrients.

Phytoplankton abundance and species richness in Port Phillip Bay and Corio Bay depends on several factors, with nutrients, light and temperature considered the most important for growth, with similar abundance levels in both Bays.

Understanding phytoplankton abundance, distribution and seasonality in Corio Bay is an important consideration in assessing the potential impacts of the project, particularly in relation to entrainment in the Floating Storage Regasification Unit (FSRU) seawater intake and marine discharges.

Abundance

Phytoplankton abundance and composition has been analysed for the samples collected at the existing refinery cooling water inlet site and from three north Corio Bay sites (Viva, Point Abeona, EPA) from October 2020 through to October 2021. Monitoring results showed that the dominant class of phytoplankton at the four sites (Viva, Point Abeona, EPA and inlet) were *diatoms* which account for 45% of the total phytoplankton abundance. The next most abundant phytoplankton class was *dinoflagellates* which accounted for 22% of the total abundance. *Cryptophytes, prymnesiophytes, prasinophytes* (marine) and *euglenophyta* each made up between 1 to 16% of the total abundance. The month with the highest phytoplankton abundance was December 2020 when a large spike in numbers were observed at all north Corio Bay sites including Viva, Point Abeona and EPA.

Figure 8-20 shows a plot of the average abundance at each of the north Corio Bay sites (dashed lines) as well as the overall average abundance (red line). The dashed black trace shows the average monthly daylight hours for the same period. There is a large spike in abundance in December 2020 and then a steady decline at each site of the following months. The graph shows that peak phytoplankton abundance coincides with the longer daylight hours and thus, abundances are likely to increase in the later and warmer months of 2021.

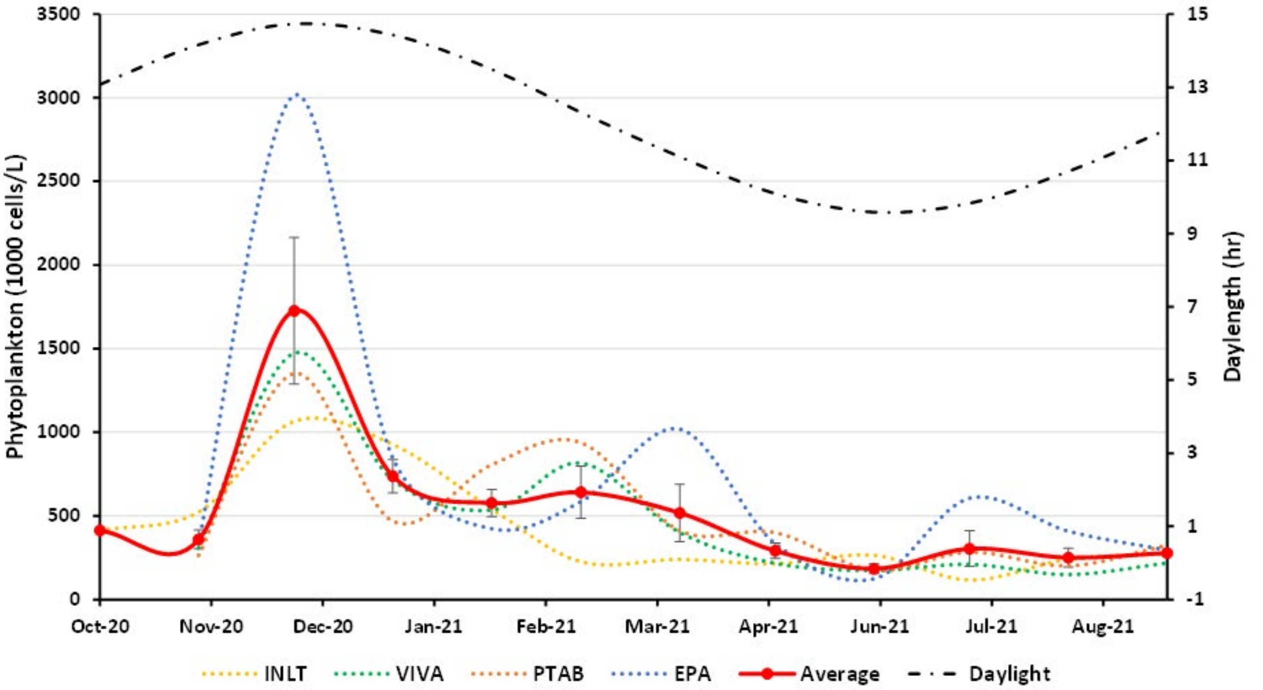


Figure 8-20 Time series of phytoplankton abundance

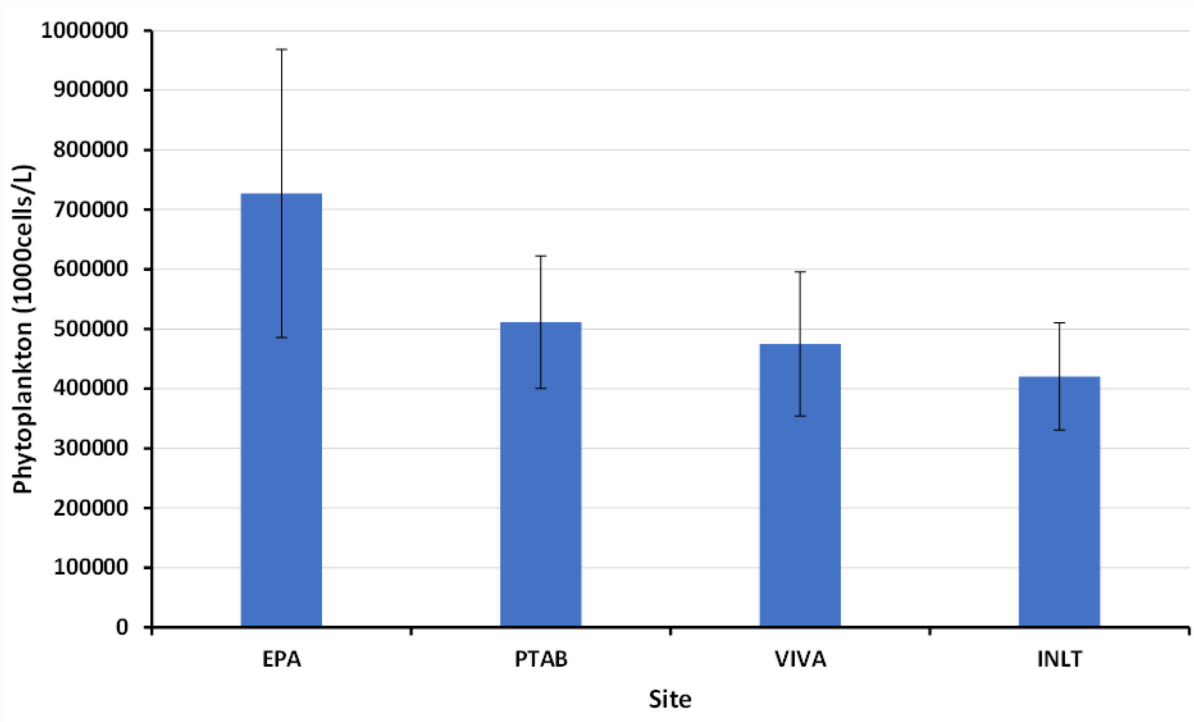


Figure 8-21 Phytoplankton abundance per site

Figure 8-21 shows a plot of the phytoplankton abundance at the inlet site and the three sites in north Corio Bay. The average abundance show that the inlet, Point Abeona and Viva sites were all similar with values between 400,000 to 500,000 cells/L. However, the EPA site was slightly higher at over 700,000 cells/L. This is mostly due to the large bloom in December 2020, however the site also had increased total abundance compared to the other sites in April, July and August where numbers at the EPA site were close to double the others.

Figure 8-22 shows time series plots of each of the major phytoplankton groups at the three sites in north Corio Bay and the inlet site. Note that the plots are on a logarithmic scale due to the high abundance. *Diatoms* were the group with the highest abundance and this group had a large bloom and peak in December 2020 followed by a steady decline in population. The next most abundant phytoplankton class was *dinoflagellates*, and this population had a more constant trend with some variations and large spikes at the EPA site in April 2021 and August 2021. It was noted that *cryptophytes* abundance range between 10,000 to 200,000 cells/L. Unlike the other groups, very low numbers of *cryptophytes* were recorded in December 2020. However, similar to *dinoflagellates* the EPA site detected small spikes in April 2021 and August 2021. *Prymnesiophytes* started with concentrations between 10,000 and 100,000 cells/L however over the year, there were several months when some sites were below 10,000 cells/L. The highest concentrations of this site were recorded at the EPA site in January 2021 and September 2021, both with concentrations of around 100,000 cells/L.

Three tests were carried out on separate days to determine the percentage loss of viability in phytoplankton populations following passage through the refinery heat exchanger. The inlet cell counts were noted as 225,000, 227,000 and 272,000 cells/L (geometric mean of 240,000 cells/L). Seawater samples were collected from the W1 discharge outlet 15 minutes later, and the geometric mean of the cell counts of the three outlet phytoplankton samples was determined to be 120,000 cells/L. Diatoms were the main species detected in the samples.

The results show that 50% of the discharged phytoplankton were living (i.e., viable). The seawater discharge from the W1 outlet flows north and reaches the existing refinery seawater inlet about 4 hours later, by which time the phytoplankton counts increase to numbers consistent with other sites around Corio Bay.

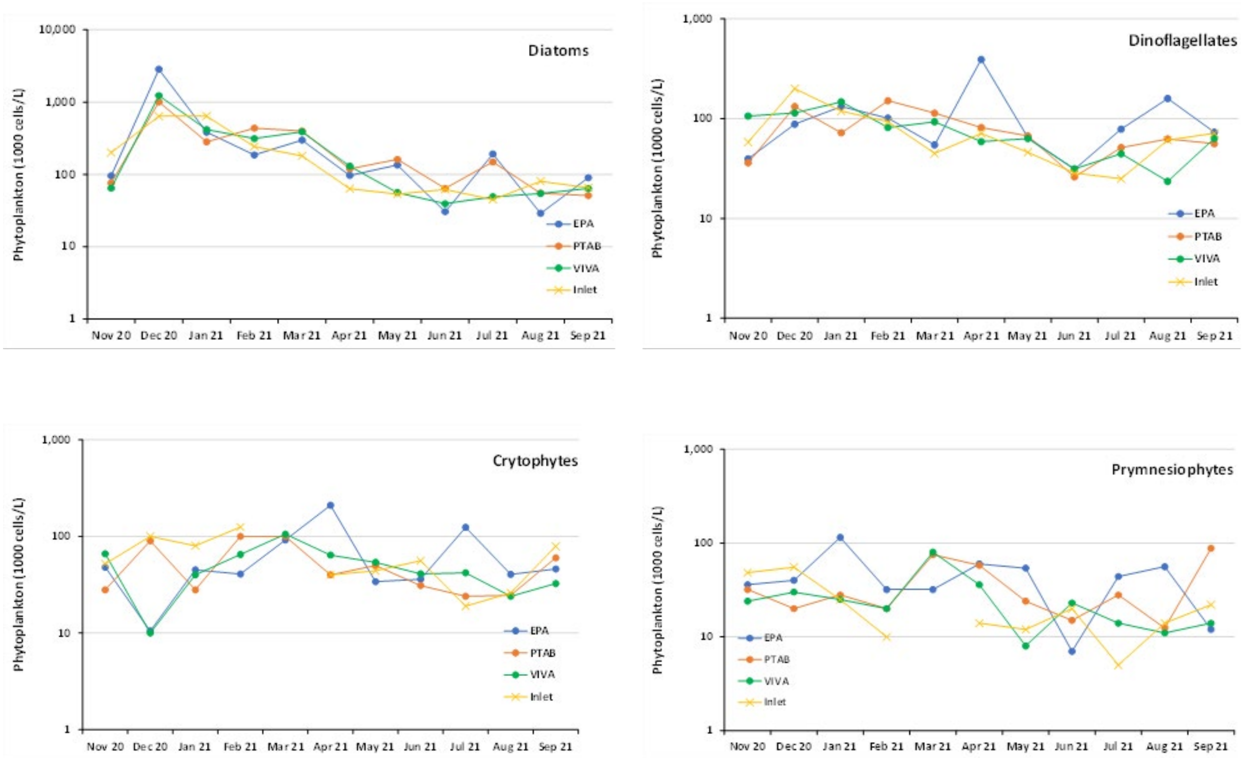


Figure 8-22 Time series of major phytoplankton groups

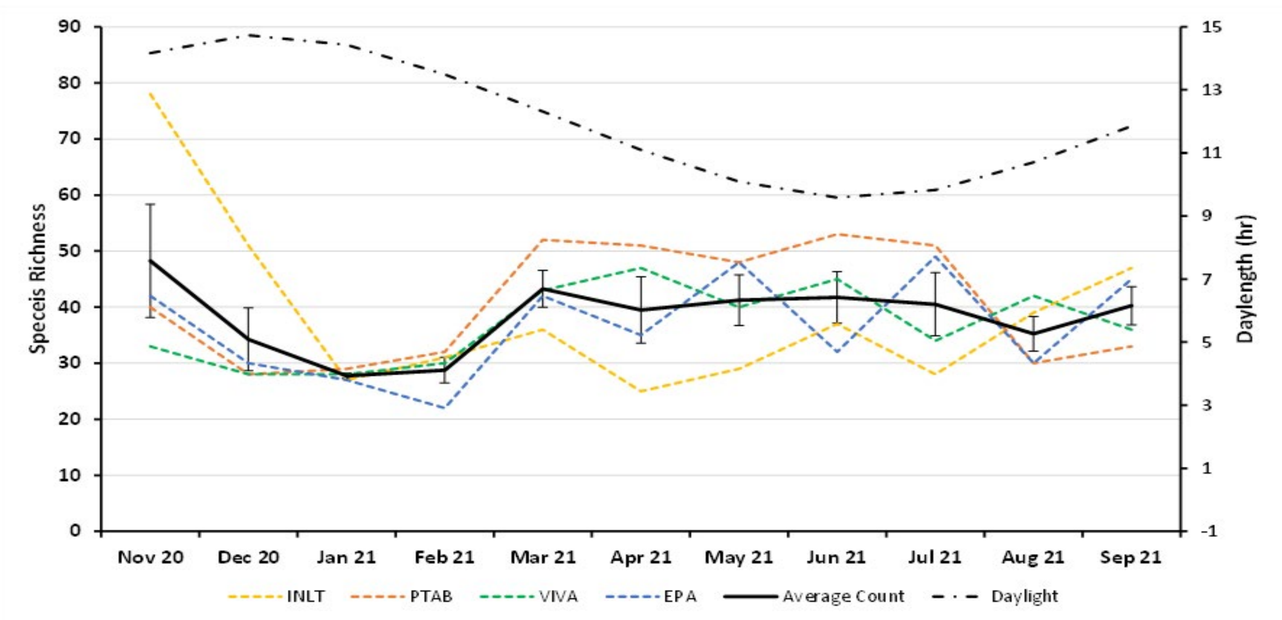


Figure 8-23 Time series of species richness

Species richness

Figure 8-23 shows a time series plot of the species richness at each of the four sites (dashed lines) as well as an overall average (black line). Species richness is the number of species in a community at any given time. The plot shows that the inlet had a large number of species present in November 2020, but a sharp decline showed lower numbers at all sites in December 2020, January 2021 and February 2021. This is likely because of the large bloom in abundance which was dominated by the major phytoplankton classes allowing less species to develop. From March to September 2021 the species richness was variable from site to site, although the general trend was stable between 20 – 50 species each month. A larger number of species was consistently observed at the Point Abeona site compared to the inlet. This is likely because the Point Abeona site is close to the Ramsar site and the largest seagrass beds of Corio Bay while the inlet site is close to the shoreline.

The dashed black line shows the average monthly daylength in hours. Species richness was lower in the months with more daylight hours and then increased when the daylength became shorter. When abundance is high, phytoplankton are dominated by a few groups which limits the growth of other species. However, when the abundance drops in the cooler weather, a large number of species can develop.

The data collected from the plankton monitoring show that the average species richness across the three sites in north Corio Bay and the inlet site ranges from 36 at the EPA site to 40 at the Point Abeona site.

In summary, the phytoplankton study shows that phytoplankton abundance is similar at all sites throughout Corio Bay, with *diatoms* being the dominant species. Phytoplankton abundance at the refinery seawater inlet was the same as elsewhere in Corio Bay, which indicates that the passage of seawater through the refinery is not having a significant effect on phytoplankton populations.

8.4.9 Zooplankton

Zooplankton are small invertebrate animals which live throughout the Bay and feed on smaller species such as bacteria and phytoplankton. Zooplankton size can range from only a few thousandths of a millimetre in diameter to a few millimetres long. The abundance of zooplankton depends on the abundance of phytoplankton communities as the zooplankton feed on phytoplankton in the water column.

Smaller zooplankton, referred to as microzooplankton, are less than 0.05 microns in diameter. These typically include dinoflagellates and ciliates and they normally feed on small phytoplankton. These species have high growth and loss rates, with a life cycle of a week or so. Larger zooplankton are referred to as mesozooplankton, are more than 150 microns in size and typically have life cycles of a few weeks, feeding on the larger phytoplankton.

The loss rate for large zooplankton was estimated to be within the range of 2% to 8% per day which reflects the dominance of smaller crustacea in Port Phillip Bay (Melbourne Water, 1992-1997 & CSIRO, 1996) and a life cycle of 2 to 7 weeks. While several studies into zooplankton have been conducted through Port Phillip Bay which includes Corio Bay, there has been little investigation of the zooplankton communities within Corio Bay itself.

Most zooplankton are weak swimmers and are moved by ambient water currents. Some plankton can move vertically through the water column in response to time of day; others stay at a certain depth range, generally in waters that are stratified by temperature or salinity layers. Others may be associated with particular seabed habitats, such as seagrass or mudflats in shallow water and have strategies to maintain their position on, in or close to those habitats. In considering these different behaviour patterns, samples for zooplankton analysis were collected as an integrated sample over the water column.

Understanding zooplankton abundance, distribution and seasonality in Corio Bay is an important consideration in assessing the potential impacts of the project, particularly in relation to entrainment in the FSRU seawater intake and marine discharges.

Abundance

Zooplankton abundance and composition has been analysed for the samples collected at the existing refinery cooling water inlet site and from three north Corio Bay sites (Viva, Point Abeona, EPA) from October 2020 through to October 2021. Monitoring results show that *paracalanus indicus* was the most abundant species at the four sites (Viva, Point Abeona, EPA and Inlet) and made up a total of 40% of the total zooplankton for the monitoring period. Acartia was the second most abundant at 30% and Noctiluca scintillans was the third most abundant species due to a large bloom in January 2021. Other dominant groups included *oikopleura, podon, gladioferens, evadne, obelia, leptomedusa* and *crab zoea* which all made up approximately 1 to 5% of total abundance.

A time series of zooplankton abundace for all species across the three north Corio Bay sites and the inlet site is shown in **Figure 8-24**. The dotted lines show the average plankton abundance at each of the sites while the solid red line shows the overall average. The dotted black trace represents the average daylight hours for each month. A significant decrease in abundance occurred in December 2020 following a large bloom of phytoplankton in November 2020. An increase in abundance was recorded in January and February 2021 where abundance was around 3,000 cells/m^3. A decrease in abundance to less than 1,000 cells/m^3 can be seen with a reduction in daylight hours in autumn and winter. As daylight hours slowly begin to increase in August, the overall zooplankton abundance began to slowly increase.

Figure 8-25 shows a plot of the zooplankton abundance at each of the north Corio Bay sites and the inlet across the entire monitoring period.

The plot indicates that the inlet had the lowest abundance at around 1,300 cells/m^3 while the EPA site had the highest at 1,900 cells/m^3. Both the Viva and Point Abeona sites were very similar in average abundance at around 1,700 cells/m^3.

Figure 8-26 shows time series plots of the major zooplankton groups at the three sites in north Corio Bay and the inlet site. *Paracalanus indicus, acartia* and *Noctiluca scintillans* were the most abundant zooplankton groups making up 40%, 30% and 10% respectively. Both *paracalanus indicus* and *acartia* experienced large blooms in November. *Acartia* especially, had abundances at the offshore sites of over 3000 cells/m^3. *Paracalanus indicus* had varied numbers from site to site with the highest numbers typically at the EPA site which experienced a peak in February 2021. Each site had decreased numbers in winter with a low in July 2021, although numbers began increasing in August. Concentrations at the inlet site remained consistently low over the year.

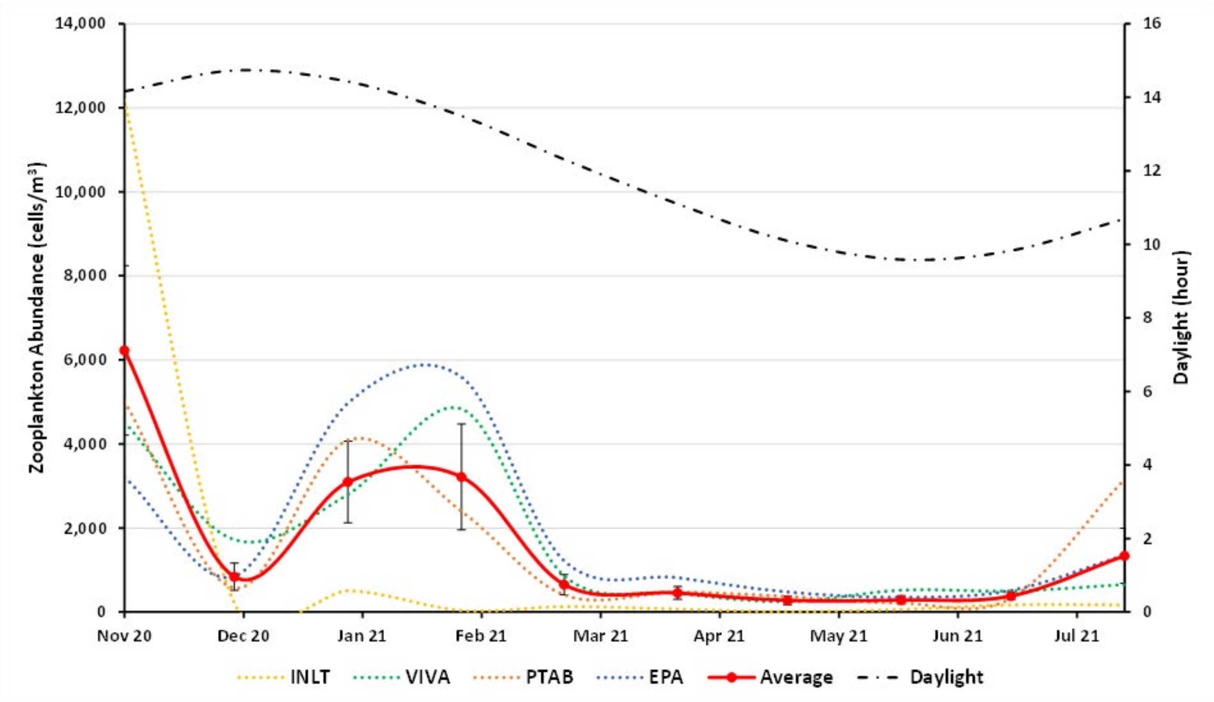


Figure 8-24 Time series of zooplankton abundance

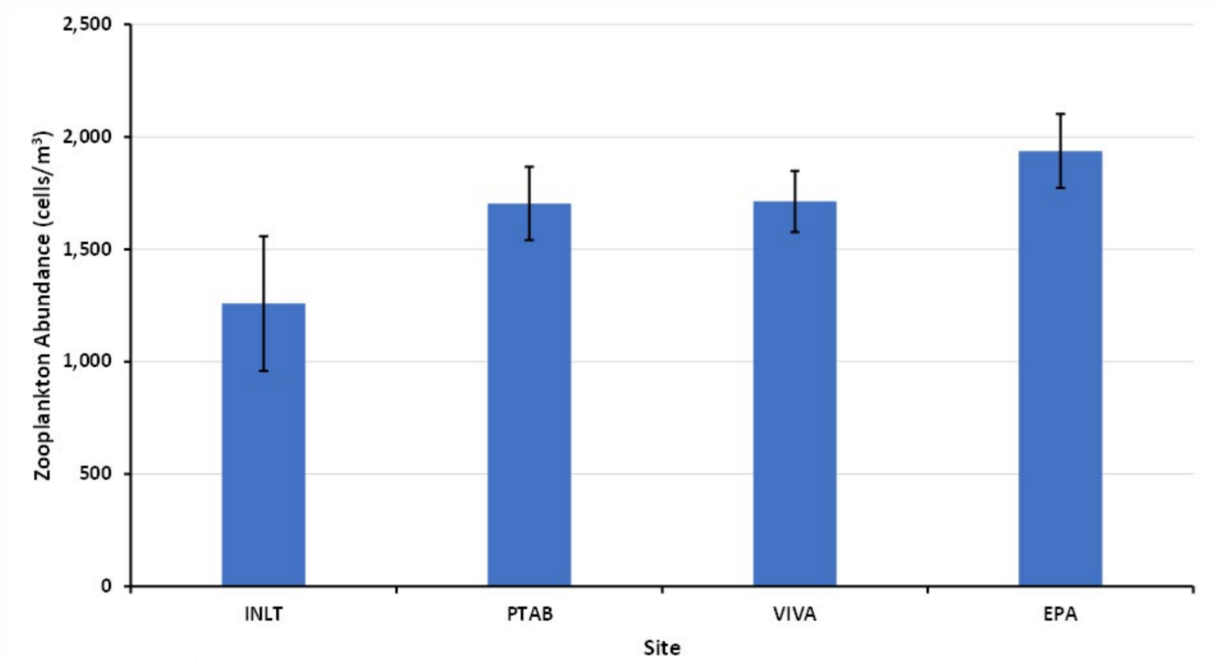


Figure 8-25 Zooplankton abundance per site

Figure 8-26 Time series of major zooplankton groups

Species richness

Figure 8-27 shows a time series plot of the species richness at each of the four sites (dashed lines) as well as an overall average (black line). Species richness is the number of species in a community at any given time. The plot shows that species richness had a steady decline over the survey period starting with an average of around 21 species in November 2020 declining to around 10 to 12 species in August 2021.

There is low species richness at most sites in November even though this month had higher overall abundance. This is because the high abundance is driven by very high numbers of several key zooplankton species such as acartia and podon sp. reducing the total number of species that are present. Based on the plot, there is no clear link between the species richness and daylight hours.

The major taxonomic groups are present most of the year, but the proportions of the zooplankton species vary considerably from month to month. There are similar temporal trends at the three sites in north Corio Bay and the inlet site. Thus, zooplankton appear to be responding to similar regional factors, such as an increase in phytoplankton numbers in Corio Bay.

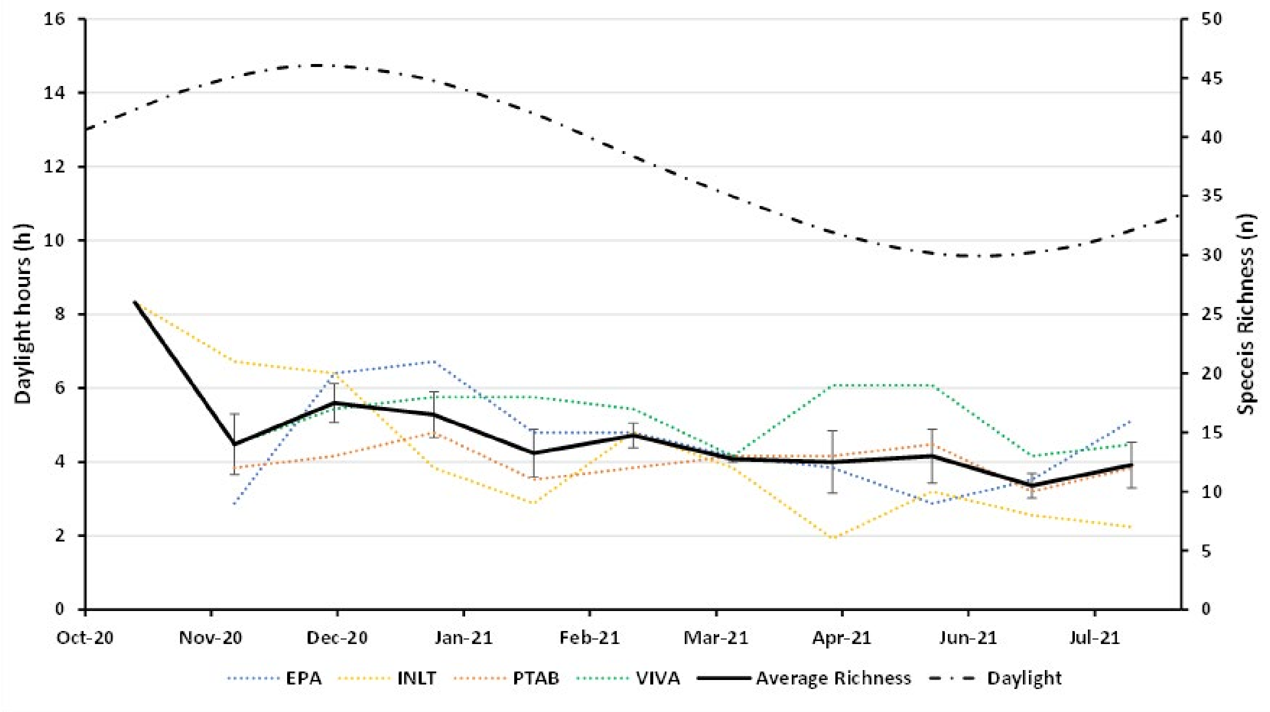


Figure 8-27 Time series of species richness

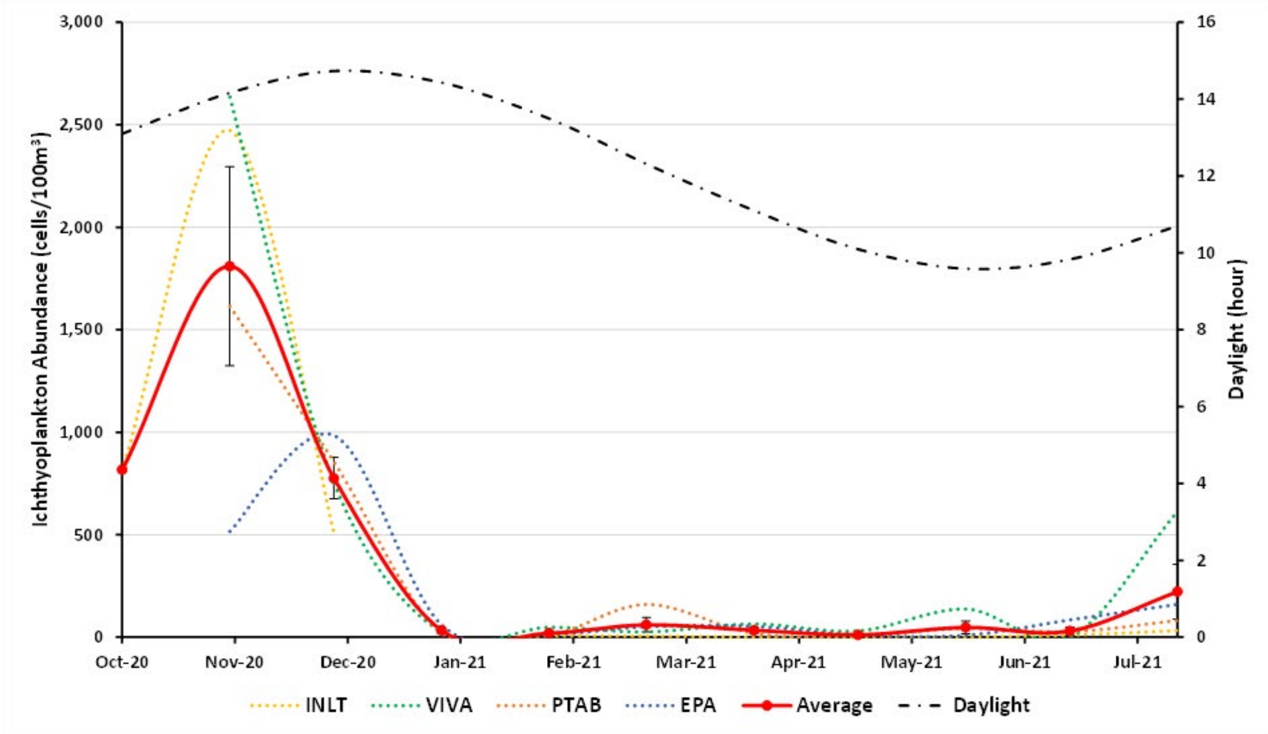


Figure 8-28 Time series of ichthyoplankton abundance

8.4.10 Ichthyoplankton

Sampling was undertaken to assess the abundance of ichthyoplankton (drifting eggs and larvae of fish) in north Corio Bay to establish the range of species that are present. However, because many of the eggs are small, and have not developed recognisable features, it is not always possible to allocate the specimens to particular species and have been listed as "fish eggs" in this study. Species that could be identified under a microscope have been listed.

Understanding ichthyoplankton abundance, distribution and seasonality in Corio Bay is an important consideration in assessing the potential impacts of the project, particularly in relation to entrainment in the FSRU seawater intake and marine discharges.

Abundance

Ichthyoplankton abundance and composition has been analysed for the samples collected at the existing refinery cooling water inlet site and from three north Corio Bay sites (Viva, Point Abeona, EPA) from October 2020 through to October 2021. There was no data for the seawater inlet site in January 2021 as the sample was damaged in transit and thus could not be analysed. Monitoring results show that the ichthyoplankton population is largely dominated by fish eggs which made up around 99% of the total abundance across the study period. Results show that some other species were also dominant around the end of 2020 such as the Australian Anchovy and Gobies. However, numbers for these species dropped away after December 2020. Results show that the spring and summer months are when ichthyoplankton are at their most abundant with very little abundance in winter months.

A time series of ichthyoplankton abundance for all species across the three north Corio Bay sites and the inlet site is shown in **Figure 8-28**. The dotted lines show the average plankton abundance at each of the sites while the solid red line shows the overall average. The dotted black trace represents the average daylight hours for each month. The plot shows a large spike in ichthyoplankton abundance in November and December 2020 with very little numbers for the remainder of the year. Extremely high numbers were recorded at the Viva site in November 2020 with far lower numbers at the EPA site. By January 2021 the concentrations were very similar between the sites and abundance dropped to consistently below 100 cells/100m^3. The graph shows a correlation between the abundance of ichthyoplankton and daylight hours with higher concentrations during months with longer days and lower concentrations during colder months when the average daylight hours are shorter.

Figure 8-29 shows time series plots of fish eggs and Australian Anchovies. Fish eggs were the most abundant group at around 99% total abundance. Fish eggs were highest in November and December 2020, but the plot shows a decline in the cooler months. However, in August 2021, the numbers start to increase at some sites.

Australian Anchovies were the dominant species in the summer months of sampling as there were very high numbers measured at the Inlet site in November 2020. However, after this short bloom in abundance, numbers of Australian Anchovy larvae declined to mostly zero through the colder months of the year.

Species richness

Figure 8-30 shows a time series plot of the species richness at each of the four sites (dashed lines) as well as an overall average (black line). Species richness is the number of species in a community at any given time. The plot shows that there is greater species richness in the samples during the months where abundance was high. In November and December 2020 species richness ranged from an average 10 to 11 species per site. In 2021 the richness decreased to an average of 2 to 4 species per site for the remainder of the monitoring period.

The ichthyoplankton survey results indicate that ichthyoplankton communities in Corio Bay are patchy and there is a variation of abundance between the different species and variation of abundance from month to month. The highest abundance occurred in spring-early summer, which matches the expected seasonal breeding pattern. By January 2021 abundance had declined, with fish eggs being the only dominant species through the cooler months. There was a more than ten-fold decrease in the abundance of fish eggs between November 2020 and February 2021.

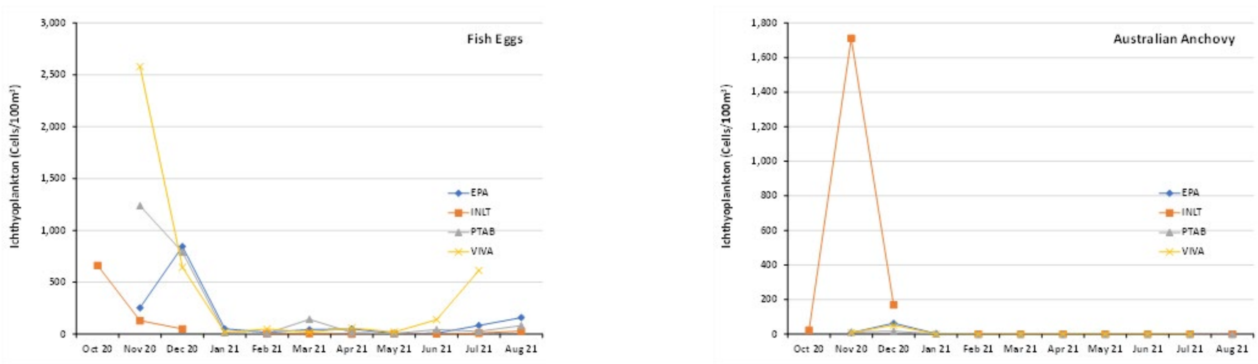


Figure 8-29 Time series of major ichthyoplankton groups

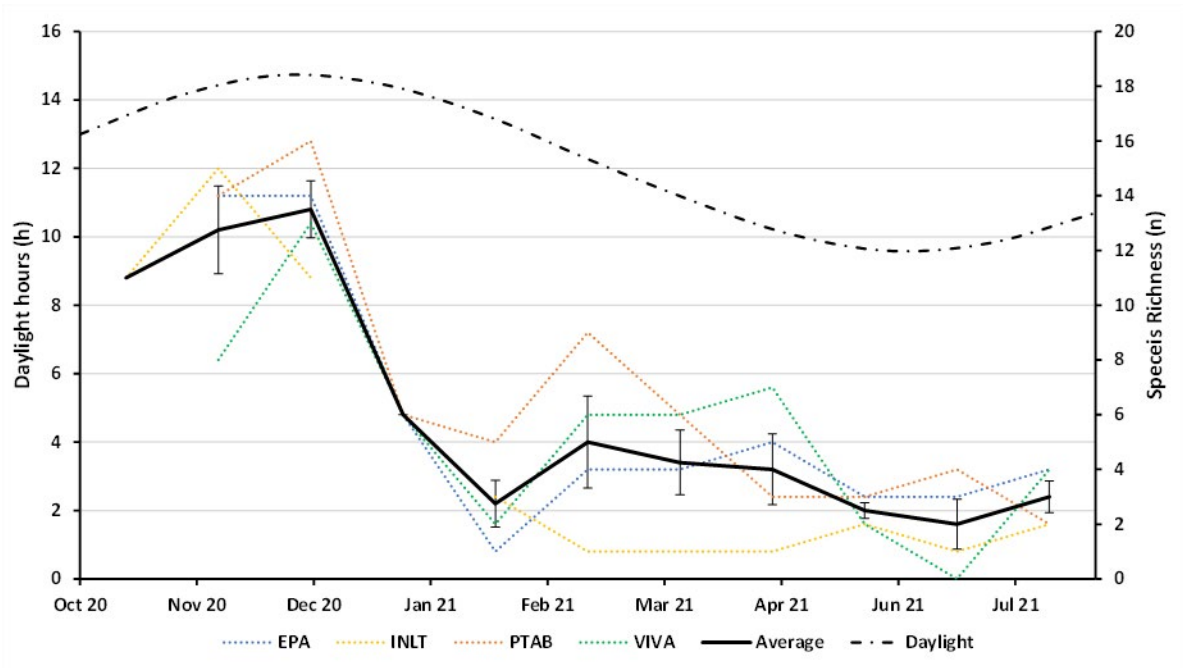


Figure 8-30 Time series of species richness

8.4.11 Fish

Understanding fish abundance, distribution and seasonality in Corio Bay is an important consideration in assessing the potential impacts of the project, particularly in relation to marine discharges.

Fish habitat

Corio Bay has a range of marine habitats including seagrass, muddy seabed, mangroves, unvegetated sediments, biogenic reef, sandy beaches and man-made structures. Associated with these habitats is a diverse fish community that includes species of commercial, recreational, conservation and ecological importance.

Most of the seabed in central Corio Bay is silt and muds which support a range of fish species that feed on zooplankton, infauna and smaller fish. Around the perimeter of the bay are areas of seagrass that provide attractive habitat for fish, particularly in the intertidal and shallow subtidal areas such as Stingaree Bay, the Avalon coast and Limeburners Bay.

Limeburners Bay also has areas of mangroves, *Avicenna marina,* and saltmarsh zones that provide habitat for small and juvenile fish. The estuarine area of Limeburners Bay is likely to be a spawning habitat for Black Bream, *Acanthopagrus butcheri*, and also a migration pathway for the Southern Shortfin Eel, *Anguilla australis*.

Fish communities

There has been commercial fishing in Corio Bay since the 1850s; however, in 2018 commercial netting was banned in Corio Bay essentially ending commercial fishing in the Bay. Recreational fishing in Corio Bay continues from both land and boat and is very popular. Based on pervious trawl surveys undertaken in Port Phillip Bay, the recreational fish community in the deeper areas of Corio Bay is dominated by snapper, flathead and King George Whiting. Other species that are retained included Elephant Fish, *Callorhinchus milii,* Yellow-Eye Mullet, *Aldrichetta forsteri,* Black Bream, *Acanthopagrus butcheri,* and Grass Whiting, *Haletta semifasciata*.

The population of King George Whiting, *Sillaginodes punctatus*, in Port Phillip Bay are juveniles up to approximately 4 years of age (Hamer et al. 2004). Older fish move out of Port Phillip to the open coastal waters where mature fish spawn, most likely in Western Victoria and south-eastern South Australia (Jenkins et al. 2000; Jenkins et al. 2016). Spawning occurs from April to July and eggs and larvae then drift from west to east in coastal waters for a period of 3 to 5 months (Jenkins et al. 2000; Jenkins et al. 2016). At the end of the larval period (September to November), post-larvae of approximately 20 mm length enter bays and inlets of central Victoria, including Port Phillip Bay, and settle near shallow seagrass beds (Jenkins et al. 2000).

An ongoing monitoring program for Whiting post-larvae abundance has been established in Port Phillip Bay at eight seagrass sites, including one in Corio Bay (VFA, unpublished data). Sampling is conducted in spring each year and shows a high variation in abundance from year to year in Corio Bay, which is consistent with Port Phillip Bay as a whole. The variation in settlement of post-larvae Whiting is mainly due to factors affecting larvae in Bass Strait prior to their entry to Port Phillip Bay, particularly the strength of westerly winds that transport larvae to the bay (Jenkins 2005), and water temperature in Bass Strait which effects growth rate and larval survival (Jenkins and King 2006).

The life stages of Snapper, *Chrysophrys auratus*, in Port Phillip Bay range from eggs to large, mature adults. The major spawning area for the west Victorian stock of Snapper appears to be Port Phillip Bay (Hamer et al. 2005; 2011). Most spawning appears to occur in the north-eastern area of Port Phillip (Hamer et al. 2011; Hamer and Mills 2017), although the presence of larvae in the Geelong Arm indicates that spawning can also occur near there (Hamer et al. 2011). According to the distribution map for Snapper in the Department of Environment, Land, Water and Planning's (DELWP) CoastKit (2020) marine and coasts tool, Snapper do not breed in Corio Bay.

Studies of Snapper reproduction in Port Phillip Bay indicate that most of the spawning occurs from mid-November to mid-January (Hamer et al. 2011). Larval survival in Port Phillip is strongly related to the availability of preferred zooplankton prey (Murphy et al. 2012; 2013) with the larval stage of Snapper lasting about one month. Acoustic pinging tags and "listening" stations have been used to track Snapper movement in Port Phillip Bay which show large movements of juvenile and adult snapper within Port Phillip Bay, including to and from Corio Bay (Hamer and Mills 2017).

Fish species of conservation significance

Several fish species that occur or have the potential to occur in Corio Bay are listed under Commonwealth and State legislation or internationally recognised lists of threatened species.

Sampling for syngnathids in seagrass has not been conducted in Corio Bay, but based on sampling similar seagrass habitats in Swan Bay, *syngnathid* species are likely to occur. The most abundant *syngnathid* species include the Spotted Pipefish (*Stigmatopora argus*), the Widebody Pipefish (*Stigmatopora nigra*) and the Hairy Pipefish (*Urocampus carinirostrus*).

School Shark, *Galeorhinus galeus*, occur mainly in deeper offshore waters, although they move into shallow, protected coastal waters for breeding. In a previous survey of Port Phillip Bay, the Point Wilson area had a number of School Shark pups, indicating that the Geelong Arm may be a nursery for the species (Stevens and West 1997). It is possible that School Shark breeding could occur in Corio Bay, although no pups were recorded from sampling in Limeburners Bay (Stevens and West 1997).

8.4.12 Seabed composition and habitat

The seabed of Corio Bay is predominantly unconsolidated sediments, with most of central Corio Bay comprising silt and clay (mud) with increasing proportions of sand around the edges. **Figure 8-31** shows the habitats and ecosystem assets present within the bay, mapped as biotopes by DELWP in CoastKit.

The sediment particle size composition of the seabed is a key factor influencing the characteristics of the marine ecological communities inhabiting the seabed.

The key biotopes in Corio Bay include muds, silty mud, *Zostera* and *Rupia* seagrass beds, shallow sand and *Caulerpa* beds. There is also a small area of

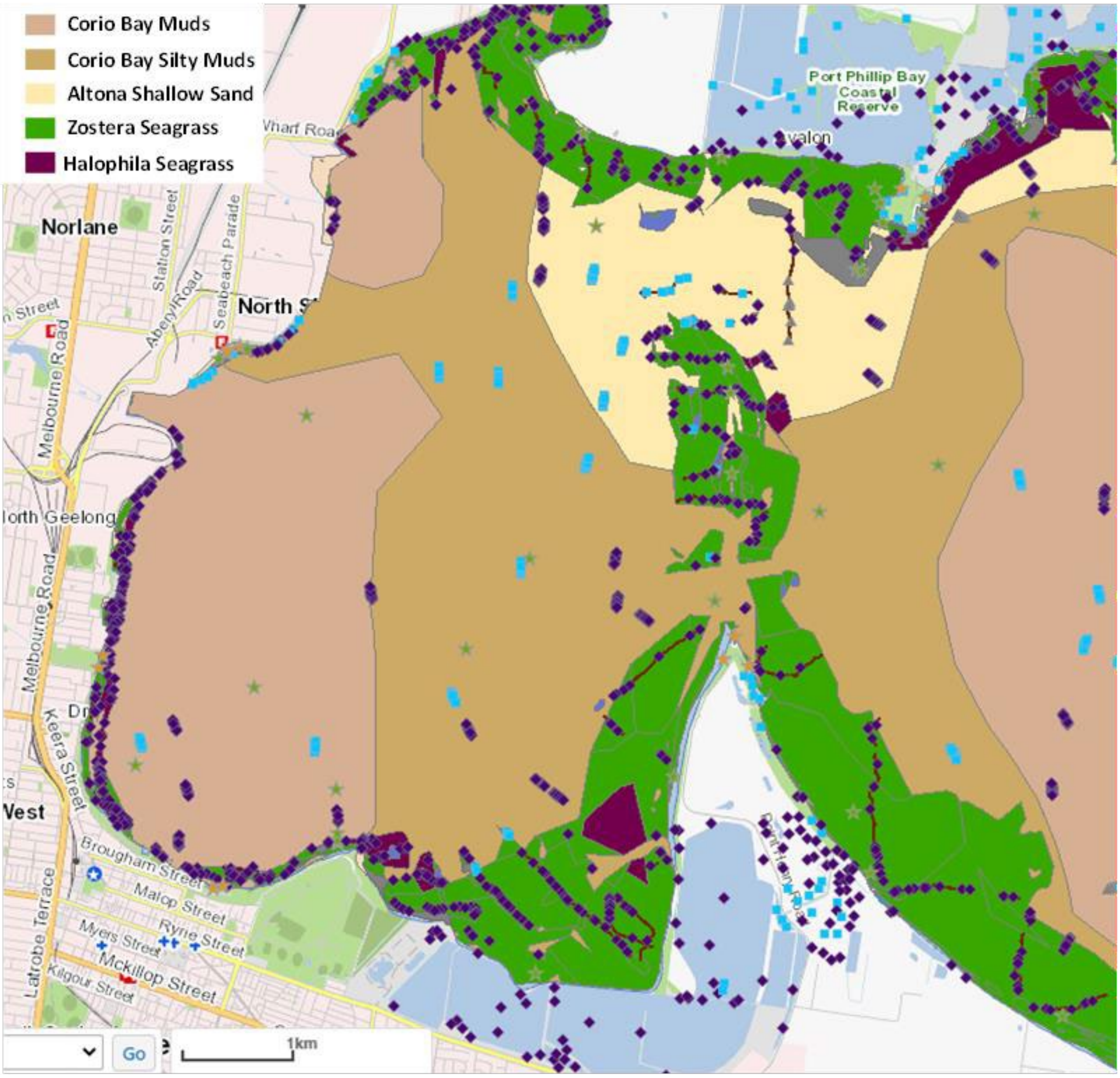


Figure 8-31 Biotopes in Corio Bay

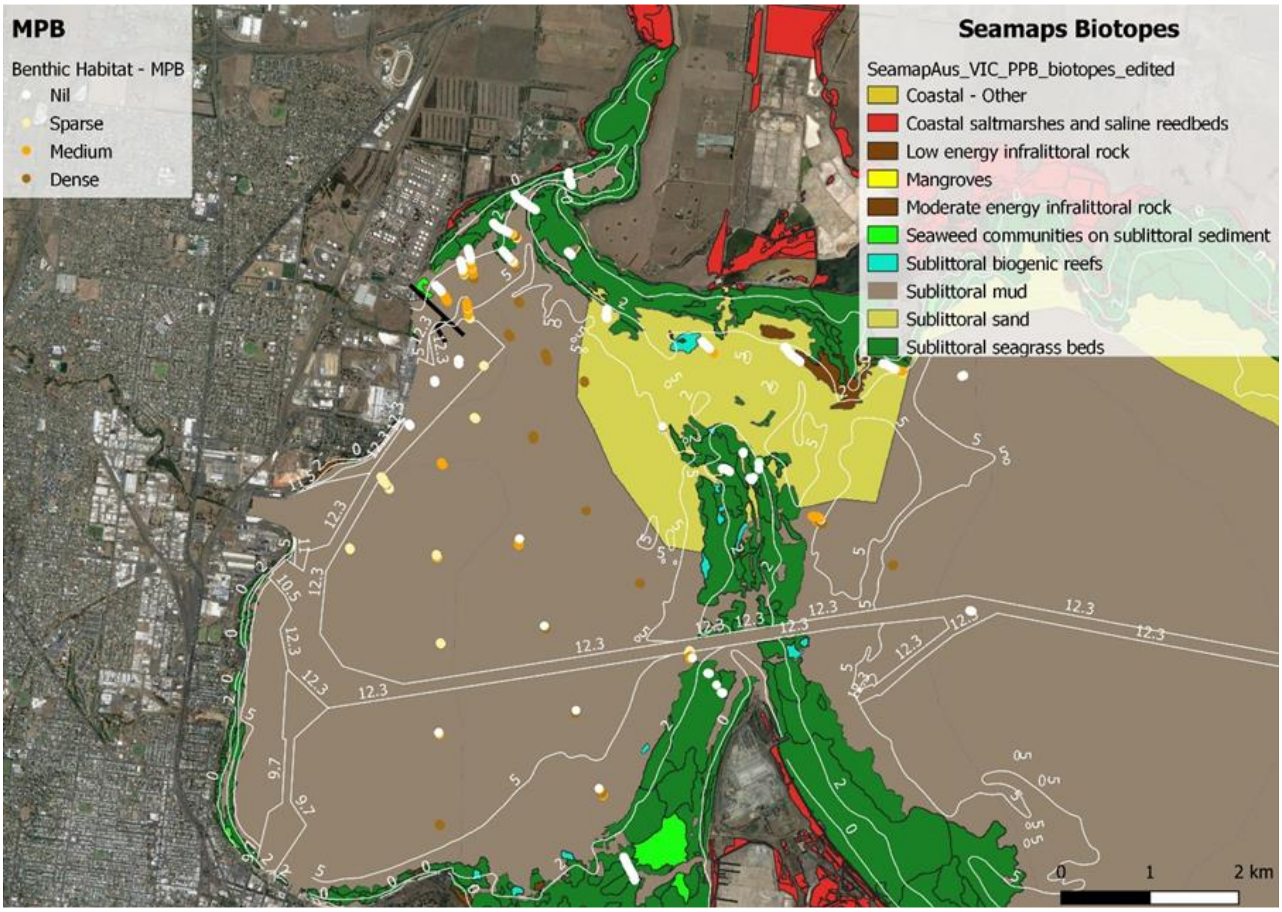


Figure 8-32 MPB in Corio Bay

mangroves in Limeburners Bay, a small section of *Pyura* biogenic reef just offshore from the seagrass beds in north Corio Bay, a small strip of *Halophila* beds on the west side of the channel into Limeburners Bay and hard substrate (mostly man-made) along the western shore.

To obtain a more detailed understanding of the seabed characteristics in north Corio Bay near the project area, the benthic habitat was surveyed along 49 transects in north Corio Bay using HD underwater image as part of the marine ecology and water quality impact assessment. The observed habitats include seagrasses with macroalgae on shallow soft seabed, and microalgae (microphytobenthos) and burrowing invertebrates (bioturbation) on deeper soft seabed.

The results were consistent with previous descriptions and mapped distributions. The central area of Corio Bay was generally muds (a mixture of clays and silts, with very low sand content), while the seabed around the perimeter was more variable with sandy muds, muddy sands and sand with shell.

Microphytobenthos

Microphytobenthos (MPB) is the general term used to define micro photosynthetic organisms (including unicellular green algae, diatoms, cyanobacteria and flagellates) that form a thin surface layer on marine and estuarine soft sediments, they can be distinguished by a green, golden or brownish colour. MPB are often the only primary producers (plants) in deeper waters on fine sediments and play an important ecological role in the marine aquatic environments. Highest MPB densities were recorded on muddy seabed and lowest densities on dense seagrass patches which shade the seabed.

MPB was found on much of the soft sediment seabed around the Refinery Pier and in Corio Bay in water of between 4 to 8m deep, as shown in Figure 8-32. The MPB patterns shown in Figure 8-32 taken from video tows during the EES marine studies are very similar to the patterns recorded in previous studies and mapping.

Filamentous algae

The term "filamentous algae" is a general term to refer to macroalgae with a filamentous plant body. Filamentous algae were observed growing epiphytic on *Zostera*, on organisms such as sponges and ascidians and on the seabed. Its distribution within the bay follows a similar pattern to that of seagrass.

Although present in all sections of the Bay, higher densities of filamentous algae were associated with shallower depths and seagrass. Within the Bay the highest abundances of filamentous algae were observed from 1 to 2 km north of Refinery Pier, as shown in Figure 8-33.

Bioturbation

Bioturbation refers to the disturbance of marine sediment by burrow-dwelling organisms, usually invertebrates such as polychaetes, crustaceans and echinoderms. The distribution of bioturbation activity was similar to the distribution of MPB. Sediment disturbance was recorded in all sections of the Bay at sites without seagrass and macroalgae.

The survey found higher levels of bioturbation were associated with greater depths. A consistent medium level of bioturbation was found at the deeper areas of both the north and centre sections of the Bay. The highest levels of bioturbation were seen at the deeper ends of transects just north of Refinery Pier and also at 2 km south of the pier. The lowest bioturbation was observed around the shallower depth contours. Some areas of high bioturbation were characterised by large burrows and usually associated with medium to high levels of MPB.

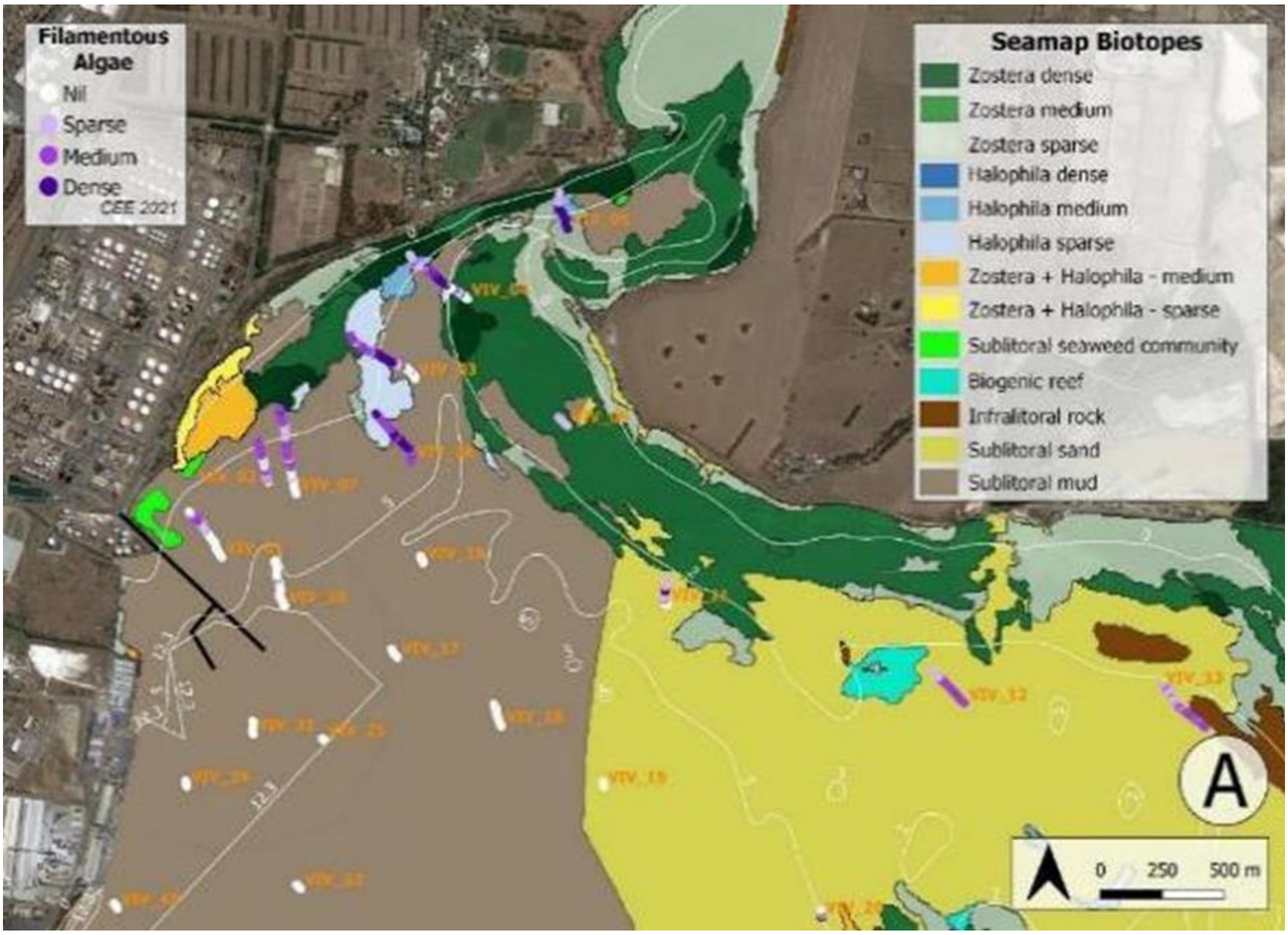


Figure 8-33 Filamentous algae in North Corio Bay

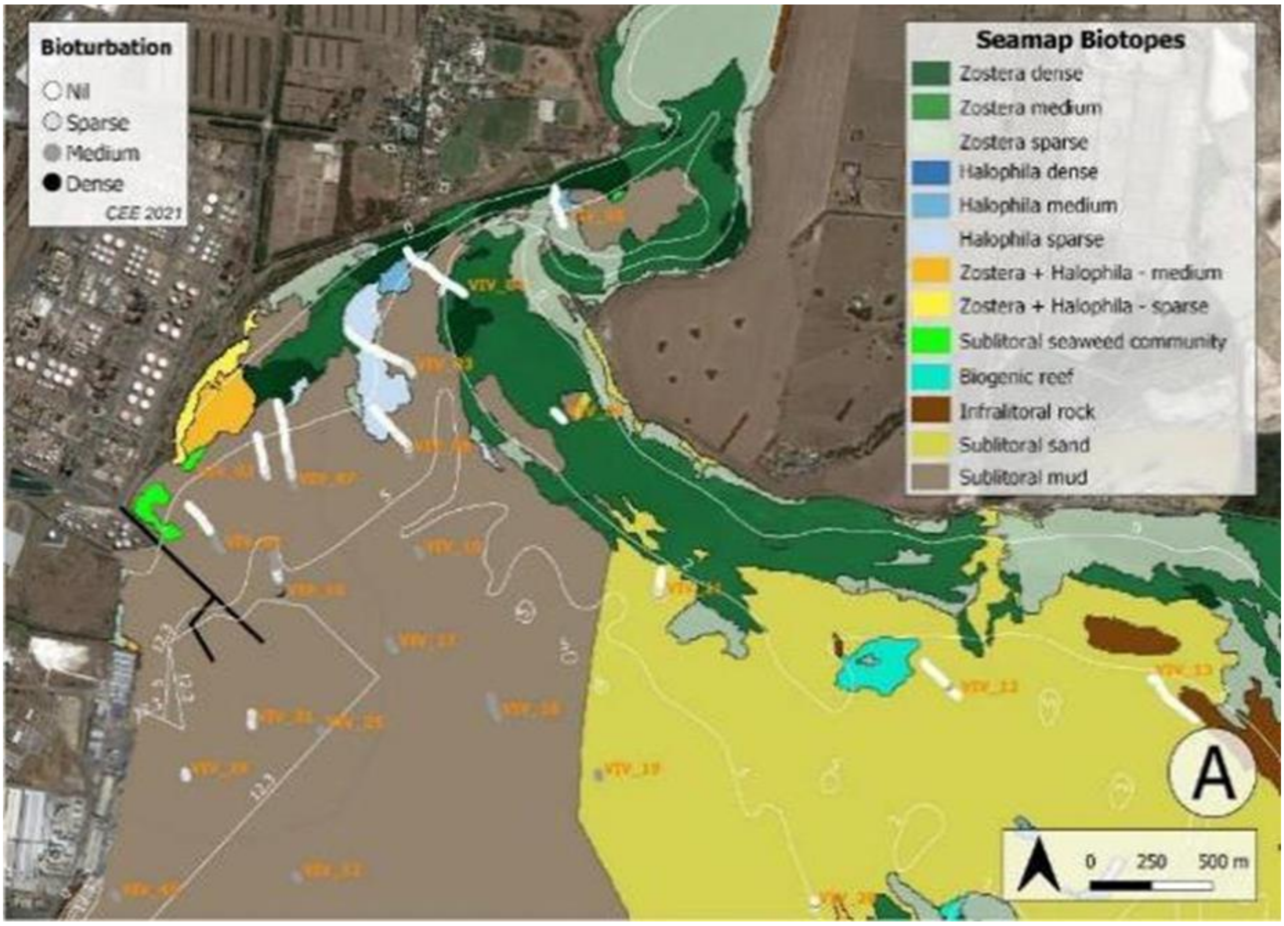


Figure 8-34 Bioturbation in North Corio Bay

8.4.13 Seabed invertebrate fauna

Studies of soft seabed biota in Port Phillip Bay undertaken in '*The zoobenthos program in Port Phillip Bay, 1969-73*' identified nine infauna community groups based on species richness, seabed composition and water depth (Poore et al 1975). One of these groups is Corio Bay, characterised by muddy sediments as a region of low species richness. In February to March 1992, soft seabed habitat epibiota and infauna were surveyed at six locations in the Geelong Arm of Port Phillip and Corio Bay ('*Benthos of the muddy bottom habitat of the Geelong Arm of Port Phillip Bay*') (Carey and Watson 1992). The main infauna identified were polychaete worms (44% of the total infauna population), small crustaceans (27% of the total population) and small burrowing clams/bivalve molluscs (representing 12% of the population). A range of introduced epibiota and infauna species were also recorded in Corio Bay, including the introduced sabellid fan worm *Sabella spallanzanii*.

Site investigations were undertaken as part of the marine ecology and water quality study for this EES to characterise the seabed habitat at 49 sites around Corio Bay. Underwater imaging from video tow transects were used to characterise benthic habitats and biodiversity. Transect site locations were selected to represent incremental distances from Refinery Pier and benthic habitats found in Corio Bay.

Benthic habitats and biodiversity were documented along 22 transects near the Geelong Refinery in northern Corio Bay. Five transects were conducted on sandy habitat, five over seagrass beds and 12 on seabed characterised by mud. Most of the biotopes in Corio Bay described in **Section 8.4.12** were present in this area. The images recorded during each tow in Corio Bay were analysed for the abundance of biota usually associated with such seabed composition, namely seagrass, macroalgae, microphytobenthos and bioturbators.

Understanding the invertebrate fauna of Corio Bay is an important consideration in assessing the potential impacts of the project, in particular from marine discharges.

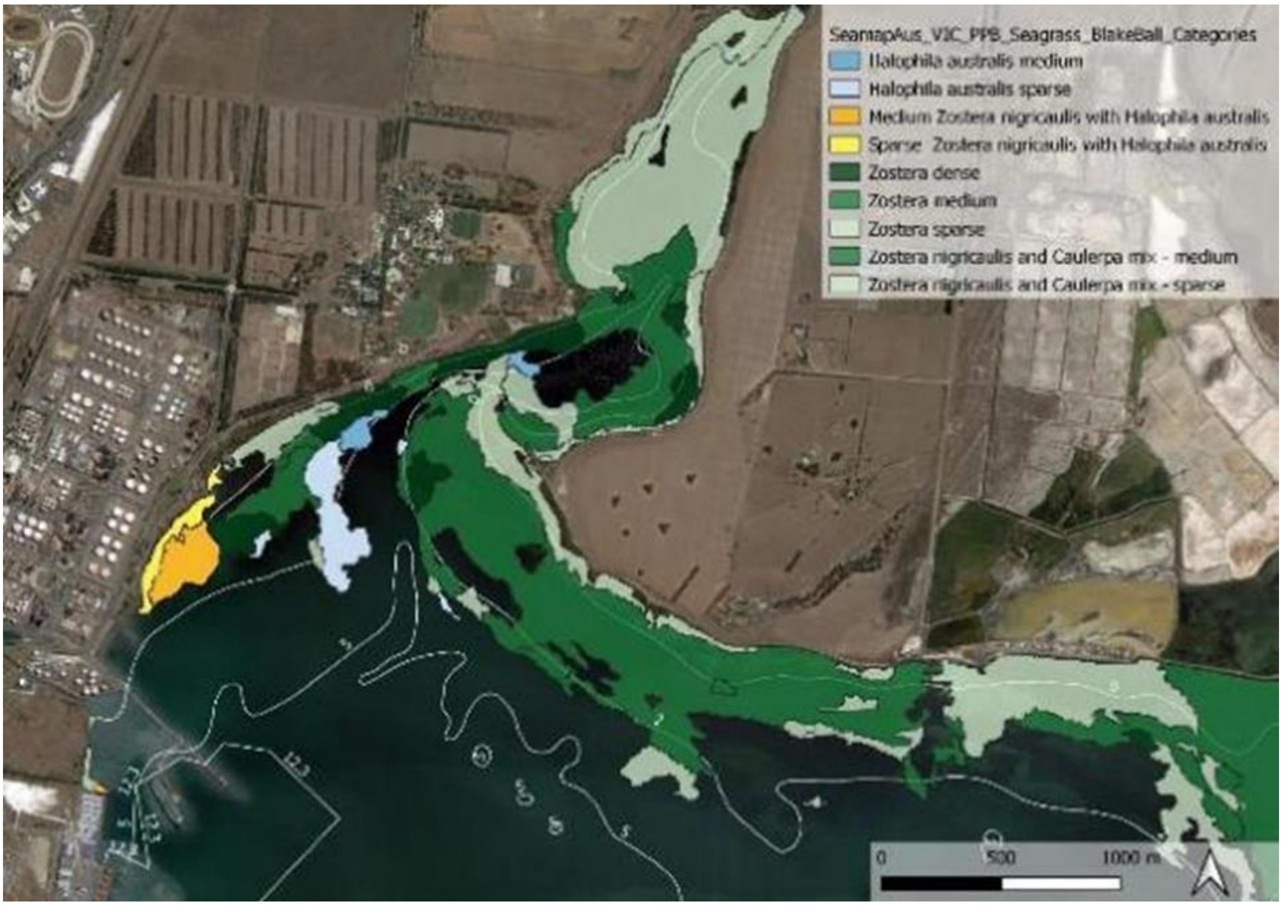


Figure 8-35 Seagrass mapping by Blake and Ball (2001)

Seagrass

Benthic macrophytes such as seaweeds and seagrasses are important primary producers in marine ecosystems and provide habitat for algal and invertebrate epiphytes, invertebrates and fish (particularly small or juvenile fish).

Seagrass was mapped in the northern end of Corio Bay and Limeburners Bay in 2001 (*Seagrass Mapping of Port Phillip Bay*') and shown in Figure 8-35 (Blake and Ball 2001). The northern shore of Corio Bay is dominated by medium density *Zostera* with some dense patches. Sparse *Zostera* is more evident further up into Limeburners Bay as well as along the shoreline of the northern coastline and at the Avalon Coastal Reserve further around to the east. In front of the Refinery, there is a mixture of sparse to medium *Zostera* and Halophila which extends offshore approximately 280 m at its thickest point. Only a very small amount of sparse *Zostera* and Halophila was recorded around Refinery Pier, located to the south along the shoreline.

Halophila seagrass is typically found in deeper water compared to *Zostera* and is normally patchy with sparse sediments between plants, whereas *Zostera* is typically found in shallower water with dense seagrass meadows on the seabed.

The location, depth and density of seagrass is subject to change over time due to variations in weather, floods, droughts, variations in turbidity, nutrient inputs, diseases, grazing and other factors. Therefore, seagrass can have large natural variations from year to year, with additional factors also influencing seagrass growth and development such as sea urchin grazing and sediment movement.

Figure 8-36 shows aerial images from NearMap which show the seagrass beds at the channel into Limeburners Bay in November 2009 and April 2011, and in June and September 2013. In 2009, seagrass around the entrance to Limeburners Bay was patchy and sparse with clumps of denser seagrass inshore of the 2 m depth contour. By 2011, the *Zostera* beds were denser, with seagrass along the eastern side of the Limeburners channel thicker and patches of bare sediment have been covered by medium to dense *Zostera*.

The seagrass beds in this area remain relatively consistent over the next two years with only minor variations. The extent of Zostera differs from season to season and year to year as it recedes and regrows. Over the 3-month period between June and September in 2013, there is a major decrease in seagrass coverage on both sides of the channel. To the west there is a significant reduction as the seagrass beds receded towards the shoreline. A band of thick *Zostera* close to the coast is evident in both figures, but the sparse *Zostera* further offshore has been replaced by bare sediment. On the eastern side of the channel, the dense seagrass has become very sparse, and the patches of bare sediment have increased in size.

Figure 8-37 shows aerial images from NearMap which show the changes in seagrass at the channel into Limeburners Bay in 2016 to 2017 and from 2020 to 2021. There was a major reduction in seagrass over a 3-month period from October 2016 to January 2017. In 2017, there is a large reduction in seagrass cover with almost all of the seagrass on the eastern side of the channel disappearing except for a strip along the shoreline. On the western side of the channel, the patches of dense seagrass reduced in size leaving large areas of bare sediment.

Figure 8-36 Seagrass variations in Limeburners Bay

Figure 8-37 Seagrass variation in Limeburners Bay

Seagrass coverage also reduced in density from March 2020 to March 2021. A reduction in seagrass can be seen in the deeper section of the Bay entrance. While the area of seagrass cover on the eastern side of the channel is much the same, there is an increase in patchiness and more bare sediment in 2021 compared to 2020.

These images show that seagrass cover can change significantly over time. While there is some seasonal variability, there are larger changes from year to year. It is clear that seagrass cover in Corio Bay is not constant and is subject to a large degree of natural change.

Seagrass near Refinery Pier

To further determine the extent of seagrass surrounding Refinery Pier, and in the vicinity of the existing discharges from the refinery, underwater imaging from the video tow transects of the seabed in Corio Bay was analysed to assess the distribution of seagrass and other benthic habitats.

Figure 8-38 shows the results of the transect tows for *Zostera*, with the white circles indicating no seagrass is evident. Light green to dark green circles and represent very sparse to very dense seagrass cover.

Zostera was found in 13 transects in the northern section of Corio Bay. High densities of *Zostera* were recorded mostly at distances greater than 500 m north and 2 km east of Refinery Pier. Dense *Zostera* was found to extend from low water to 3.7 m depth, with sparse *Zostera* extending down to 5.5 m depth.

Areas of seabed with high densities of the bare stems of *Zostera* were observed on some towed video transects. Although algal epiphytes were present on the bare stems, the density of the epiphytes over the stems is not considered sufficient to have prevented light from reaching the seagrass. In addition, healthy seagrass was observed at the same depth on other parts of a transect or nearby. The presence of bare stems together with abundant sea urchins at these sites indicates that grazing of seagrass leaves by sea urchins may be a cause of the loss of leaves from *Zostera*.

Figure 8-39 shows the results of the transect tows for *Halophila*, with the white circles indicating no seagrass is evident. Light green to dark green circles represents very sparse to very dense seagrass cover.

Sparse to dense patches of *Halophila* were recorded at seven transects on the north section of Corio Bay. *Halophila* species are comparatively small with short stems and leaves, that might grow under highly dense *Zostera* meadows. As expected, there is *Halophila* cover at depths greater than where *Zostera* is found such as the channel into Limeburners Bay, although there are several locations where there is a mixture of the two seagrass types, particularly on the eastern side of the channel, closer to a depth of 3 to 5 m. Dense *Halophila* was found to extend from 1 to 4.3 m depth, with spare *Halophila* extending down to 5.9m.

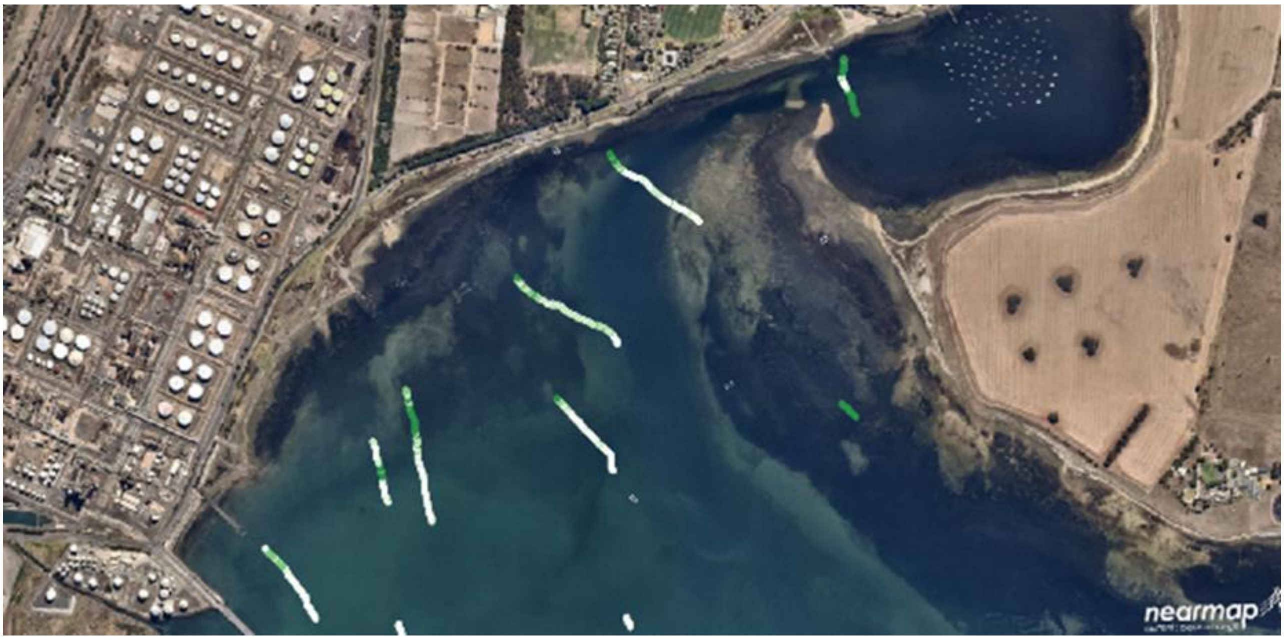


Figure 8-38 Zostera seagrass transects (Nearmap date: March 2021)

Figure 8-39 Halophila seagrass transects (Nearmap date: March 2021)

Sea urchins

Sites in Corio Bay with high sea urchin abundance were devoid of seagrass due to the grazing of seagrass leaves by sea urchins. Although *Zostera* has been previously reported at these sites, the photographic transects show an absence of seagrass at these sites in 2021 and high sea urchin numbers. In the north of Corio Bay and near Limeburners Bay there was dense seagrass with limited sea urchins present. However, in the area close to the W5 discharge point of the refinery, there was an absence of seagrass and a presence of sea urchins.

8.4.14 Marine mammals

Port Phillip Bay and Corio Bay are home to several dolphin species such as the common dolphin (*Delphinus delphis*), the common bottlenose dolphin (*Tursiops Truncatus*) and the Burrunan dolphin (*Tursiops australis*). Dolphins are a common sight in Corio Bay, particularly the Burrunan dolphin. Other species, such as the common bottlenose dolphin, are typically found in deeper water, although they swim into the Bay at times.

Seals also live in Port Phillip Bay but do not breed in the Bay. They seem to prefer sites around Port Phillip Heads, however, may occasionally venture up to Corio Bay.

Given the shallow bathymetry of Corio Bay, the bay is not visited by larger whales such as killer whales, blue whales or southern right whales. Corio Bay is not known as an important area for large marine mammals as it is not an established breeding or feeding ground for whales.

8.4.15 Penguins

The nearest penguin breeding colony to Corio Bay is the breakwater at St Kilda. Penguins are habituated to a wide range of human-related activities including boating, shipping, dredging and industrial activities. The penguins from St Kilda feed in shipping channels between St Kilda harbour and Williamstown, and also disperse widely in Port Phillip Bay following schools of anchovies and pilchards. While there is not an established colony of penguins in Corio Bay, individuals or small groups of penguins may enter the bay from time to time to feed on anchovies.

8.4.16 Introduced marine species

A comprehensive survey of introduced species in the Port of Geelong took place in August to October 1997 and found a total of 19 different exotic species. The 19 identified invasive species are widely spread over Corio Bay and 14 of them were detected at Refinery Pier.

Port Phillip Bay is known to have a large number if introduced species. These species cause additional stress and impact on the existing environment including competition with native species, elimination of native species and alteration of habitats. High abundance of non-native species detected during the 1997 surveys indicate that they are already having an impact on the ecosystem of Port Phillip Bay and Corio Bay.

8.4.17 Threatened species

There are 25 marine threatened or migratory species listed under the EPBC Act and the *Flora and Fauna Guarantee Act 1988* (FFG Act) that may occur in Corio Bay, as shown in **Table 8-2**.

Understanding the marine species inhabiting and visiting Corio Bay is an important consideration in assessing the potential impacts of the project, in particular from marine discharges and entrainment from the FSRU seawater intake.

Table 8-2 Listed threatened species potentially occurring in the study area

Common Name	Species Name	EPBC Act listed	FFG Act listed
Mammals			
Southern Right Whale	*Eubalaena australis*	Endangered, Migratory	Listed
Humpback Whale	*Megaptera novaeangliae*	Vulnerable, Migratory	Listed
Burrunan Dolphin	*Tursiops australis*	Listed marine (NA)	Listed
Sharks			
White Shark	*Carcharodon carcharias*	Vulnerable, Migratory	Listed
Grey Nurse Shark	*Carcharius taurus*		Listed
Freshwater/marine migratory fish			
Australian Mudfish	*Neochanna cleaveri*		Listed
Marine fish			
Southern Bluefin Tuna	*Thunnus maccoyii*		Listed
Australian Whitebait	*Lovettia sealii*		Listed
Turtles			
Leatherback Turtle	*Dermochelys coriacea*	Endangered, Migratory	Listed
Loggerhead Turtle	*Caretta*	Endangered, Migratory	
Green Turtle	*Chelonia mydas*	Vulnerable, Migratory	
Marine invertebrates			
Southern hooded shrimp	*Athanopsis australis*		Listed
Brittle star	*Amphiura triscacantha*		Listed
Sea-cucumber	*Apsolidium densum*		Listed
Sea-cucumber	*Apsolidium handrecki*		Listed
Brittle star	*Ophiocomina australis*		Listed
Sea-cucumber	*Pentocnus bursatus*		Listed
Sea-cucumber	*Thyone nigra*		Listed
Sea-cucumber	*Trochodota shepherdi*		Listed
Chiton	*Bassethullia glypta*		Listed
Opisthobranch	*Platydoris galbana*		Listed
Opisthobranch	*Rhodope genus*		Listed
Stalked Hydroid	*Ralpharia coccinea*		Listed

Marine mammals

Southern Right Whales intermittently pass along the central Bass Strait coast and may enter for short periods into Port Phillip Bay. Central Bass Strait, including Port Phillip Bay, is generally outside the migration path of the eastern Australian Humpback Whale population and is not a feeding, breeding or calving area. Corio Bay is not known to be an aggregation or breeding area for Southern Right Whales or Humpback Whales.

Brydes Whales are unlikely to occur frequently along the southern Australian coastline or in Bass Strait and there are no records of Brydes Whales in Victorian waters. Similarly, there have been no observations recorded of the Pygmy Right Whale in Victoria near Corio Bay or Port Phillip Bay. Small pods of Killer Whales are observed in Bass Strait from time to time, however, are not likely to venture into Corio Bay.

There are no records of Dusky Dolphins in Victorian waters and there does not appear to be any breeding or feeding grounds for Dusky Dolphins in Corio Bay. The Burrunan Dolphin is a resident of Port Phillip Bay and may swim and feed in Corio Bay at times.

Fish

White Sharks occur in all oceans of the world, including Bass Strait and Port Phillip Bay. They are highly mobile, and it is likely that individual White Sharks would pass through Corio Bay from time to time. There are no recent records of Grey Nurse Sharks in Victoria south of Mallacoota and they are unlikely to be found in the central Bass Strait region or in Corio Bay. Mackerel Sharks may occasionally and temporarily enter coastal waters, however, there are no records from Victorian Coastal Waters or Bass Strait.

The Australian Mudfish is a small galaxiid fish that has been recorded in the Yarra River (Fulton et al. 2006). The Mudfish is a diadromous species with both freshwater and marine life stages. Adult Mudfish occur in swampy areas in the lower reaches of coastal streams, but larvae disperse to marine waters (Fulton et al. 2006). Spawning occurs in winter and juvenile Mudfish return upstream in the spring-early summer (Koster et al. 2019). Larvae may occur in Corio Bay from winter to early summer.

The Australian Grayling is another diadromous species with both freshwater and marine life stages (Crook et al. 2006). Australian Grayling are not listed as an ecological value for the Point Wilson area of the Ramsar site and, while it is possible that larvae could occur in Corio Bay during the marine phase, the ichthyoplankton surveys did not identify any Grayling.

Southern Bluefin Tuna are an oceanic species, widely distributed in southern oceans from New Zealand to southern Africa and into the South Atlantic Ocean. They prefer deep ocean waters or the productive waters of the continental slope and are therefore unlikely to be found in Corio Bay. Australian Whitebait are also unlikely to be found in Corio Bay as they occur primarily in Tasmania and are only known from the Tarwin River and Anderson Inlet in Victoria.

Turtles

Leatherback Turtles are occasionally seen in Victoria between April and May when the waters of Bass Strait are warmest. Sightings and strandings have been recorded all along the Victorian Bass Strait open coast, Port Philip Bay and the Gippsland Lakes which means these turtles could visit Corio Bay.

The Loggerhead Turtle inhabits tropical and subtropical seas, though it is likely they occasionally occur in south-east Australia in the warmer months. There are 13 records of Loggerhead Turtles in Victoria, however none are from Corio Bay. The Green Turtle is also a tropical species and generally only occurs in waters where temperatures average 20°C or more. It may occasionally occur in temperate waters, however there are only seven records of Green Turtles in Victorian waters, most of them dead specimens found on beaches.

8.4.18 Underwater noise

Underwater acoustic monitoring was conducted in Corio Bay from August to September 2021 for a period of 37 days to characterise the ambient environment.

The most substantial contribution to the soundscape in Corio Bay is from vessel noise occupying frequency bands below approximately 1000 Hertz, with many distinct tones related to vessel propulsion observed in the 30-200 Hertz range present for a significant amount of time each day. The soundscape also includes a faint dusk and dawn invertebrate chorus, with the primary contributor likely being snapping shrimp.

The monitoring results demonstrate that when compared to long term recordings of other Australian harbours, such as Freemantle Inner Harbour, Corio Bay has higher median sound levels, and has a soundscape primarily defined by anthropogenic contributors, with shipping being the dominant factor. It is likely that animals present within and around Corio Bay are accustomed (habituated) to living in a noisy environment and those individuals more sensitive to noise would have left the area.

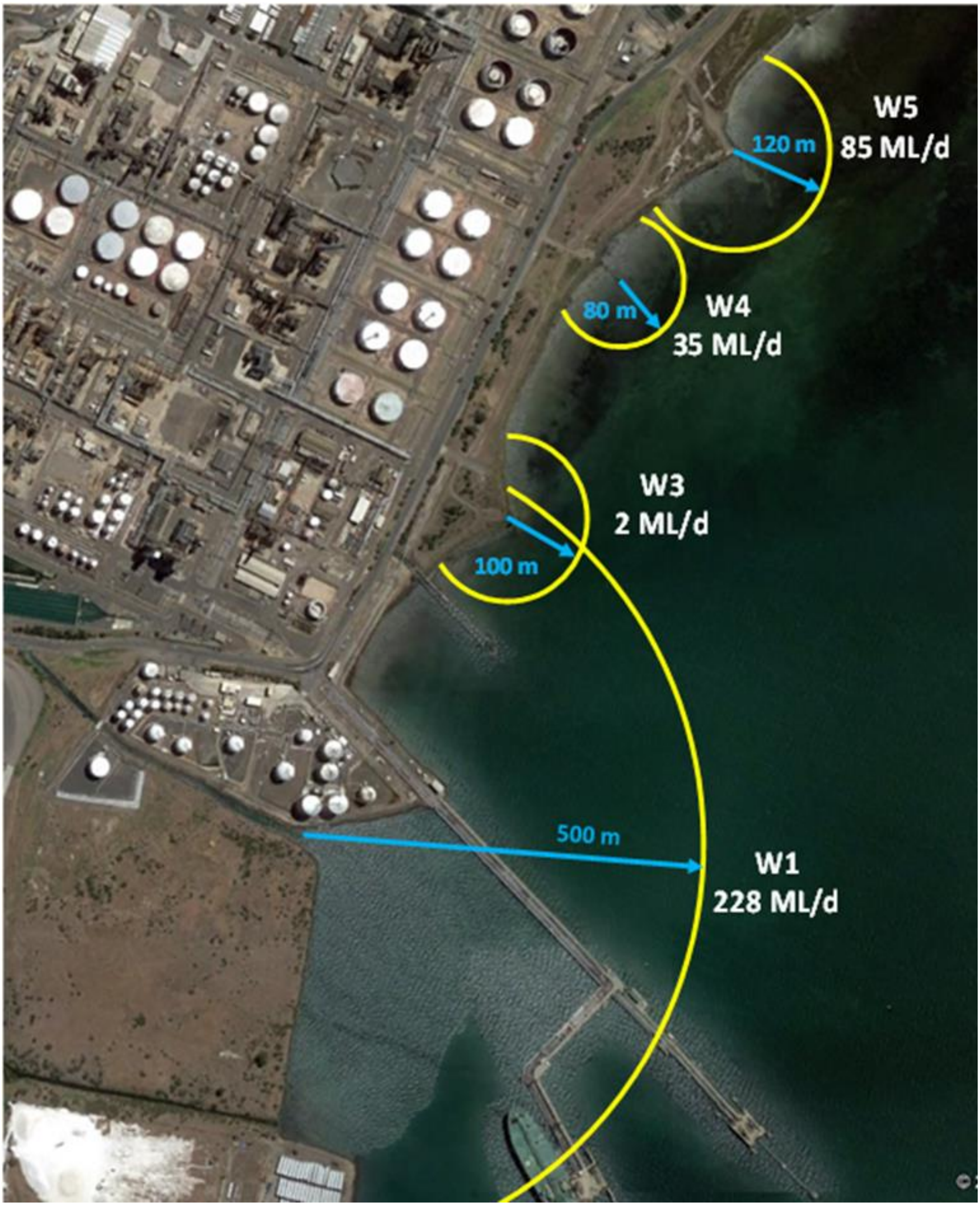


Figure 8-40 Discharge point mixing zones

8.4.19 Geelong Refinery discharges

Viva Energy's Geelong Refinery uses approximately 350 ML/day of seawater for cooling purposes as part of normal refinery operations which has occurred for over 60 years. The seawater inlet channel extends 120 m into Corio Bay just to the north of Refinery Pier. Chlorine is added to the seawater at around 0.3 to 0.4 mg/L to control biofouling in the pipes and heat exchangers. The chlorine concentration decreases substantially during the time of passage through the pipe network in the refinery. The discharged seawater is warmer than the ambient seawater due to the transfer of heat in the refinery processes.

After use, the seawater is returned to Corio Bay via four discharge points along the foreshore in front of the refinery. The largest of the discharge points is W1 which is the main discharge channel located south of the Refinery Pier and has a flow limit of 228 ML/day. The refinery EPA Licence (Licence 46555 held by Viva Energy Refining Pty Ltd) permits the four discharges to release up to 35 kg/d of chlorine in 350 ML/day of seawater **Table 8-3**.

The location of the four discharge points, the discharge rate and the extent of the mixing zones as defined in the EPA Licence are shown in **Figure 8-40**. The largest discharge point (W1) has a mixing zone radius of 500 m. W5 has the second largest discharge rate of 85 ML/day and a mixing zone radius of 120 m. W4 is the second smallest discharge of 35 ML/day with the smallest mixing zone radius of 80 m. W3 is the smallest discharge of 2 ML/day and has a mixing zone radius of 100 m.

The discharge from W1 results in a temperature increase up to 10°C above ambient. The warmer water which is discharged through the channel creates a buoyant plume about 1 m deep that disperses into the Bay. **Figure 8-41** shows a contour map of the warm plume from field measurements conducted in May 2021. The plume from the channel disperses between the shoreline and the pier and is pushed northward by the current. At the time of measurement, the discharge temperature was 23°C and the ambient water temperature over the top metre was 13°C. Therefore, there is some dilution of the plume as the plume temperature decreases to 19°C at approximately 50 m from the exit of the channel and then continues to decrease towards ambient as the plume spreads and disperses into

Figure 8-41 Warm water temperature plume from W1 discharge point

the bay. Elevated temperature of the surface plume tends to extend over the top metre of water, and at lower depths the seawater temperature decreases back to the ambient temperature recorded elsewhere in the Bay.

Given the seawater circulation patterns of Corio Bay, it is expected that the warm water plumes will travel northward. Temperature profiles were taken in the Bay in a line extending north from Refinery Pier and between the 2 m contour and the shoreline.

Figure 8-42 shows the locations and average temperature at each profile site averaged over the top 1m of depth and a reference site located further to the east with an ambient seawater temperature of 12.9°C. The profiles along the shoreline show elevated water temperature up to 1°C above the ambient temperature. This confirms that the warm water plume is dispersing northward with the natural currents of Corio Bay.

Figure 8-43 shows two of the refinery discharge points and two public drains that flow into Corio Bay. It can be seen that the refinery discharge points have little impact on seagrass in the area with only a small area of bare sediment around W5 where the main plume disperses. However, the two public drains have a larger impact on the seagrass as the runoff carries sediments into the Bay. It appears that these sediments create bare patches where seagrass is unable to grow and are visible along the shore to the north and south of discharge W5.

Viva Energy records the temperature and residual chlorine level in the four discharge points for monitoring purposes. The analysis of monitoring data showed that the residual chlorine level and temperature rise in the four discharge points are within the current EPA Licence limits. **Table 8-3** shows the existing discharges from each of the refinery discharge points compared to the limits set out in the EPA Licence.

Understanding the existing Geelong Refinery cooling water discharges in terms of temperature and chlorine is an important consideration when assessing the potential impacts of the project, in particular the marine discharges from the FSRU which are to be recycled through the refinery as cooling water and discharged into Corio Bay through the existing refinery discharge outlets. The application for the EPA Development Licence relating to the discharge of FSRU wastewater from the refinery will be made by Viva Energy Refining Pty Ltd, holder of the current refinery EPA Licence 46555. The potential impacts on the marine environment from warm or cool water discharges are discussed in **Section 8.8.1**. The potential impacts on the marine environment from chlorine discharges are discussed in **Section 8.8.2**.

Table 8-3 EPA Licence discharge limits and existing discharges for the Geelong Refinery

Discharge point	Type	EPA Licence limit	Existing discharges	Unit
W1	Flow	228	228	ML/day
	Chlorine	0.1	0.06	mg/L
	Temperature	35	+ 8	°C
W3	Flow	2	2	ML/day
	Chlorine	0.2	0.18	mg/L
	Temperature	35	ambient	°C
W4	Flow	35	35	ML/day
	Chlorine	0.2	0.06	mg/L
	Temperature	35	+ 9	°C
W5	Flow	85	85	ML/day
	Chlorine	0.1	0.05	mg/L
	Temperature	35	+ 10	°C
Total for all four discharges	Flow per day	350	350	ML/day
	Residual chlorine	35	20	kg/d

Figure 8-42 Average seawater temperature near the refinery discharge points

Figure 8-43 Discharges into Corio Bay

8.5 Project activities relevant to this study

8.5.1 Construction

The following construction activities are relevant to the marine environment study:

- Localised dredging at the new berth and within the swing basin and excavation of a trench for the installation of the seawater transfer pipe
- Construction of the Refinery Pier extension
- Construction of the temporary loadout facility at Lascelles Wharf.

An estimated 490,000 m^3 of dredged material would be required to be removed over an area of approximately 12 ha adjacent to the existing shipping channel to provide sufficient water depth at the new berth and within the swing basin for visiting LNG carriers to turn. This corresponds to 1.6% of the amount of sediment dredged from Corio Bay historically (approximately 30 million m^3). It is proposed to deposit the dredged material within the existing dredged material ground (DMG) in Port Phillip to the east of Point Wilson.

In addition to the dredging of sediment associated with the berth pocket and swing basin, the design of the FSRU includes a seawater transfer pipe from the FSRU to the existing refinery seawater inlet to transfer FSRU discharge water to the refinery for cooling water purposes. The current design indicates that approximately 8,800 m^3 of sediment would need to be excavated in order to install the pipe below the seabed. It is proposed that the excavated material be reused to backfill the excavation, creating a mound over the pipe.

Assessment of potential impacts related to dredging and excavation of seabed sediments as well as disposal of sediments is important as these activities would result in:

- Modifications to the seabed which could result in effects on productivity (conversion of carbon dioxide to marine plant tissue), changes in the distribution of habitat, effects on threatened and listed species and effects on infauna, epibiota and plankton
- Turbidity and reduced light which could result in effects on seagrass communities, plankton communities, fish and food supply for seabirds feeding in the Ramsar site
- Settlement of mobilised sediments on the seabed which could result in effects due to clogging or burial of seagrass communities, threatened or listed species and invertebrates
- Mobilisation of contaminants which could result in adverse toxic effect or bioaccumulation in benthic communities, plankton communities, fish larvae, larger pelagic communities, marine mammals, and seabirds feeding in the Ramsar site
- Mobilisation of nitrogen which could result in changes to phytoplankton abundance or species richness
- Generation of underwater noise.

The project would involve construction of an extension to Refinery Pier. The proposed Refinery Pier extension would be Refinery Pier No. 5, located to the north-east of Refinery Pier No. 1. The angled pier extension would be approximately 570 m in length, with a pier head of approximately 35 m by 35 m. Construction activity would involve pile driving for a period of up to 6 months. Assessment of potential impacts during construction of the pier extension is important as this would result in underwater noise generation during pile driving as well as the creation of additional hard substrate habitat.

A temporary loadout facility (20 m by 13 m) would be constructed at Lascelles Wharf to load and unload the proposed pier extension construction material by barge. Construction of this facility would consist of the installation of 10 piles supporting a concrete slab which would be joined to the piles. The 10 piles include four fender piles, four jetty piles and two abutment piles. Hydraulic hammers would be used to drive the piles and works are anticipated to occur over four weeks. Assessment of potential impacts related to the construction of this facility and its presence for the duration of the construction phase is important as it would result in underwater noise generation during pile driving and reduced light under the facility.

The hydrodynamic modelling carried out to inform an assessment of potential impacts is described in **Section 8.6** and the construction impact assessment is discussed in **Section 8.7**.

8.5.2 Operation

The following operational activities are relevant to the marine environment study:

- Continuous mooring of an FSRU at the new Refinery Pier berth for approximately 20 years, using seawater as the heating medium for regasification. The seawater would be discharged into Corio Bay after reuse in the refinery as cooling water or via a diffuser located on the pier extension on a limited number of occasions.

- Receipt of up to 45 LNG carriers per annum which would moor alongside the FSRU for up to 36 hours and would be assisted by four tugboats during arrival and departure.

The usual regasification mode of the FSRU for this project is open loop. The open loop regasification mode of operation proposed for the project would involve transfer of the chilled discharge water from the FSRU (approximately 7°C below ambient temperature) via a seawater transfer pipe to the existing refinery seawater intake for reuse in the refinery as cooling water.

The refinery currently uses approximately 350 ML/day of seawater for cooling purposes which heats the seawater to approximately 9°C above the entry water temperature of Corio Bay. Reuse of the FSRU discharge as refinery cooling water would reduce the temperature of the warmed seawater discharged to approximately 2°C above the entry temperature when the discharge rate is 350 ML/day. The FSRU discharge would replace all or some of the seawater intake from Corio Bay by the refinery. If the FSRU seawater output is lower than the refinery requirement for seawater on any given day due to gas production rates, the refinery would simply draw the remaining volume of seawater through the existing refinery seawater intake and the refinery cooling water discharge would be greater than 2°C above the entry temperature due to less cooled water from the FSRU but no higher than the current refinery discharge. Following reuse, the seawater would be discharged via the four existing refinery discharge outlets as shown in **Figure 8-44**.

The alternative open loop discharge arrangement assessed in the EES would involve discharge from the FSRU directly into Corio Bay through a diffuser located under the new pier. The diffuser would be used to discharge excess seawater during refinery maintenance periods when the rate of FSRU discharge exceeded the refinery demand for seawater (unlikely) or in the event that the refinery was permanently decommissioned in the future and the option for reuse of the FSRU discharge water was no longer available.

The FSRU could also operate in closed loop mode, also assessed in the EES, where a proportion of the LNG cargo would be used to fuel boilers to regasify the LNG on the FSRU. This mode of operation would be used in the event that some mechanical components of the FSRU were being maintained or there was an issue with the pumps or pipe transferring the seawater to the refinery.

The estimated gas production profile for the project is shown in **Table 8-4**. This indicative profile is based on typical gas demand rates throughout the year. The FSRU is anticipated to produce up to 500 terajoules (TJ)/day of gas which would require approximately 300 to 350ML/day of seawater for the regasification process. On a limited number of peak demand days, the gas production rate would fluctuate throughout the day, but the maximum daily flow rate of seawater would be 350ML/day.

Table 8-4 Indicative production profile

Season	Estimated gas production (TJ/day)	Number of regasification trains	Seawater consumption (ML/day)
Summer (Dec – Feb)	250	1	120 to 150
Autumn (Mar – May)	350	2	200 to 250
Winter (Jun – Aug)	500	2	300 to 350
Spring (Sept – Nov)	350	2	200 to 250

In all cases, the seawater consumption and the associated seawater discharge is below 350ML/day which is the worst-case scenario adopted for the marine modelling (discussed in **Section 8.6**) and environmental impact assessment (discussed in **Section 8.8**) and consistent with the current discharge and operating licence for the refinery.

Operation in both open and closed loop mode, as well as discharge of seawater into Corio Bay through the existing refinery discharge outlets and the diffuser located under the new pier, have been assessed in Technical Report A: *Marine ecology and water quality impact assessment* and summarised in this chapter.

Assessment of potential impacts related to use and discharge of seawater is important as these activities would result in:

- Entrainment of plankton, larvae and other small organisms as a result of seawater being drawn into the FSRU which has the potential to result in adverse effects on populations and productivity
- Discharge of cool or warm and chlorinated seawater into Corio Bay which has the potential to result in changes to the chemical or physical attributes of the marine environment and indirect effects on habitat conditions, biota, and the ecological character of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site
- Additional underwater noise and light spill which has the potential to result in adverse effects on noise and light sensitive species.

Up to 45 LNG carriers would travel through the existing shipping channel into Corio Bay and moor adjacent to the FSRU per annum. Unloading of LNG from the LNG carrier to the FSRU would take up to 36 hours. The LNG carriers would be assisted by four tugboats during arrival and departure. Additional marine impacts associated with the movement of LNG carriers in and out of Corio Bay, such as turbidity from tugs, vessel strikes, vessel grounding, spills and leaks of fuels and chemicals and imported pests were also assessed.

The hydrodynamic modelling carried out to model potential impacts is described in **Section 8.6** and the operation impact assessment is discussed in **Section 8.8**.

8.6 Hydrodynamic modelling

Hydrodynamic modelling is the study of fluids, such as seawater, in motion. Near-field and regional hydrodynamic models were developed for the project and used to:

- Simulate the existing currents, temperatures, and salinities in Corio Bay
- Predict the fate and transport of fine sediments (clay and silt) that are likely to be mobilised during dredging and dredge spoil disposal
- Predict the path and dispersion of the discharge plumes, including cooled or warmed chlorinated discharges from the Geelong Refinery and the FSRU
- Simulate the potential transport and dispersion of plankton and larvae from different regions of the Bay and predict the entrainment of plankton in the seawater intakes during operation of the FSRU.

The near-field model was used to predict the path, initial dilution and extent of the discharge plumes close to the point of discharges. The predictions from the near-field modelling were then incorporated into the regional model which was used to simulate the existing conditions of Corio Bay and predict potential impacts related to construction and operation of the project.

The subsequent sections provide a description of the near-field and regional modelling that was undertaken, how the simulations of the models were verified and the various scenarios that were modelled to predict potential impacts.

As the seawater discharges from the project would occur at the same points and at the same rates as the existing refinery discharges with a lower temperature, the modelling predictions for the project were able to be tested empirically by taking actual temperature and chlorine samples from the existing refinery plumes. The modelling was found to provide an accurate, if not conservative, representation of the current (and hence project) discharges and provide a strong basis for assessing potential impacts on the marine environment.

8.6.1 Near-field modelling

Computational Fluid Dynamic model

A Computational Fluid Dynamics (CFD) near-field model was used to simulate the existing refinery seawater intake and to simulate discharge plumes close to the four existing refinery discharge outlets, with and without the project. The mixing and dispersion simulations was performed using the CFD software, Ansys/CFX, which is licensed to Advisian (Worley Group). It computes the Navier-Stoke equations for flow behaviour and uses a thermal model for heat transfer calculations. Heat transfer is the flow of thermal energy from a hot object to a cooler object.

While initial dilution would occur due to the momentum and buoyancy of discharge plumes, the density difference between the discharge plume and the ambient seawater would also influences plume behaviour. As discussed in **Section 8.4.18** and **8.5.2**, current refinery discharges are 8 to 10°C warmer than ambient seawater. The project would involve pumping the FSRU seawater discharge into the existing refinery seawater inlet and reusing this seawater in the refinery cooling water system replacing the seawater currently taken in via the inlet. As the FSRU discharge is approximately 7°C below ambient temperature, future refinery discharges would be 1 to 3°C warmer than ambient seawater when the FSRU is operational compared

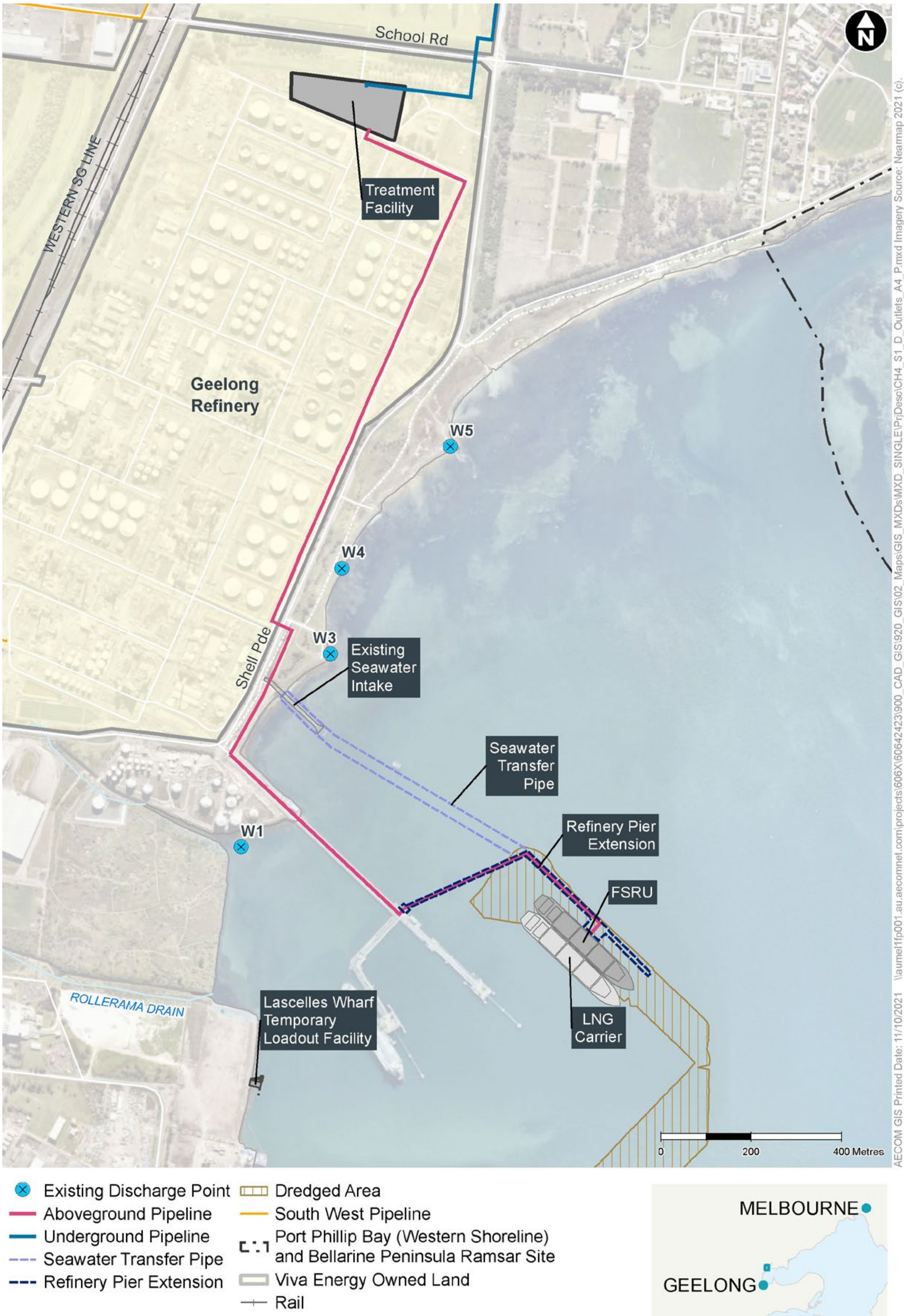


Figure 8-44 Existing refinery discharge outlets

with the current 8 to 10°C above ambient from the refinery. Discharges that are warmer than ambient seawater would spread out on the surface and modelling predictions show a 2 to 3°C reduction in temperature within 100 metres of the discharge points.

The predictions from the CFD near-field model were connected into the regional hydrodynamic model at 20 metres along the path of the modelled discharge plumes on the sea surface. Important parameters such as mass and heat were conserved to ensure that the model predictions were as accurate as possible and representative of actual outcomes.

Temperature monitoring was conducted around the area of the existing refinery discharge plumes to measure vertical temperature profiles. Contour maps of temperature measurements confirm that the plumes flows to the north, following the currents of the Bay. The measured temperature patterns show more lateral mixing than the near-field modelling predictions, however, the measured decline in plume temperature is approximately 3°C at 100 metres from the discharge point which is consistent with CFD near-field model predictions.

INITDIL model

As there is potential for the FSRU to discharge directly into Corio Bay on occasions when discharging into the refinery cooling water system is not feasible, most notably if the refinery was partially offline for maintenance activities or in the event that the refinery was permanently decommissioned in the future and the option for reuse of the FSRU discharge water was no longer available, modelling of this discharge was also undertaken to assess the potential impacts of a direct discharge into Corio Bay. In this situation, cool seawater (approximately 7°C below ambient seawater temperature) would be discharged directly from the FSRU through a diffuser located under the new Refinery Pier extension when the refinery is offline.

The CEE INITDIL near-field model was used to simulate the discharge plume within 50 metres of the proposed diffuser which would be approximately 300 metres long with 100 small high-velocity ports and located 0.5 metres below Lowest Astronomical Tide (LAT) under the new pier. The INITDIL model was used for the diffuser as this model has the capability to simulate discharge plumes created from multiple high velocity discharge points.

The high-velocity ports would discharge the seawater at around 5 metres per second (m/s) and at an angle of 30° away from the underside of the pier. The cool seawater would be spread out across a number of outlets rather than being concentrated directly from a single point of discharge on the FSRU. This configuration would result in greater mixing and dilution.

While initial dilution would occur due to the momentum and buoyancy of discharge plumes, the density difference between the discharge plume and the ambient seawater would also influences plume behaviour. Discharges that are cooler than ambient seawater would travel downward to the seabed.

As with the CFD near-field model, the connection from the INITDIL near-field model to the regional hydrodynamic model was made at 20 metres along the path of the diffuser discharge plume on the seabed. Important parameters such as mass and heat were conserved to ensure that the model predictions were as accurate as possible and representative of actual outcomes.

The predictions of the INITDIL near-field model were verified and checked using two other models, including the Cederwall plume model and the US EPA dilution model known as Visual Plumes (VPLUMES).

The INITDIL near-field model was also used to simulate the discharge plume directly from the FSRU during closed loop operation. In this mode, the seawater would be discharged via several closely spaced pipes at 3 to 5 m/s at 9 metres below the water surface. The pipes would point downwards at angle of 30 to 45 degrees below the surface. The predicted dilution in this case is 4:1 which means that there would be four parts of seawater for every1 part of discharge.

8.6.2 Regional modelling

Regional hydrodynamics and water quality were modelled using the Aquatic Ecosystem Model 3D (AEM3D). This model is a three-dimensional hydrodynamic and water quality model which has been used for a number of assessments in Port Phillip Bay. The AEM3D model was adapted to focus on Corio Bay by incorporating a fine 3D grid with cells of 20 metres by 20 metres and 1 metre deep. The hydrodynamics of the bay were represented within this fine scale grid.

After the predictions of the near-field model were incorporated into the regional model it was used to:

- Simulate the existing currents, temperatures, and salinities in Corio Bay
- Predict the fate and transport of fine sediments (clay and silt) that are likely to be mobilised during dredging and dredge spoil disposal

- Predict the path and dispersion of the discharge plumes, including cooled or warmed chlorinated discharges from the refinery and the FSRU
- Simulate the potential transport and dispersion of plankton from different regions of the bay and predict the entrainment of plankton during operation of the FSRU.

The following 2019-2020 oceanographic and meteorological data inputs were used to develop and run the regional model:

- Bathymetry data from online databases and supplemented by recent surveys undertaken in the project area
- Meteorological data obtained from the Australian Bureau of Meteorology (BoM) including wind speed and direction, air temperature, relative humidity, shortwave solar radiation and longwave radiation, tide heights, seawater temperature and salinity. Some parameters such as seawater temperature and salinity were verified using data obtained from monitoring conducted during the 12-month marine monitoring program for the project
- Hovells Creek typical monthly inflow rates via Limeburners Bay in the north of Corio Bay as this is the main streamflow into Corio Bay.

Simulated sea levels in Corio Bay were consistent with the records at Geelong over the July 2019 to February 2020 period and the tidal phase and high tide levels were accurately reproduced by the regional model as shown in **Figure 8-45**.

Relative humidity: the amount of water vapour in the air at a given temperature compared to the amount of water vapour the air can actually hold

Shortwave solar radiation: Incoming ultraviolet, visible and a limited portion of infrared energy from the sun

Longwave radiation: Heat generated from absorption of shortwave solar radiation is emitted as longwave infrared radiation

Simulated sea levels in Corio Bay were consistent with the records at Geelong over the July 2019 to February 2020 period and the tidal phase and high tide levels were accurately reproduced by the regional model as shown in **Figure 8-45**.

Currents were measured in Corio Bay in summer 2020 and autumn 2021 during the 12-month marine monitoring program for the project. Current roses were generated from the measured data as well as the regional model predictions and compared. It was found that the modelled currents were comparable to the observed currents, however, the model overpredicts the northerly water movement.. This would result in a more conservative prediction which amplifies the likelihood of discharges reaching the Ramsar site north of the FSRU.

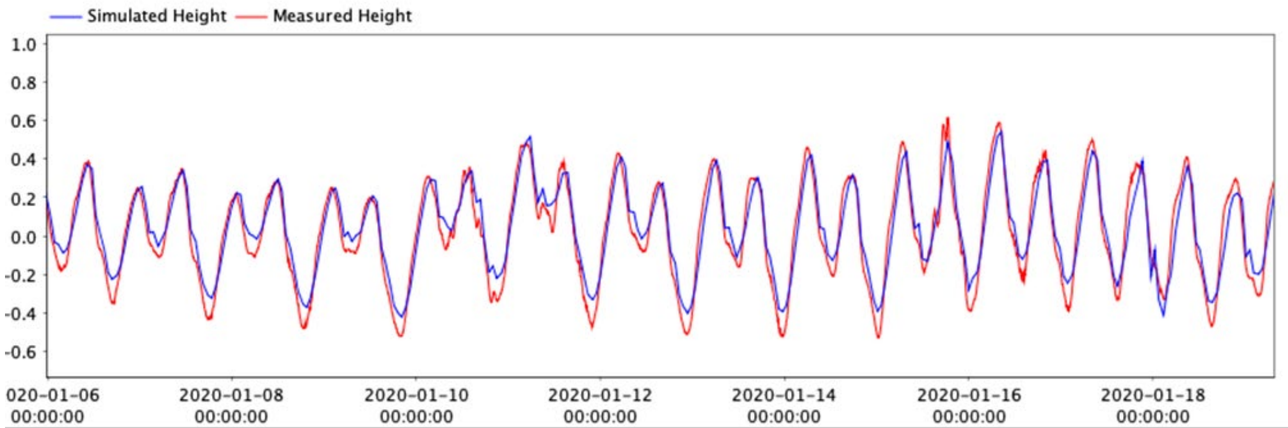


Figure 8-45 Predicted and observed tide levels in Corio Bay

8.6.3 Modelling scenarios

Dredging and dredge spoil disposal during construction

As described in **Section 8.5.1**, the project would involve dredging of approximately 490,000 m^3 of material over an area of approximately 12 ha adjacent to the existing shipping channel and disposal of the dredged material at the existing DMG in Port Phillip to the east of Point Wilson. The material to be dredged is mostly clay and silt and would be removed by a backhoe dredger and transported by barges to the disposal site (refer to **Section 8.7** for more detail).

The regional model was used to simulate the dispersion and settling of fine sediments released by dredging and from disposal of dredge spoil from a barge at the dredged material ground. The model was configured to simulate four different sediment sizes, each with a density of 2,600 kg/m^3 including:

- Clay with a particle size of 2 micron which makes up 46% of the dredged material
- Silt with a particle size of 30 micron which makes up 17% of the dredged material
- Fine sand with a particle size of 125 micron which makes up 12% of the dredged material
- Sand with a diameter of 250 microns for the remaining 25% of the dredged material.

Sediment dispersion was simulated based on a rate of loss of 6.5 kg/s of material during dredging and 76 kg/s of material during disposal. Settling rates were calculated based on the type of material that was being modelled and it was found that clay particles settle at a slow rate and experience coagulation while settling. These modelling outputs were used to inform the potential impacts of sediment settlement and dispersion on the marine ecosystem.

Discharge plumes during operation

A number of discharge scenarios were simulated using a combination of the near-field and regional hydrodynamic models to predict the potential temperature and chlorine plumes during operation of the project.

A number of different scenarios were modelled to establish the base case and develop an understanding of the existing temperature chlorine plumes created as well as predict what the temperature and chlorine plumes would look like once the FSRU is in operation.

A summary of the modelled scenarios is provided below:

- Case 1: Existing discharge conditions – existing temperature and residual chlorine plumes were modelled for the four existing refinery discharge outlets to determine the base case
- Case 2: Peak 350 ML/day flow to refinery inlet – temperature and residual chlorine plumes were modelled for the peak flow scenario where the FSRU would operate in open loop mode and use 350 ML/day of seawater and transfer all of it to the refinery inlet
- Case 3: Average 250 ML/day flow to refinery inlet – temperature and residual chlorine plumes were modelled for the average flow scenario where the FSRU would operate in open loop mode and use 250 ML/day of seawater and transfer all of it to the refinery inlet
- Case 4: Peak 350 ML/day flow to diffuser – temperature and residual chlorine plumes were modelled for the peak flow scenario where the FSRU would operate in open loop mode use 350 ML/day of seawater and discharge all of it through the diffuser under the pier when the refinery is offline
- Case 5: Average 250 ML/day flow to diffuser – temperature and residual chlorine plumes were modelled for the average flow scenario where the FSRU would operate in open loop mode use 250 ML/day of seawater and discharge all of it through the diffuser under the pier when the refinery is offline
- Case 6: Closed loop mode with peak discharge of 350 ML/day – temperature and residual chlorine plumes were modelled for the scenario where the FSRU would operate in closed loop mode and discharge seawater via several closely spaced pipes at the rear of the FSRU

Further detail about the parameters that were used for each scenario is provided in Section 6 of Technical Report A: *Marine ecology and water quality impact assessment*.

Entrainment during operation

Entrainment is the unwanted passage of fish or small marine organisms through a water intake. Entrainment of fish larvae or plankton that may spawn in Corio Bay, including the Ramsar site and Limeburners Bay, could affect the food chain and in turn the ecological character of the Ramsar site and food availability for migratory shorebirds.

A detailed survey of plankton (phytoplankton, zooplankton and ichthyoplankton (fish eggs and fish larvae)) in Corio Bay was conducted as part of the marine ecology and water quality impact assessment from November 2020 to November 2021.The objective of the survey was to assess the type and spatial distribution of plankton in Corio Bay and the effects of the circulation patterns, channel deepening and refinery use of seawater for cooling. The sampling included collection and identification of phytoplankton, zooplankton and ichthyoplankton at up to ten sites in Corio Bay. One sampling site was in the existing refinery seawater inlet, with the other nine sites distributed around Corio Bay and the Geelong Arm of Port Phillip Bay. An analysis of the results show that the plankton distribution was well mixed through the Bay with no significant difference detected between plankton in North Corio, South Corio and the Geelong Arm. Data about plankton abundance, distribution and seasonality in Corio Bay was collected as part of the 12-month monitoring program and this data formed an integral part of the entrainment modelling conducted for the project.

The movement and dispersion of plankton and larvae in Corio Bay and Port Phillip Bay was assessed by incorporating the data collected during the 12-month monitoring program into the regional model and tracking particles (as a proxy for plankton and larvae) using the regional model. The dispersion of plankton and larvae was simulated from various starting points in Corio Bay and the potential for entrainment into the existing refinery intake and the proposed FSRU intake was predicted.

The following three locations were selected as starting points for the particle dispersion simulations:

1. Ramsar site along the north coast of Corio Bay
2. Fish breeding area in north Corio Bay
3. Fish breeding area in south Corio Bay.

Figure 8-46 Ramsar site and counting locations A to G

Figure 8-46 shows the Ramsar site in northern Corio Bay (depicted by the red outline), within which the particles were released, and the seven locations (depicted as A to G) where particles were counted. Location A represents the refinery intake. Location B represents the FSRU intake. The other locations were examined to assess the movement and dispersion of particles (or plankton or fish larvae) throughout north Corio Bay.

Approximately 10,000 equally spaced particles (this number is based on the modelling grid size selected) were placed in the model and tracked. The position of each particle was calculated every 20 seconds and recorded every 2 hours. The recorded locations were then used to determine how many particles reach 'entrainment zones' within the regional model grid.

The entrainment zone for the existing refinery seawater intake was defined as a 50 x 50 metre area extending from the water surface to 2 m below the surface (A). A similar entrainment zone for the FSRU intake was defined comprising a 50 x 50 metre area extending from 9 to 11 metres below the water surface which corresponds to the depth of the seawater intakes on the FSRU (B).

Particles that entered the entrainment zone were counted and assumed to be entrained. The counts were made for 7-, 14- and 28-day periods after release and repeated for release at high tide and low tide.

8.7 Construction impact assessment

This section describes the potential impacts on the marine environment associated with construction of the project which includes the following activities:

- Localised dredging at the new berth and within the swing basin and excavation of a trench for the installation of the seawater transfer pipe
- Construction of the extension to Refinery Pier
- Construction of the temporary loadout facility at Lascelles Wharf.

8.7.1 Dredging

As described in **Section 8.5.1**, 490,000 m^3 of dredged material would be required to be removed over an area of approximately 12 ha adjacent to the existing shipping channel to provide sufficient water depth at the new berth and within the swing basin for visiting LNG carriers to turn. The FSRU berth would be dredged to a depth of 13.1 metres and the swing basin would be dredged to a depth of 12.7 m. **Figure 8-47** shows the location and dimensions of the area to be dredged. Subject to approval, it is planned to deposit the dredged material the existing dredged material ground (DMG) in Port Phillip to the east of Point Wilson located approximately 26km from Refinery Pier as shown in **Figure 8-48**. In addition, approximately 8,800m^3 of sediment would need to be excavated in order to install the seawater transfer pipe below the seabed. It is proposed that the excavated material be reused to backfill the excavation, creating a mound over the pipe. The seawater transfer pipe footprint is shown in **Figure 8-47**. Potential impacts during seabed excavation would be similar to the potential impacts of the dredging program, however, would affect a smaller spatial extent and would occur for a shorter period of time.

Shipping channels for the Port of Geelong have been progressively enlarged and modified over a period of approximately 150 years to allow for safe ship access to the port. Approximately 30 million m^3 of material has been dredged from Corio Bay in the past. The proposed dredging volumes for this project represent approximately 1.6% of the amount of sediment that has been dredged from Corio Bay over the last 150 years. The 12ha of extra dredged area would increase the area already dredged in the Port of Geelong, including the main channels in Corio Bay and the entrance channels in the Geelong Arm from 310ha to 322ha. The 12 ha to be dredged constitutes less than 0.3% of the 4,300 ha of Corio Bay.

Dredging would be carried out by a backhoe dredge operating from a barge with jack-up piles or spuds (**Figure 8-49**). The backhoe would have a large bucket (approximately 16 m^3) and would excavate in a semi-circle in front of the barge. When this is completed, the spuds are lifted, the barge moves forward, the spuds are re-set in the seabed and dredging re-commences. The dredge would operate 24 hours per day, 7 days a week, and at normal production rates, would be able to remove the planned 490,000 m^3 of sediment in approximately 8 weeks. At the dredging site, the sediment would be loaded into split hopper barges of approximately 1,600 m^3 capacity. When full, the barges would transport the material to the dredged material ground and discharge into the south-western portion of this site. It is anticipated that each barge would make three round trips per day.

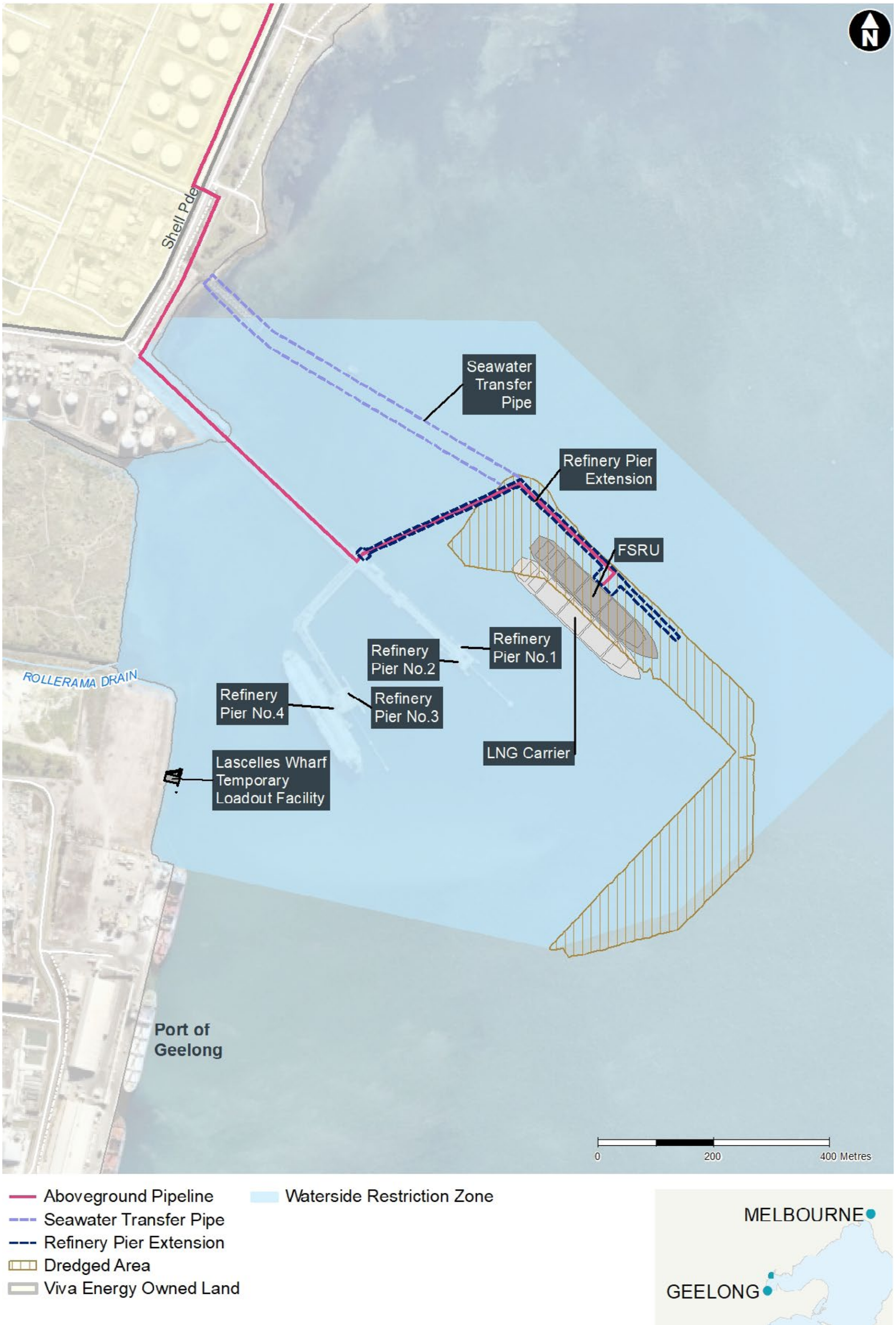


Figure 8-47 Proposed construction activities relevant to this study

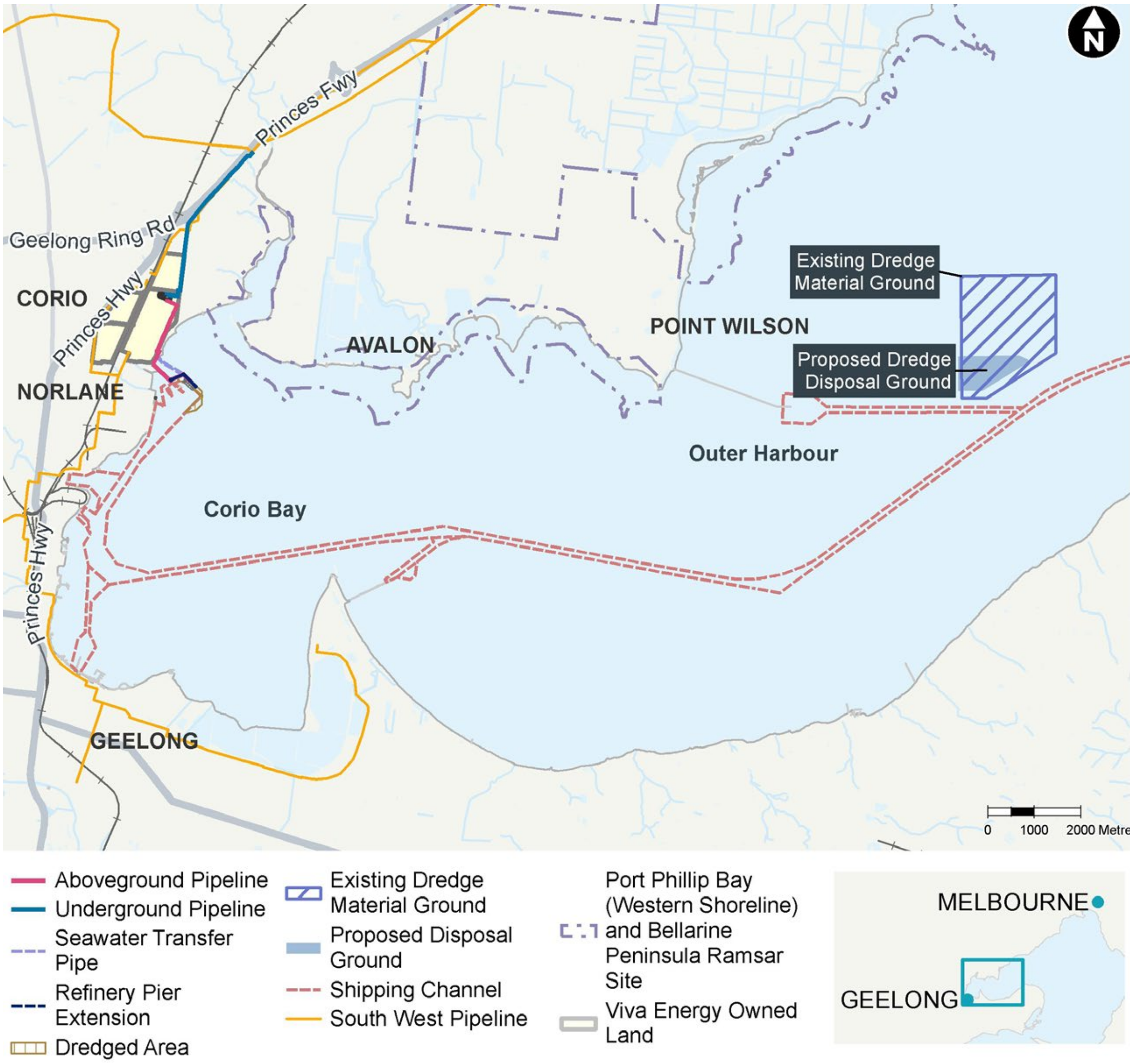


Figure 8-48 Proposed dredged material ground near Point Wilson

Figure 8-49 Example of dredging by a backhoe dredge (Source: Boskalis, 2021)

Selection of the dredged material ground

As described in earlier sections, approximately 30 million m^3 of material has been dredged in Corio Bay over the last 150 years to create shipping channels. Much of this sediment has been deposited in the defined dredged material ground to the east of Point Wilson. It has assumed that the dredging spoil from this project also would be deposited in the Point Wilson site unless there is an environmental constraint or if a preferred disposal option emerges during the assessment and regulatory process.

Sediments throughout Corio Bay are slightly contaminated with metals, some reflecting elevated natural concentrations (e.g., arsenic, nickel) and some from urban and industrial sources (e.g., cadmium, chromium, copper, zinc) along the western shore. Metal inputs from the northern catchment via Hovells Creek also are apparent (e.g., cadmium, cobalt and vanadium) in Corio Bay sediments.

Sediments previously placed in the Point Wilson DMG have similar levels of contamination to the proposed dredged material (as demonstrated in the 2020-2021 sampling program). The most recent material placed in the Point Wilson DMG came from dredging near Refinery Pier No. 4 and the eastern side of Corio Channel. This involved a total of 400,000 m^3 of dredged sediment, which is a similar volume to the 490,000 m^3 proposed for the project, with similar sediment characteristics and concentrations of metals. As such, adding new sediment will not change the existing conditions at the Point Wilson DMG.

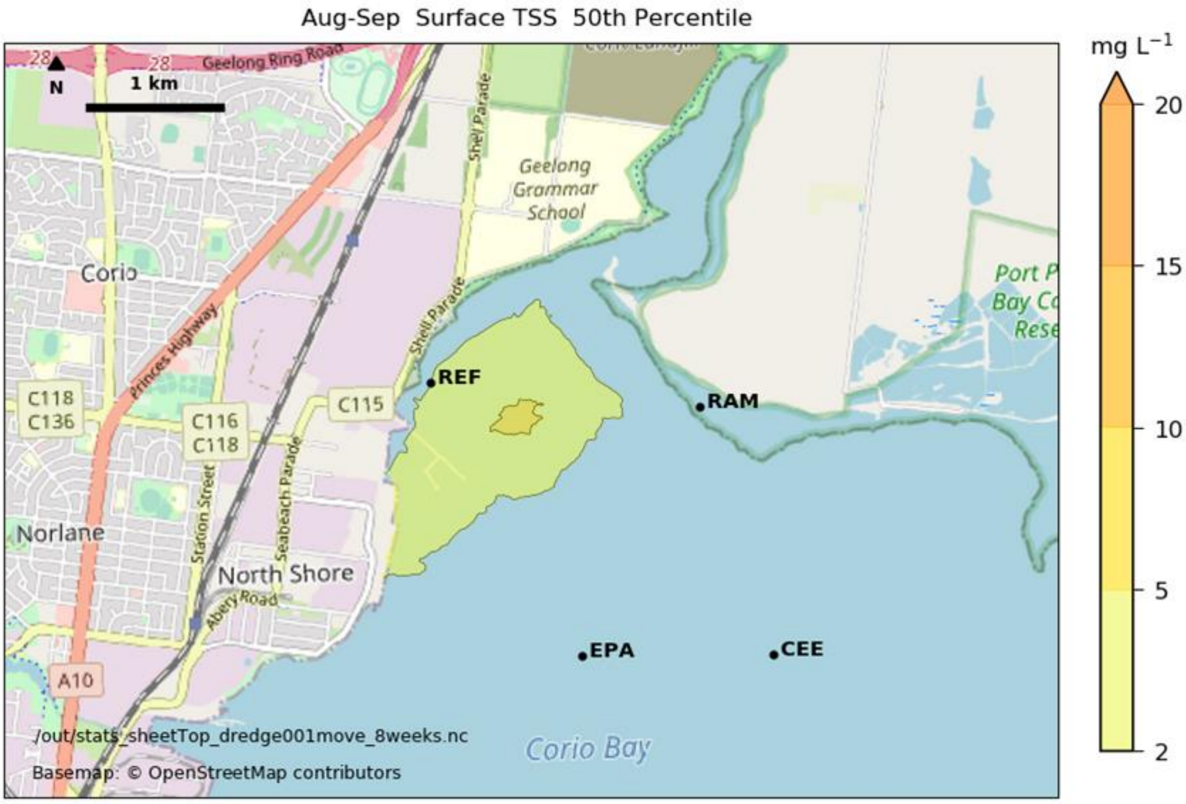
Extensive sampling and testing of sediments from the proposed dredging area and the Point Wilson DMG were conducted as part of Technical Report B: *Dredged sediment disposal options assessment*. The following was noted:

- The physical characteristics of the sediment at the area to be dredged at Refinery Pier and the Point Wilson DMG are generally very similar. Similar sediment characteristics assist the growth of existing biological communities at the Point Wilson DMG following the placement of dredged sediment
- Sediments at the area to be dredged at Refinery Pier reported 95% upper confidence limit (UCL) and/or mean concentrations greater than the default guideline values (DGV) for antimony, arsenic, lead, mercury and nickel (e.g., concentrations of these metals exceeded the assessment criteria). Sediment elutriate analysis was subsequently performed for these metals/metalloids and the mean elutriate concentrations within the sediment dataset were below the DGV indicating a low potential for bioavailability (and hence ecotoxicity) to marine biota. Silver and zinc elutriate concentrations were reported above the DGV in the Coffey (2020) data set however these were not considered to be significant exceedances that would contribute to adverse impacts to aquatic biota
- Low levels of perfluorooctane sulfonate (PFOS) were detected in sediments at the ambient baseline locations, Loading Site and Point Wilson DMG; and in seawater collected within the outer harbour of Corio Bay (all below the adopted default guideline value [DGV]). In addition, per- and polyfluoroalkyl substances (PFAS) were reported in seawater above the laboratory limit of reporting (LOR) at concentrations ranging between 0.0004 and 0.0009 µ/L. With the exception of PFOS, the PFAS detected in seawater were not recorded in the sediment samples collected from any location (including the area to be dredged at Refinery pier) indicating ubiquitous concentrations of PFAS in seawater across Corio Bay.

The results identified that the material in all layers pose no potential adverse impacts on ecological receptors at either the dredging site or the Point Wilson DMG. On the basis of the sediment quality assessment undertaken for this project in accordance with the National Assessment Guidelines for Dredging 2009, it was concluded that the sediments proposed to be dredged are suitable for unconfined offshore disposal at the Point Wilson DMG.

As the sediment analysis results show that the material in all layers pose no unacceptable risks to ecological receptors at the dredging sire or the Point Wilson DMG, separation and isolation of the surface layer of dredged sediment is not considered necessary. There would be high resource and energy requirements to separate and isolate the surface layer and therefore it would be impractical and unjustified to carry out this additional step when the overarching environmental benefit is low.

Other spoil disposal sites are possibly available in Port Phillip Bay. However, travelling further would use more energy (fuel), generate more greenhouse gass emissions and prolong the dredging period for no environmental benefit. Containment, rather than open placement, of Corio Bay sediments in the Point Wilson DMG has not been used previously and is not indicated as required. Containment under a clay cover has been used for disposal of more contaminated sediments from Hobsons Bay and the Port of Melbourne.



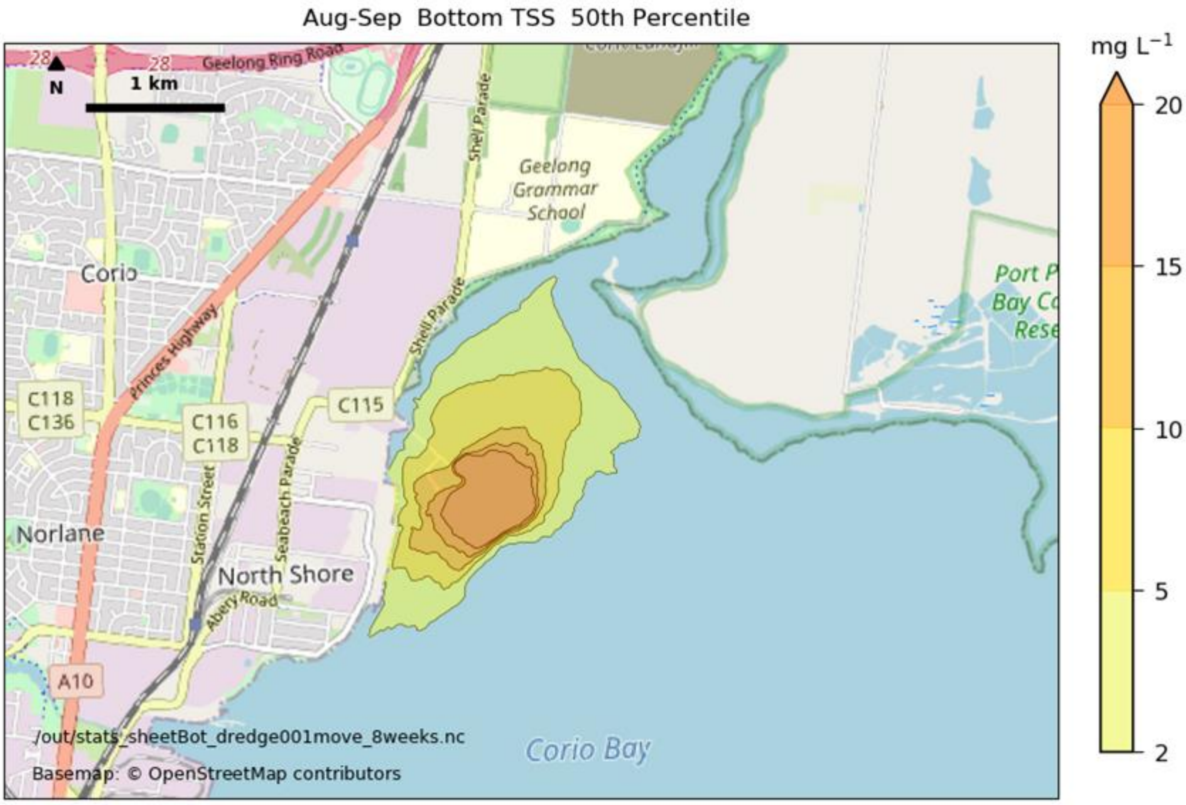


Figure 8-50 Median total suspended solids concentration at the surface and seabed (Aug-Sep)

Disposal on land is an option but the Ramsar site precludes use of the northern coast and urbanisation precludes use of the western and southern coasts. There are presently some initiatives being considered by regulatory authorities to create wetlands using dredged material, but these are not sufficiently developed to enable consideration of the project in that context. Other land-based disposal options considered in the technical studies included disposal and drying within the refinery site or disposal at waste treatment or landfill sites. These are not preferred options as they are energy intensive involving marine and land-based transportation, higher cost and not considered warranted as the extensive testing and risk assessments did not identify adverse impacts to ecological receptors at either the dredging site or the Point Wilson DMG. As such, the Point Wilson DMG was adopted as the preferred spoil disposal site.

Suspended solids and turbidity

Dredging and disposal of dredged material would result in spill and loss of material into the water column resulting in increased suspended solids concentrations and turbidity. The spill and loss rates would depend on the type of material being dredged. The material to be dredged consists of clay, silt and sand and is similar to the material encountered at the Point Wilson DMG. It has been assumed that only clay and silt would contribute to dispersed suspended solids in the water column and potential turbidity impacts as sand would settle out rapidly on the seabed near the dredge.

Predictions of the modelling that was conducted as described in Section 8.6.3 *Dredging and dredge spoil disposal during construction*, show the median suspended solids (SS) concentration in north Corio Bay over the 8 week dredging period during the months of August and September (refer to Figure 8-50). There would be a small 7 ha patch of 5 mg SS/L above ambient and a large 210 ha patch of 2 mg SS/L above ambient at the surface. There would be larger patches and higher concentrations on the seabed with a 35ha patch of 20 mg SS/L above ambient and a 290ha patch of 2 mg SS/L above ambient. This means that the seabed would experience higher levels of suspended solids concentrations over larger patches of area compared to the surface.

The REF site shown in Figure 8-50 is located at the existing refinery seawater inlet and the RAM site is located at the Ramsar site. The time series of surface suspended solids above background concentrations at the REF site over the 8 -week dredging period (if conducted in August and September) is shown in Figure 8-51. The existing refinery seawater inlet is close to the dredging area and would experience the highest suspended solids concentrations. The blue line on the time series plots shows the predicted instantaneous suspended solids concentration during dredging and approximately every 2 weeks there would be a spike where the concentrations exceed 10 mg/L and increase up to 20 mg/L. The pink line shows that the 5-day moving average suspended solids concentration is between 2 and 5 mg/L and the green line shows the 8-week moving average is 3.5 mg/L, corresponding to a turbidity of about 1.2 NTU.

The time series of surface suspended solids above background concentrations at the RAM site over the 8- week dredging period (if conducted in August and September) is shown in Figure 8-52. The blue line on the time series plots shows the predicted instantaneous suspended solids concentration during dredging and the plot shows that the peak suspended solids concentration would be 12mg/L which would last only a few hours. The pink line shows that the 5-day moving average suspended solids concentration is between 0 to 3mg/L. the green line shows the 8-week moving average is 0.3NTU. This means that the Ramsar site would experience lower levels of turbidity compared to the refinery inlet site which is closer to the area that would be dredged. Turbidity experienced at the Ramsar site would be considerably lower than would be experienced in a strong wind or storm event in Corio Bay.

The results of the modelling show that Corio Bay has higher turbidity (approximately 1.2NTU) than Port Phillip Bay. Short periods of elevated turbidity and suspended solids levels occur naturally in Corio Bay during periods of strong winds when wave action mobilises shallow and shoreline sediments. During the 8-week dredging period, areas of elevated suspended solids and turbidity would be expected, however, these areas would be limited to the dredging zone and surrounding area. The Ramsar site and central Corio Bay would only have minor increases in turbidity for short periods of time. The main sediment plume associated with the dredging does not extend to the Ramsar site including Limeburners Bay. It is likely that the existing refinery seawater intake would draw in more turbid seawater during this period, therefore a temporary silt curtain between the dredging area and the intake would be installed (refer to MM-ME04) to minimise the elevated turbidity and suspended solids concentrations.

Overflow systems would drain excess water from dredged material during the dredging program

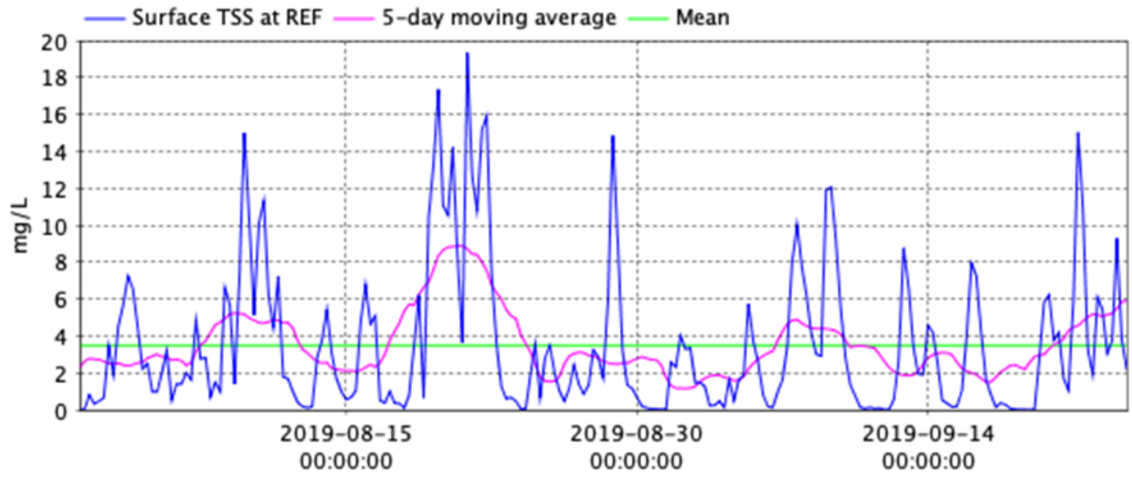


Figure 8-51 Time series of total surface suspended solids concentration at REF site (Aug-Sep)

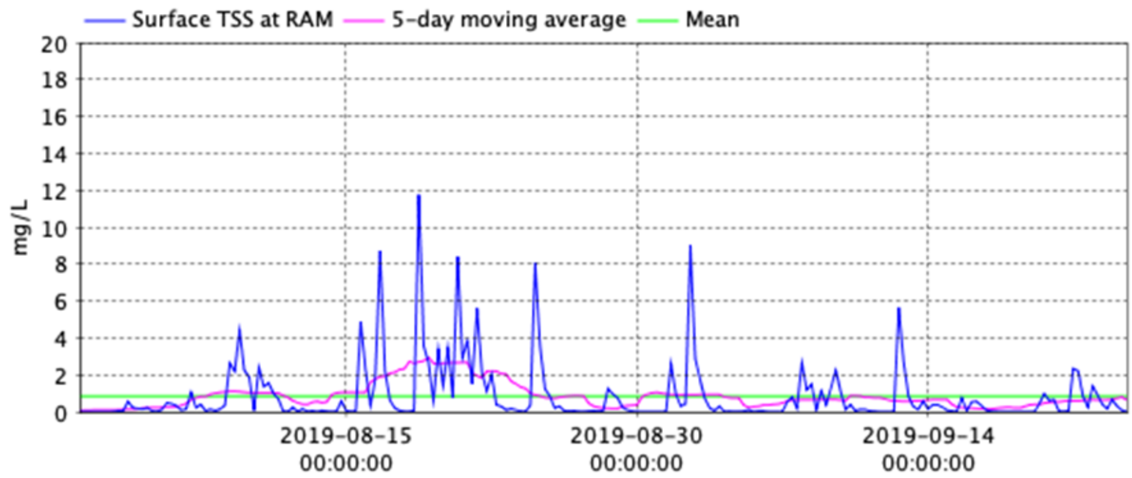


Figure 8-52 Time series of total surface suspended solids concentration at RAM site (Aug-Sep)

to improve the efficiency of the program, to limit the extent of turbidity plumes in Corio Bay during the dredging program, the overflow period for barges with a small or medium-size backhoe dredge would be limited to 20 minutes and 14 minutes for barges with a large size backhoe dredge (refer to MM-ME03). This would assist in limiting the sediment spill rate to below 9 kg/second and the extent of the turbidity plume.

Turbidity would be monitored during the dredging program at four sites in north Corio Bay, selected in consultation with the appropriate regulatory authority. Threshold limits would be assigned to trigger actions to restrict turbidity releases (refer to MM-ME05). This could include strong winds or storm events occurring during dredging. Actions to restrict turbidity releases could include reducing the period of overflow from barges to zero, slowing the dredging cycle of the backhoe dredger or ceasing operations in extreme weather.

The sensitivity of the modelled results to seasonal conditions was checked by running the model for an 8-week dredging program over the November and December period. The results were similar to the August to September predictions although the spatial extent of the plumes were smaller during November and December as a result of different weather patterns (primarily wind). The results showed that the elevated suspended solids and turbidity would be limited to the dredging area and nearby areas. In order to minimise impact, the 8-week dredging program would avoid the spring season (September, October and November) as this is the period of the year where there is a high growth of seagrass and phytoplankton and key species of fish are in larval or juvenile stage (refer to MM-ME02).

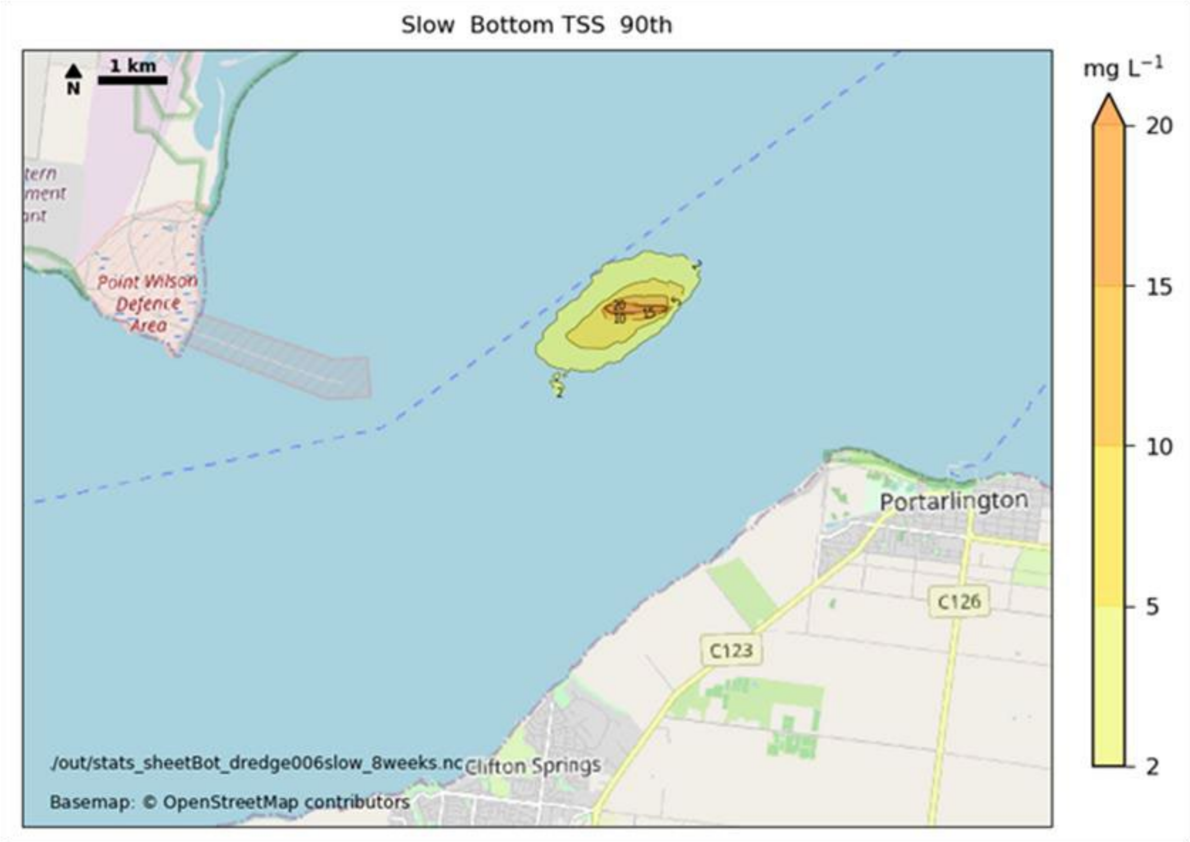


Figure 8-53 90th-percentile total suspended solids concentration at the seabed – slow barge

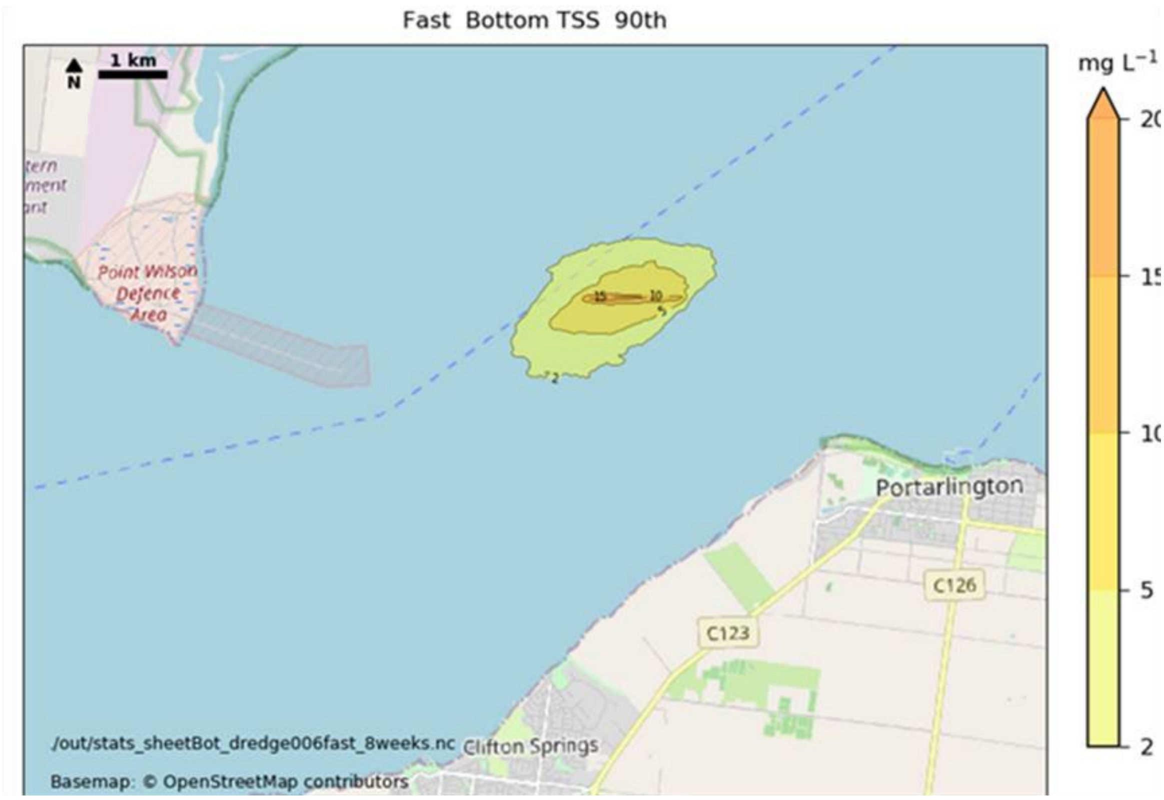


Figure 8-54 90th-percentile total suspended solids concentration at the seabed – fast barge

The dredged sediment would be transported and discharged from split hopper barges at the dredged material ground approximately 8 km to the east of Point Wilson and 26 km from Refinery Pier. This would occur six times per day with an average discharge rate of 9,000 m^3/d for the 8-week dredging program. Disposal would result in some loss of material into the water column leading to increased suspended solids concentrations and elevated turbidity.

As described in **Section 8.6.3** *Dredging and dredge spoil disposal during construction*, the regional model was used to simulate the dispersion and settlement of the spilled material at the Point Wilson DMG. If the barge travels slowly during disposal, approximately 50 tonnes of material would be lost in the water column and if the barge travels at a faster rate approximately 66 tonnes of material would be in lost in the water column. Modelling predictions show there would be very little suspended solids concentrations at the surface and any elevated concentrations would return to ambient conditions approximately one hour after release from the barge.

Figure 8-53 and **Figure 8-54** shows the 90-percentile suspended solids concentrations at the seabed of the Point Wilson DMG for the slow and fast barge options respectively. There would be a plume along the barge track with elevated suspended solids concentrations (up to 20 mg/L) and a larger patch with low suspended solids concentrations. At the surface, there would be very little SS and it would return to ambient conditions in approximately one hour after release as most of the discharge occurs at 4m depths under the barge. There would be a longer plume at the seabed along the barge track with elevated concentrations for the fast barge option.

Overall, the localised plumes would occur over a muddy seabed that would be receiving a layer of dumped sediment. There could be a minor impact on phytoplankton, however, this would be small as impacted area is small compared to the broader Geelong Arm and the impacted area would experience periods of clear water and turbid water each day during the dredging program.

Accretion of solids on the seabed

The suspended solids resulting from the proposed dredging and disposal would eventually settle and accrete (accumulate) on the seabed. Accretion of solids on the seabed could cause harm to seagrass communities, infauna or mobile marine communities as sediments could smother or bury plants and animals, reduce the amount of light that reaches these communities and reduce visibility. The regional model was used to model the accretion of solids on the seabed as described in **Section 8.6.3** *Dredging and dredge spoil disposal during construction.*

Figure 8-55 show the modelled increment in seabed elevation due to sedimentation if dredging was conducted during the months of August and September. The highest accretion of 20 millimeters (mm) occurs on the seabed in the area to be dredged and deepened. Lower accretion rates of 2 to 10mm would occur over a larger area surrounding the dredging zone. The rate of accretion (0.04mm/day to 0.2mm/day) would have negligible impact on the muddy seabed and the infauna or mobile marine communities. Seagrass naturally traps sediments and studies show healthy seagrass beds with sedimentation rates of up to 20 mm/year (Cabaco et al., 2008) and 31mm/year (Potouroglou et al., 2017). The accretion rate on seagrass beds, none of which are in the dredged area, is predicted to be from zero to 3mm, which is expected to have negligible to very minor impact as seagrass naturally traps and accumulates sediment.

Figure 8-56 shows the change in seabed elevation due to the settling of spilled material during disposal of sediments at the Point Wilson DMG for the fast barge option. The maximum increase in seabed elevation as a result of settling would be 20 mm over the localised area where disposal would occur. This is minor in relation to the 400 to 500 mm that would be added to this area from the proposed Point Wilson DMG. As discussed previously, the material to be dredged consists of clay, silt and sand and is similar to the material encountered at the Point Wilson DMG. The results of infauna studies, discussed in **Section 8.4.13**, show the abundance and types of infauna are the same in the area to be dredged and the Point Wilson DMG.

Therefore, the disposal of dredged sediments from North Corio Bay in the Point Wilson DMG would not alter the sediment characteristics and the same infauna communities that are present in the area to be dredged would develop in the new sediment surface at the Point Wilson DMG. Monitoring of seabed biota abundance, diversity and composition at the area to be dredged and at the Point Wilson DMG will be conducted to detect any significant changes and to monitor recovery (refer to MM-ME06).

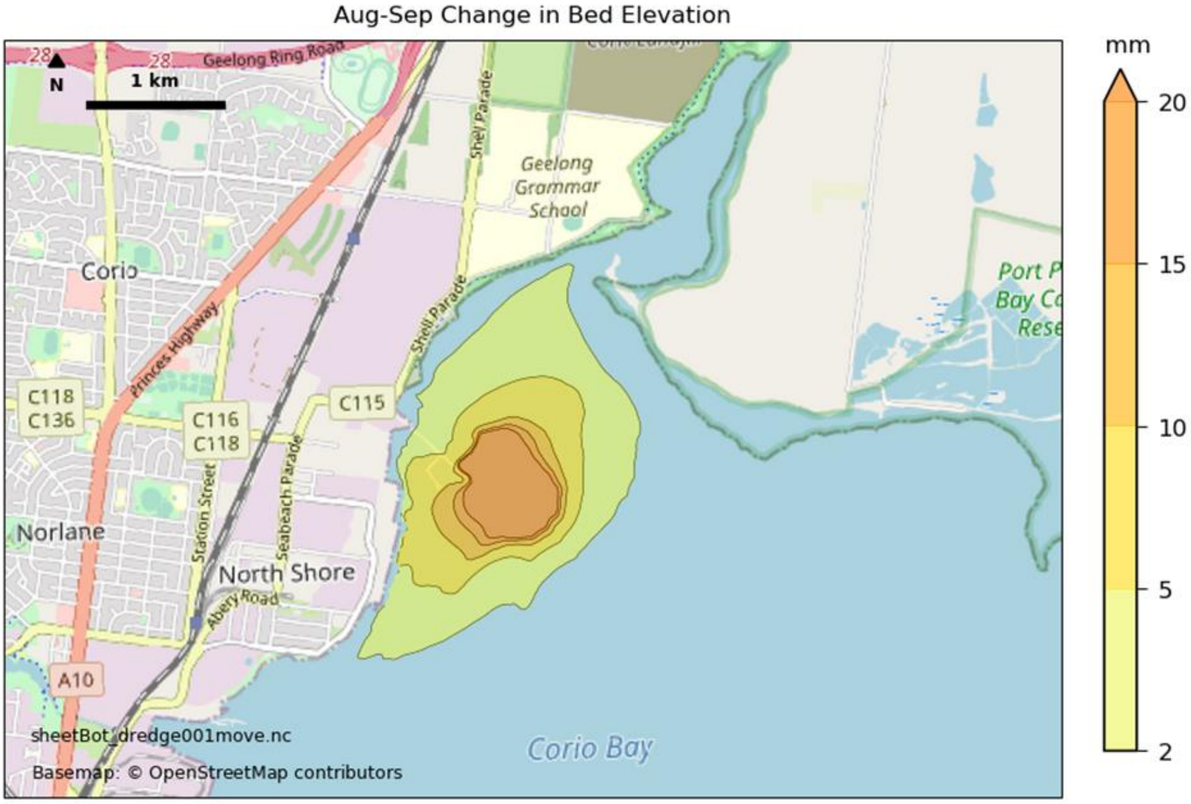


Figure 8-55 Increment in seabed elevation over the 8 week dredging period (Aug-Sep)

Figure 8-56 Changes in seabed elevation after 8 weeks with fast barge disposal

Changes in light availability

Light attenuation would increase in the areas where elevated suspended solids concentrations and increased turbidity are predicted to occur during the 8-week dredging program. The increase in turbidity and light attenuation would occur over an area of about 160 ha and would result in a minor loss in productivity of seagrass in the shallow waters within this zone. If dredging occurs in spring, seagrass growth would slow considerably. There would be little effect in winter when seagrass is mostly dormant.

The light transmission would recover quickly to the original conditions after dredging ceases i.e., within one or two days. Any seagrass growth slowed by turbidity would recover shortly after completion of dredging. In order to minimise impact, the 8-week dredging program would avoid the spring season (September, October and November) as this is the period of the year where there is a high growth of seagrass and phytoplankton (refer to MM-ME02).

Figure 8-57 shows a comparison between the modelled median suspended solids concentrations at the surface during the 8-week dredging period during the months of August and September and the dense seagrass beds.

As discussed in Section 8.7.1 *Selection of the dredged material ground*, the smaller brown area represents a patch of 5mg SS/L above background at the surface, and the larger light brown area represents a patch of 2 mg SS/L above background at the surface. The green zones on the map indicate areas that have dense seagrass – all of these zones are inshore of the 2 m depth contour. These zones have been confirmed through a combination of towed camera images, aerial imagery and field observations.

It can be seen that the area of predicted 5 mg SS/L does not extend over any seagrass. The area of predicted 2 mg SS/L extends over a 6ha patch of seagrass. The increase in turbidity and light attenuation is expected to result in a temporary loss in productivity of seagrass in the shallow waters within and around the area to be dredged. If dredging occurs in summer or autumn, seagrass growth would slow considerably. There would be little effect in winter when seagrass is mostly dormant. Modelling results indicate that fine sediments remaining in the water column would settle out in 1 to 2 days after dredging stopes. Hence, light transmission is expected to recover quickly to original conditions after dredging ceases and seagrass recovery would begin shortly afterwards.

Figure 8-57 Comparison of median total suspended solids concentration at the surface (Aug-Sep) and seagrass beds

The use of a temporary silt curtain during the dredging program would reduce the suspended solids concentration over this patch of seagrass and over adjacent seagrass patches along the shoreline (refer to MM-ME04).

Mobilisation of contaminants and nitrogen

Seabed sediments could contain elevated levels of contaminants, particularly when surrounded by industrial areas as is the situation in Corio Bay. These sediments could be released into the water column during dredging or disposal and impact the marine environment. A detailed assessment of contaminants in the sediments of Corio Bay was undertaken at the area to be dredged, the Point Wilson DMG and areas surrounding the Point Wilson DMG. The findings of these assessments are summarised below and discussed in greater detail in Technical Report B: *Dredged sediment disposal options assessment.*

Technical Report B: *Dredged sediment disposal options assessment* was completed with reference to the National Assessment Guidelines for Dredging (NAGD - Commonwealth of Australia, 2009). NAGD sets out five phases in the assessment of potential contaminants:

- Phase I – Evaluation of existing information
- Phase II – Sampling and analysis of sediments
- Phase III – Elutriate and bioavailability testing
- Phase VI – Toxicity and bioaccumulation testing
- Phase V – Weight of evidence assessment.

In 2020, Coffey reviewed existing information (Phase I) and described the sampling and analysis of sediments in the area where dredging is proposed (Phase II), as well as results from elutriate testing (Phase III) (Coffey, 2020). Further sediment samples were collected in 2021 and a contaminant risk analysis undertaken by AECOM as part of Technical Report B: *Dredged sediment disposal options assessment*.

Table 8-5 presents the measured 95-percentile sediment concentrations of metals in the top 1 m of sediment from the proposed dredging area. 95-percentile concentrations are compared to NAGD guideline values.

Elutriate testing: tests designed to measure and predict the release of contaminants from sediment into the water column

Bioavailability: the proportion of total metals that are available for incorporation or uptake into marine biota (bioaccumulation)

Ecotoxicity: toxic effects caused by natural or man-made substances on marine biota

Table 8-5 Coffey 2020 Sediment Sampling

Contaminant	NAGD Guideline Value	95 % UCL (0 – 0.5 m)	95 % UCL (0.5 – 1.0 m)
Arsenic	20	16.2	18.3
Cadmium	1.5	0.6	1.0
Chromium	80	41.3	43.8
Copper	65	17	14
Lead	50	**75**	**95**
Mercury	0.15	**0.22**	**0.21**
Nickel	21	**22.9**	**25.5**
Silver	1	0.8	<0.1
Zinc	200	80.5	65.0
TBT (ug/kg)	9	0.5	0.5
TPH	550	175	267
PAHs (total)	10	0.40	0.33

Note: 'TBT' – Tributyltin, 'TPH' – Total petroleum hydrocarbons, 'PAHs' – Polycyclic aromatic hydrocarbons

Table 8-6 Coffey 2020 elutriate results for lead, mercury and nickel

Contaminant	Marine ecosystem 95% Guideline Value	Elutriate range (ug/L) 18 samples	Elutriate 95% UCL (ug/L) 18 samples	Site seawater range (ug/L) 2 samples
Lead	4.4	**1 – 7 (1 sample above guideline value)**	2.2	<1
Mercury	0.4	0.1	-	0.1
Nickel	70	1 - 22	-	1 - 2

Elutriate tests (Phase III) were undertaken by Coffey to assess sediment results that exceeded guideline values and to assess the quantity of metals that could be dissolved in seawater. The elutriate testing results for lead, mercury and nickel were compared to the trigger values for marine ecosystems (95% protection level) from Australian and New Zealand Guidelines (ANZG, 2018). The results from the elutriate testing are summarised in **Table 8-6**.

Lead was detected above the trigger value in one elutriate sample, however the 95 % concentration was below the trigger value. The concentrations of mercury and nickel were below the trigger value in all elutriate and seawater samples.

Sediment samples collected by AECOM in 2021 from the top 2.5 m of the dredging site are presented in **Table 8-7** below.

Sediment elutriate analyses were then carried out for the metals exceeding the guideline value. The mean elutriate concentrations were below the guideline value indicating a low potential for bioavailability (and hence ecotoxicity) to marine biota (refer to **Table 8-8**).

Table 8-7 Sediment contamination at dredging site – 0.0 – 2.5 m bgs

Contaminant	95 % UCL AECOM, mg/kg	95 % UCL< Coffey and AMA, mg/kg	Guideline Value, mg/kg
Antimony	1.89	1.56	2
Arsenic	13.9	15.9	20
Cadmium	0.87	0.86	1.5
Chromium	37	46	80
Copper	25	20	65
Lead	**74**	**72**	50
Mercury	**0.32**	**0.27**	0.15
Monobutyltin as Sn	--	1.31	-
Nickel	21	**25**	21
Silver	--	0.11	1
Tributyltin as Sn	--	0.0006	0.009
Zinc	73	77	200
PFOS (1%TOC)	0.00023	0.00042	0.06
PAHs (1% TOC)	0.163	0.249	10

Note: 'PFOS' - perfluorooctane sulfonate, 'PAHs' – Polycyclic aromatic hydrocarbons

Table 8-8 Sediment elutriation results

Contaminant	Maximum Conc. (mg/L) AECOM (2021)	Maximum Conc. (mg/L) Coffey (2020)	Mean Conc. (mg/L) Combined Data	Mean Seawater Conc. (mg/L)	Guideline Value (mg/L, unless otherwise specified)
Arsenic	**0.019**	0.01	0.0044	0.003	0.0125
Lead	0.001	0.007	0.0006	<0.001	0.0044
Mercury	<0.00005	<0.0001	-	<0.00005	0.0004
Nickel	0.005	0.022	0.002	0.07	0.07
PFOS µg/L	0.0099	0.006	0.004	0.002	0.00023

Note: 'PFOS' - perfluorooctane sulfonate

The assessment found that the physical characteristics of the sediment within the area to be dredged and the Point Wilson DMG are generally very similar as would be expected as the Point Wilson DMG has received material from past dredging programs in Corio Bay. Some limited areas of sediments within the area to be dredged reported slightly elevated levels of metals including antimony, arsenic, lead, mercury and nickel. Elutriate testing was subsequently performed for these metals and elutriate concentrations were below guideline levels indicating a low potential for bioavailability (and hence ecotoxity) to marine biota.

Surveys conducted during the 12-month marine monitoring program indicate that infauna communities which inhabit the seabed have long been habituated to these metal levels. As there is a long residence time for seawater in Corio Bay and a reasonable level of sediment bioturbation (disturbance of sediments by living organisms), plankton would also be habituated to the sediment conditions. There could be some minor and short-term localised increase in the level of metals in a few species, however, this would cease and return to existing conditions after the completion of the 8-week dredging program.

Dredging and disposal of sediments would result in the release of some of the water held within the sediment known as pore water. Pore water typically contains higher levels of nutrients than in the water column. The ecological influence of these additional nutrients depends on the amount of nutrients released and the existing concentrations in the water column. As discussed in **Section 8.4.5** *Nutrients*, plant growth in Port Phillip Bay is nitrogen-limited and the total nitrogen to total phosphorous ratio is low at only 3:1, which indicates that nitrogen is usually the limiting nutrient for algal growth.

It is estimated that 1.2 kg/d of ammonia and 0.1 kg/d of nitrate would be released from the sediment pore water during dredging. Over an 8-week dredging period, the release of total nitrogen is estimated to be 70 kg. This is approximately 0.03% of the total nitrogen in Corio Bay of 21,100 kg. It is estimated that 0.8 µg/L of total nitrogen per day would be released from the sediment pore water during disposal at the Point Wilson DMG.

PFOS is not considered to represent an ecotoxicity concern during sediment dredging and disposal activities considering:

- PFOS sediment concentrations were below the 99% species protection value guideline value and therefore in accordance with NAGD (2009) assessment process, elutriate analysis would not be required
- PFOS (and other PFAS) is considered to be ubiquitous in Corio Bay seawater as demonstrated by the PFAS concentrations reported in seawater which are at similar concentrations to PFOS elutriate
- The PFOS 99% species protection values is considered to be conservative and unreliable with limited applicability to marine biota in Corio Bay
- The PFOS concentrations were all reported below the direct ecotoxicity guideline value.

Further information is provided in Technical Report B: *Dredged sediment disposal options assessment*.

North Corio Bay has a productive phytoplankton population as described in **Section 8.4.8**. During the proposed dredging program, there is likely to be a localised reduction in plankton populations near the dredging zone due to higher turbidity. The turbidity would decline quickly after dredging ceases, and it is possible that there could then be a small, localised phytoplankton bloom due to the release of nutrients during the dredging program. There is a small possibility that weather conditions at the end of the dredging program could favour a bloom of more toxic algae. Regular monitoring of plankton during and after dredging would be undertaken to monitor for toxic algal blooms and enable appropriate notifications to be made if required (refer to MM-ME07).

Plankton and productivity

The majority of aquatic ecosystems depend on conversion of carbon, nitrogen and phosphorous into plant tissue by photosynthesis. This process is carried out by phytoplankton in the water column and MPB and large marine plans on the seabed including seagrasses and seaweeds.

The total primary productivity of Corio Bay is estimated to be10,600 tonnes of carbon per year (tC/year), which is 3.4% of the primary production in Port Phillip Bay. Phytoplankton and seagrass are the major contributors, each providing approximately 40% of total productivity. MPB and seaweeds are smaller contributors, each providing approximately 10% of total primary productivity in Corio Bay. Detailed calculations of how these figures were derived are shown in Technical Report A: *Marine ecology and water quality impact assessment*.

The solid red lines on **Figure 8-58** show the 12ha area of seabed that would be dredged and the 550m long by 8m wide trench (0.5ha) that would be excavated for installation of the seawater transfer pipe. **Figure 8-58** also shows the predicted suspended solids plume on the seabed during the dredging program. The area shaded in orange shows the 35ha patch with 20mg SS/L above ambient concentrations and the area shaded in pink shows the 160ha patch with 5 mg SS/L above ambient concentrations. The spatial extent of the plume on the surface would be smaller than that shown in **Figure 8-58**.

Dredging of sediments over an area of 12 ha would result in the removal of MPB and unattached filamentous seaweeds. Following completion of dredging, MPB would recolonise the dredged area over a period of six months, however, the community is likely to be at low density as a result of the increased depth and reduced light availability. As described in **Section 8.7.1** *Changes in light availability,* elevated suspended solids concentrations and turbidity during the 8-week dredging program would result in increased light attenuation and would reduce phytoplankton, seagrass, seaweed and MPB productivity.

Table 8-9 shows the impacts on primary productivity from dredging activities.

Figure 8-58 Area of impact from proposed dredging in Corio Bay

Table 8-9 Estimated change in primary production – dredging

Primary producer	Corio Bay (tC/year)	Reduction in area (%)	Reduction in productivity (tC/year)
Phytoplankton	4,400	0.6 %	26
MPB	1,200	0.8 %	10
Seagrass	4,000	0.4 %	17
Seaweeds	1,000	1.5 %	15
Total production	**10,600**		**68***

** Note that this figure also includes impacts on primary productivity related to the construction of the temporary loadout facility at Lascelles Wharf discussed in Section 8.7.3*

As shown in **Table 8-9** the total primary productivity of Corio Bay could be reduced by 68 tC/year in the year of construction due to the direct removal of seaweed and MPB and due to effects on phytoplankton, MPB, seagrass and seaweeds from increased turbidity and light attenuation over an 8-week period. This is equivalent to 0.6% of the productivity for the year, and within the range of natural variability from month-to-month-and year-to-year and does not constitute a significant impact. No long-term change in productivity is expected from phytoplankton or seagrass outside the zone of short-term higher turbidity due to dredging.

Underwater noise

Dredging generally produces continuous broadband sound with a peak level in the source spectrum between 100-1000 Hertz. As the soundscape in Corio Bay is dominated by continuous sounds such as vessel traffic, dredging noise would contribute to the cumulative sound field in the bay and its impact would merge with the potential impact of other, existing sound sources.

Dredging noise may invoke a behavioural response in marine mammals and fish species. In an unmitigated 'worst-case' scenario, the most significant impacts to be expected are temporary behavioural responses over a range of several hundred meters for most species (fish and marine mammals) and for diving birds (when submerged) up to several kilometres from the project area. However, these ranges do not take into account the complexity and context-specific nature of behavioural responses and may under- or overestimate the true onset levels. After noise emissions have ceased, animals would gradually return into the area.

A study of bottlenose dolphins in foraging areas in Aberdeen Harbour, Scotland (an area with a high level of vessel disturbance), indicated that their presence declined as dredging intensity increased.

Behavioural impact ranges for marine mammals for dredging noise could extend to a maximum of 1.84 kilometres from the source. It is most likely that behavioural responses would be subtle and short-lived at the outer limits of the predicted impact ranges, and more severe and longer lasting close to the sound source. The potential exclusion zone (where animals would avoid the area) would be comparatively small relative to the overall habitat of the marine mammals and is not likely to have any ecologically significant consequences for the animals.

There is a possibility that fish species in the project area would be exposed to noise levels that cause a behavioural response at ranges of up to 100 metres. It is unlikely that the threshold for hearing impairment would be experienced by fish as the temporary shift in the auditory threshold (which would result in temporary hearing loss) and recoverable injury ranges would be 10 metres or less over a period of 12 to 48 hours.

The project proposes to use one of the following dredging vessels:

- Boskalis, Magnor
- Hall, Woomera, or the
- Heron Machiavelli.

The Magnor is the largest of the proposed vessels and was built in 2015. The Magnor was adopted for the Port of Melbourne maintenance dredging program for a period of 12 weeks for 24 hour works, 7 days a week and is known for its efficiency, clean technology and low noise emissions.

In order to minimise noise generation at the source, the number or duration of sound exposure periods (i.e., periods where louder noise generating activities occur) would be kept to an absolute minimum necessary to achieve the construction targets during dredging (refer to MM-UN01).

Underwater noise generated during dredging would be temporary and would only result in minor localised increases to the existing underwater noise levels in the vicinity of the project area. Animals are likely to temporarily avoid the area for the duration of the activity, however, the temporary exclusion zone would be small relative to the overall habitat for animals, and it is likely that animals would gradually return to the area after the noise emissions have ceased or abated.

8.7.2 Extension to Refinery Pier

The project would involve the construction of an extension to Refinery Pier which would take up to 18 months. The proposed Refinery Pier extension would be Refinery Pier No. 5, located to the north-east of Refinery Pier No. 1. The angled pier extension would be approximately 570m in length, with a pier head of approximately 35m by 35m. This activity would involve pile driving for a period of up to 6 months.

Addition of pier habitat

The pier arm would be supported by sets of steel piles at approximately 50 m spacings. Pier piles support a wide variety of marine growth and provide habitat for different species from those found in soft sediment. It is expected that the additional pier structures would attract the same assemblage of marine growth as the current piers and seawalls in Corio Bay. The additional hard substrate habitat provided by the piles would be approximately 1.2 ha, which is small in the context of existing hard surfaces in Corio Bay.

Based on observations of diver-biologists conducting the marine investigations, under existing piers and seawalls in Corio Bay (CEE 2018) and Port Phillip Bay (CEE 2019, 2021), the new pier arm would be colonised by a range of encrusting invertebrates and seaweeds, and would provide habitat for small fish including gobies, blennies, triplefins, spiny globe fish and pipefish.

A range of introduced pest species have been common in Corio Bay for decades. Species including the fan worm *Sabella spallanzani* and Japanese kelp *Undaria pinnatifida* would also be likely to colonise the pier from established populations throughout Corio Bay.

Underwater noise

Pile driving during construction represents the most significant anthropogenic change to the existing soundscape in Corio Bay due to the impulsiveness of the signals, as compared to the ambient noise which is dominated by continuous noise. The sound from pile driving is transient, repetitive, and discontinuous. With several piles installed per day, pile driving activity could potentially lead to a temporary and spatially limited exclusion of marine mammals from the surrounding area of the construction site. After noise emissions have ceased, it is expected that animals would gradually return into the area.

Pile driving impulses introduce a substantial amount of energy into the sediment which may be detected by bottom-living marine invertebrates as ground vibration and induce behavioural responses, however there is a lack of quantitative information on the impacts of such exposure on marine invertebrates. Given the rapid attenuation of vibrational signals beyond the near field of a sound source, it is unlikely that these stimuli are causing more than behavioural effects (such as flight or retraction) or physiological (e.g., stress) responses.

The modelling results indicate that dolphin and seal behaviour is likely to be affected over a range of up to 800m from the construction site during pile driving activities. Temporary Threshold Shift (TTS) exceedances, which would result in temporary hearing loss, are only expected in the immediate vicinity of the construction site during these activities. Sounds generated by impulsive sources such as pile driving have been tested directly and proven to cause noise-induced TTS in marine mammals at high received levels. However, as dolphins and seals are known to be highly mobile species, no marine mammal is likely to stay within the TTS range of 100 m around the construction site for the entire piling sequence or even a single pile; the likelihood of incurring TTS is therefore negligible.

There is a moderate likelihood that Australian anchovy, the only fish species in the project area with high sensitivity to underwater sound, will be exposed to noise levels exceeding their threshold for onset of behavioural responses at ranges exceeding 1 km; behavioural impact ranges for all other fish species are likely limited to ranges closer to the sound sources, i.e., more likely in the range of 10–100 m. Pile driving noise is expected to exceed the noise exposure thresholds for recoverable injury for fish at a distance of up to 60 m and the threshold for onset of TTS at a distance of up to 870 m from the sound source. However, given that the duration required to accumulate the acoustic energy to reach the threshold is 12 and 48 hours, respectively, it is unlikely that any fish species will experience such impacts.

It can be expected that pursuit-diving seabirds such as cormorants and penguins react to underwater sound emissions by altering or abandoning their foraging pursuits; penguins are likely to avoid ensonified areas (areas filled with sound) for the duration of a sound-producing activity before returning to their habitat. Pile driving impulses can be assumed to lead to diving birds avoiding the area up to a 5.76km distance.

While hammer energy and pile dimension are largely pre-defined parameters constrained by engineering considerations, the effect ranges can be altered by reducing the rate of penetration and the number of piles installed per day. Reducing the hammer energy and the number of hammer strikes would be the primary means of reducing noise at the sound source. Methods of secondary noise mitigation (barriers) can include isolation casing, fabric barriers, coffer dams, etc. (refer to MM-UN01).

To reduce the risk of TTS, Acoustic Harassment Devices (AHDs) may also be used during noise-critical activities such as the onset of pile driving to deter marine mammals from the vicinity of the works, or soft-start or ramp-up procedures may be used to allow marine mammals to move away to avoid increasing noise before full power is reached, potentially exposing them to hearing damage.

Implementing a safety zone around loud sound sources is also proposed as an efficient way to reduce the risk of causing TTS in marine mammals and avifauna (refer to MM-UN02). Visual monitoring of the surrounding area prior to commencing loud activities (such as impact pile driving) is a standard practice to reduce the risk of exposing marine mammals to intense sound in the vicinity of the source. Construction workers would also be trained to understand potential for underwater noise impacts and measures to reduce emissions (e.g., switching off machinery or equipment not required on a vessel while moored) would be endorsed (refer to MM-UN03).

Underwater noise generated during construction of the pier would be temporary and would only result in minor localised increases to the existing underwater noise levels in the vicinity of the activity area. Animals are likely to temporarily avoid the area for the duration of the activity, however, the temporary exclusion zone would be small relative to the overall habitat for animals, and it is likely that animals would gradually return to the area after the noise emissions have ceased or abated.

8.7.3 Temporary loadout facility at Lascelles Wharf

A temporary loadout facility (20 m by 13 m) would be constructed at Lascelles Wharf to load and unload the proposed pier extension construction material. Construction of this facility would consist of the installation of 10 piles supporting a concrete slab which would be joined to the piles. The 10 piles include four fender piles, four jetty piles and two abutment piles. Hydraulic hammers would be used to drive the piles and works are anticipated to occur over four weeks.

Primary productivity

The temporary loadout facility would result in reduced light on the seabed. As a result, impacts on primary productivity are anticipated for the duration of the construction period which is expected to be approximately 18 months. Investigations show that there is a patch of approximately 65 m^2 of seagrass under the temporary loadout facility which would be impacted and would result in a loss of total primary productivity (this impact is considered in the total primary productivity loss shown in **Table 8-9**). The temporary jetty would be removed at the end of the construction period and the small area of seagrass under the temporary jetty would recover when full light conditions return.

Underwater noise

Sound impacts from construction of this temporary facility would be impulsive, as per the pile driving undertaken to construct the extension to Refinery Pier. Impacts on marine animals are anticipated to be temporary and of a severity similar to those described for pile driving in **Section 8.7.1** *Underwater noise*.

8.7.4 Summary of residual impacts

Localised dredging at the new berth and within the swing basin, installation of the seawater transfer pipe, construction of the temporary loadout facility at Lascelles Wharf and construction of the extension to Refinery Pier have the potential to impact the marine environment during the construction phase of the project.

There would be an area of elevated suspended solids and turbidity at the dredging site and in the area surrounding the dredging site as a result of dredging. The increase in turbidity would be localised and would cause temporary reduction in plankton, MPB and seagrass productivity within and around the area surrounding the dredging site in north Corio Bay. The Ramsar site along the north coast and central Corio Bay would experience only a minor increase in turbidity but the change would be insufficient to cause any adverse impacts on productivity in the Ramsar site or in central and south Corio Bay. Significant amounts of suspended solids or turbidity are not anticipated to enter Limeburners Bay. The effects of increased turbidity at the Point Wilson DMG would be localised to the disposal site and would only last an hour or two after the release of each load of dredged sediment.

During the 8-week dredging program, light attenuation is predicted to increase as a result of increase in turbidity. This would occur over an area of approximately 80 ha, and a short-term loss in productivity of seagrass is expected within this zone. Light transmission would recover quickly to the original conditions after dredging ceases i.e., within one or two days. Thus, productivity is anticipated to recover shortly after the completion of dredging.

Infauna studies showed the abundance and types of infauna are the same in the area to be dredged and at the Point Wilson DMG (both around 80 to 88 organisms/sample). As such, it is considered that the proposed disposal of the extra sediment from north Corio Bay in the Point Wilson DMG would not alter the sediment characteristics and the same infauna community that occurs within existing sediments would develop in the new sediment layer at the Point Wilson DMG.

Based on the contaminant testing, small quantities of lead, mercury and nickel would be released during dredging. A limited number of samples reported slightly elevated levels of these contaminants above guideline limits. The mean elutriate concentrations were below the guideline value indicating a low potential for bioavailability (and hence ecotoxicity) to marine biota. Infauna have long been habituated to these metal levels and no change in the infauna community would occur. It is considered that plankton are also habituated to the sediment contaminant conditions. There may be some minor short-term localised increase in metals in the water column, but this would cease after the 8-week dredging program is completed.

Over an 8-week dredging period, the release of total nitrogen is estimated to be 70 kg. This is around 0.03% of the total nitrogen in Corio Bay of 21,100 kg. During the dredging program, there is likely to be a localised reduction in plankton populations due to higher turbidity, and the release of almost 70 kg of ammonia. The turbidity would decline quickly after dredging ceases, and it is possible that there could then be a small, localised phytoplankton bloom due to the release of nutrients during dredging.

The temporary loadout facility would result in reduced light on the seabed. There is a patch of approximately 65 m^2 of seagrass under the temporary loadout facility which would be impacted and would result in a loss of total primary productivity for the duration of the construction period which is expected to be approximately 18 months.

As a result of the potential impacts discussed above the total primary productivity of Corio Bay could be reduced by 68 tC/year in the year of construction due to the direct removal of seaweed and MPB and due to effects on phytoplankton, MPB, seagrass and seaweeds from increased turbidity, light attenuation and shading. This is equivalent to 0.6% of the productivity for the year, and within the range of natural variability from month-to-month-and year-to-year and does not constitute a significant impact. No long-term change in productivity is expected from phytoplankton or seagrass outside the zone of short-term higher turbidity due to dredging and outside the zone of shading due to the temporary loadout facility.

The pier arm would be supported by sets of steel piles at approximately 50 m spacings. Pier piles support a wide variety of marine growth and provide habitat for different species from those found in soft sediment. It is expected that the additional pier structures would attract the same assemblage of marine growth as the current piers and seawalls in Corio Bay. The additional hard substrate habitat provided by the piles would be approximately 1.2 ha, which is small in the context of existing hard surfaces in Corio Bay.

Underwater noise generated during construction would be temporary and would only result in minor localised increases to the existing underwater noise levels in the vicinity of the project area. Animals are likely to temporarily avoid the area for the duration of the activity, however, the temporary exclusion zone would be small relative to the overall habitat for animals, and it is likely that animals would gradually return to the area after the noise emissions have ceased or abated.

The study concluded that potential impacts related to construction activities, such as turbidity, light attenuation, habitat modification and underwater noise would be temporary and localised and would not result in significant impacts to nearby populations and communities. It is likely that any altered conditions (e.g., turbidity, light availability) would return to original conditions within a short period of time after the construction activity ceases.

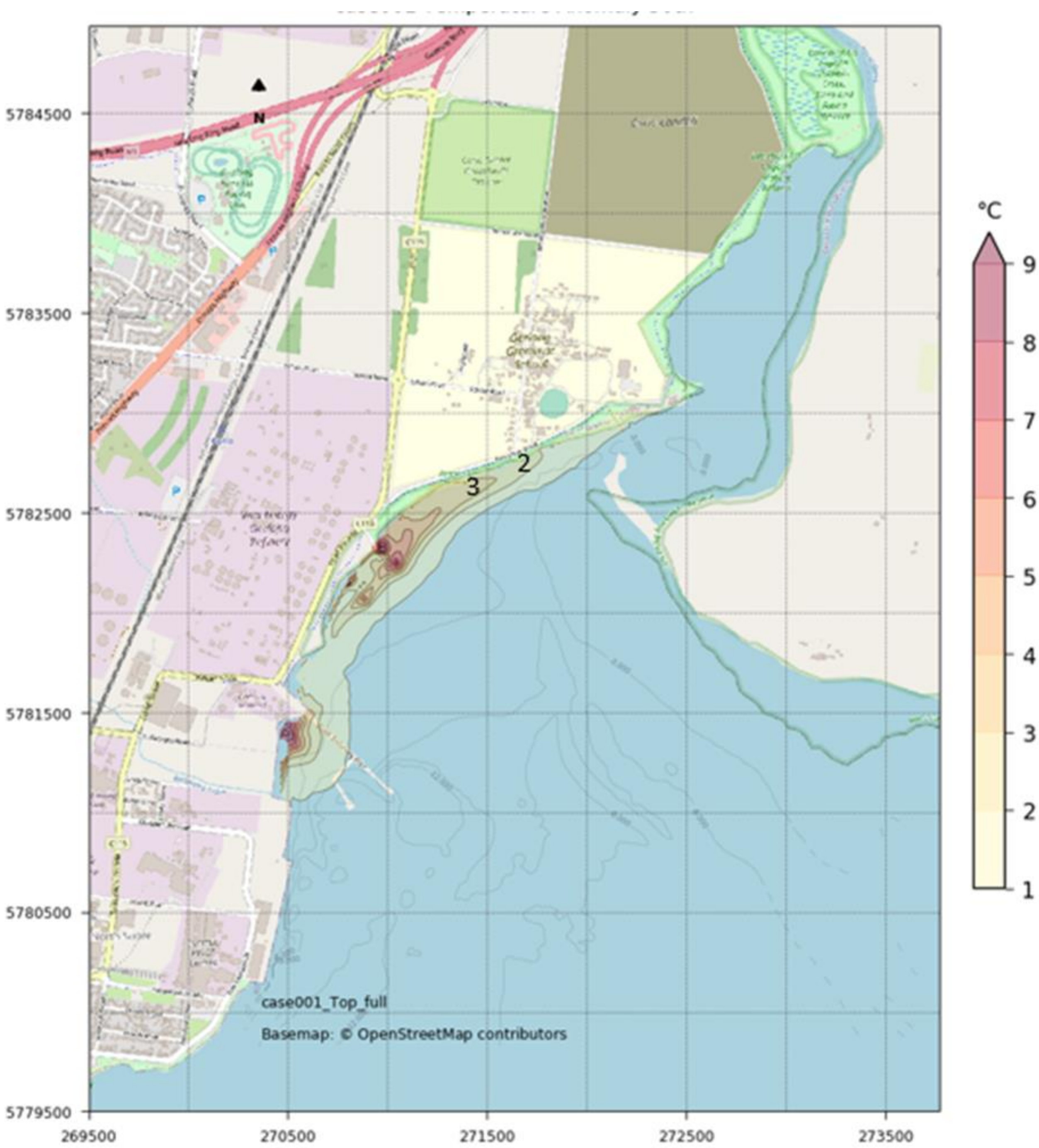


Figure 8-59 Predicted 50th percentile (median) temperature change – existing refinery temperature plumes

8.8 Operation impact assessment

This section describes the potential impacts on the marine environment associated with operation of the project which includes the following activities:

- Continuous mooring of an FSRU at the new Refinery Pier berth for approximately 20 years, use of seawater as the heating medium for regasification and discharge of seawater into Corio Bay
- Receipt of up to 45 LNG carriers per annum which would moor alongside the FSRU for up to 36 hours and would be assisted by four tugboats during arrival and departure

A detailed description of the FSRU operating modes and the indicative production profile is found in **Section 8.5.2** and a description of the hydrodynamic modelling completed to simulate existing conditions and predict potential impacts when the project is operational is found in **Section 8.6**.

The potential impacts from operation in both open and closed loop mode, as well as discharge of seawater into Corio Bay through the existing refinery discharge outlets and the diffuser located under the new pier, are discussed in this section. The potential impacts from receipt of up to 45 LNG carriers per annum and other operational activities within the marine environment are also discussed.

8.8.1 Temperature

This section describes the potential impacts on the marine environment associated with warm or cool water discharges (dependent on operating mode of FSRU) into Corio Bay during operation of the project.

Existing temperature plumes

The refinery currently uses approximately 350ML/day of seawater for cooling purposes which heats the seawater to approximately 9°C above ambient temperature. After use, the seawater is returned to Corio Bay via four discharge points (W1, W3, W4 and W5 from south to north) along the foreshore in front of the refinery (refer to **Figure 8-44**). A description of the flowrate of seawater from each discharge and the temperature and chlorine levels from each discharge is provided in **Section 8.4.18**.

Figure 8-59 shows the predicted 50th percentile (median) temperature difference (i.e., temperature difference from ambient) at the water surface for the existing refinery discharges. The plume of warmer water from the existing refinery discharge is located in shallow water and extends along the entire length of shoreline from the refinery discharge points to the entrance to Limeburners Bay. The existing refinery temperature plume reaches the mouth of Limeburners Bay, however, does not extend any further into the Ramsar site.

The temperature increase is currently 3°C within 150m of discharge W1. The 3°C contour extends to approximately 200m offshore from W4 and W5 and 700m to the north along the shore. The plume of warmer water from the existing refinery discharges is approximately 1°C above ambient at the entrance to Limeburners Bay. Water has a high heat storage capacity and therefore there is little change in temperature contours from hour-to-hour or day-to-day. As described in **Section 8.4.13** *Seagrass*, the seagrass along the refinery shore under the existing temperature plume is in healthy condition.

Temperature monitoring around the area of the existing refinery discharge plumes was conducted to measure vertical temperature profiles and verify the accuracy of the temperature modelling predictions conducted for the marine studies. Contour maps of temperature measurements confirm that the plumes flow to the north following the currents of the bay and also confirm that the actual temperatures in Corio Bay are consistent with the modelled results.

The current discharges have been occurring for over 60 years and surveys of the seagrass beds beneath the existing plumes show that seagrass grows prolifically in close proximity to all refinery discharge points. There is a possibility that the warm plume increases the growing season for seagrass and hence increases productivity.

Predicted temperature plumes – peak flow

This scenario would occur when the FSRU is operating in open loop mode with a seawater intake of 350ML/day and transferring all of the cooled discharge water from the FSRU (at approximately 7°C below ambient temperature) to the existing refinery seawater intake for reuse in the refinery as cooling water. The flow through the refinery would heat the seawater and it would be discharged to Corio Bay through the four existing discharge points (W1, W3, W4 and W5) at 7°C cooler than the existing refinery discharge temperatures (i.e., approximately 1 to 3°C above ambient temperature).

Figure 8-60 show the predicted 50-percentile (median) temperature difference at the surface for the future peak flow case. With the project in operation, there would be a smaller temperature plume along the shoreline compared to the existing situation, and most of the plume would only be 1 to 2°C above ambient seawater temperature as

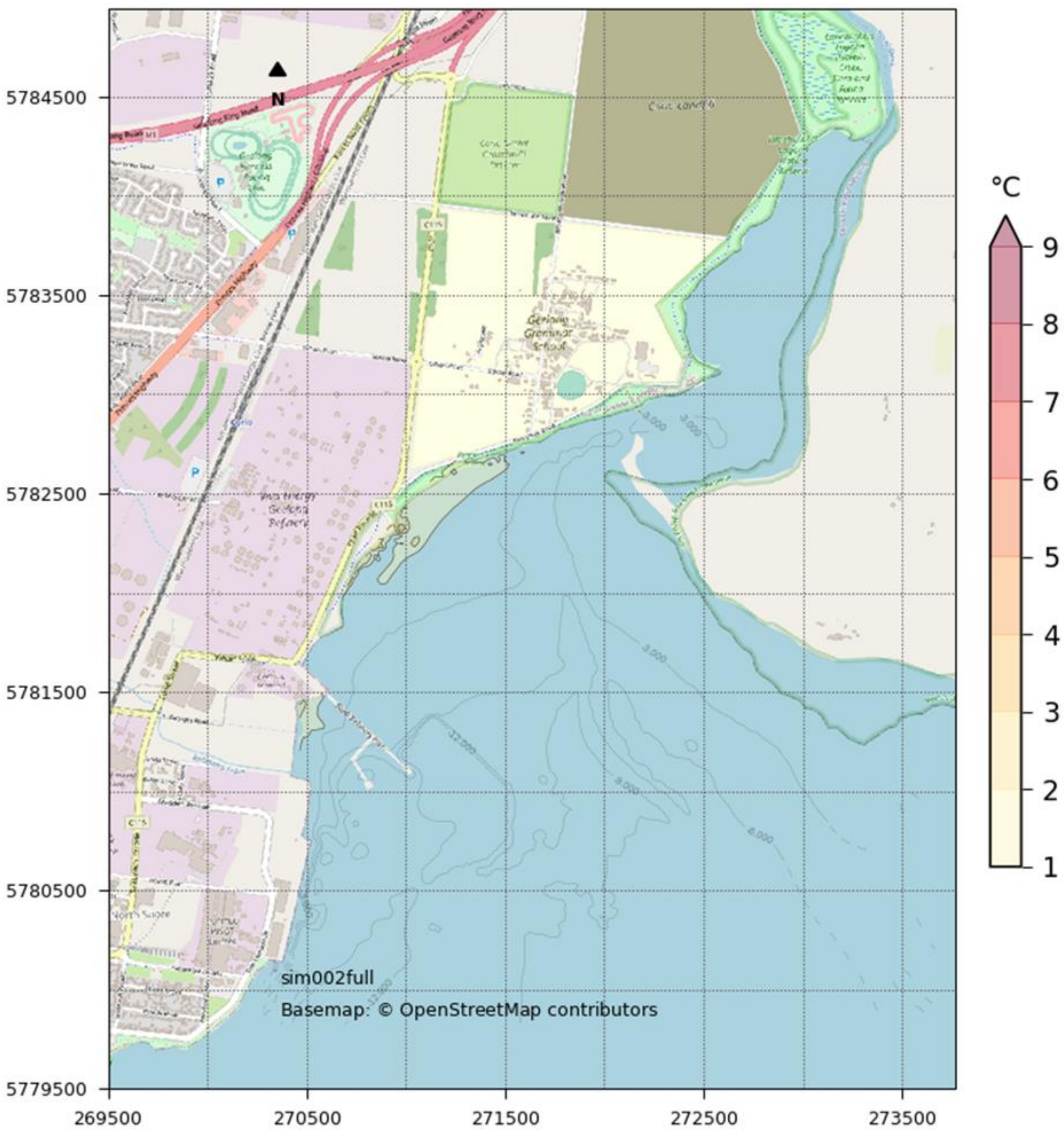


Figure 8-60 Predicted 50th percentile (median) temperature change – future peak flow case

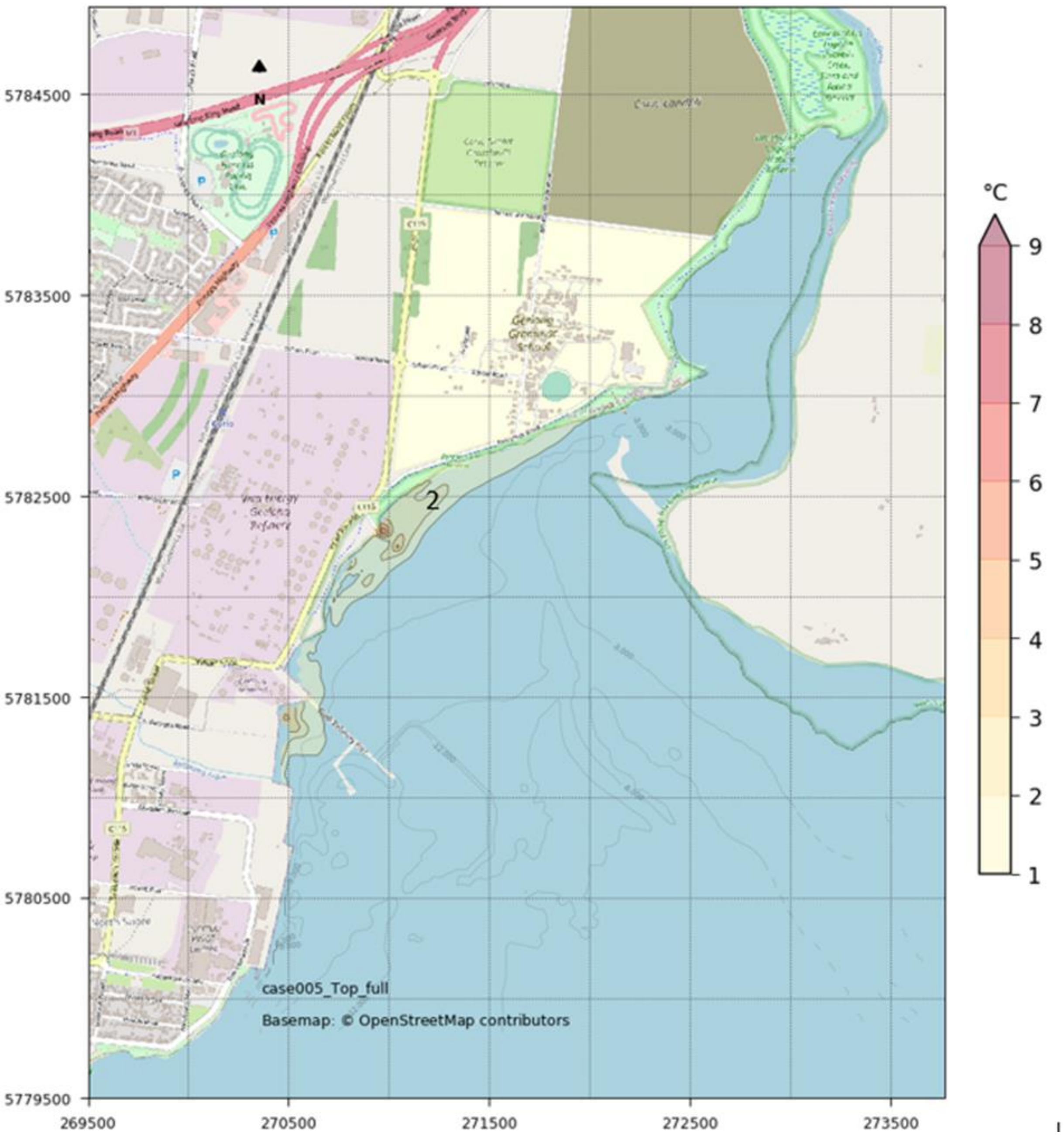


Figure 8-61 Predicted 50th percentile (median) temperature change – future average flow case

a result of the cooled water input from the FSRU. The project would result in a smaller plume with lower temperatures in Corio Bay which is considered to be an environmental improvement from reuse of the FSRU discharge water. The temperature plume does not reach the Ramsar site including Limeburners Bay.

The reuse of discharge from the FSRU in the refinery for cooling water purposes would be maximised to ensure that there is a reduction in temperature plume from existing refinery discharge (refer to MM-ME01).

Predicted temperature plumes – average flow

This scenario would occur when the FSRU is operating in open loop mode with a seawater intake of 250ML/day and transferring all of the cooled discharge water from the FSRU (at approximately 7°C below ambient temperature) to the existing refinery seawater intake for reuse in the refinery as cooling water. The refinery would draw the remaining volume of seawater required (100ML/day) through the existing refinery seawater intake. The flow through the refinery would heat the seawater and it would be discharged to Corio Bay through the four existing discharge points (W1, W3, W4 and W5) at temperatures that are closer to ambient than the current situation, however, higher than the peak flow case discussed in **Section 8.8.1** *Predicted temperature plumes - peak flow* as there would be less chilled water input from the FSRU.

Figure 8-61 show the predicted 50-percentile (median) temperature difference at the surface for the future average flow case. For the average flow case, the plume extends north along the shore to a similar distance as the plume under the existing refinery discharges, however, with smaller temperature increases above ambient. The warm plume decreases to less than 1°C difference within 300m off the shore and at the entrance to Limeburners Bay.

As with the peak flow case, the temperature plume for the future average flow case would be smaller and less intense (i.e., smaller temperature rise) than the current refinery temperature plume. The temperature plume does not reach the Ramsar site including Limeburners Bay.

Predicted temperature plumes – peak diffuser discharge

An alternative discharge arrangement for the project assessed in the EES would involve discharge from the FSRU directly into Corio Bay through a diffuser located under the new pier. The diffuser would be used to discharge excess seawater during refinery maintenance periods when the rate of FSRU discharge could exceed the refinery demand for seawater (unlikely) or in the event that the refinery was permanently decommissioned in the future and the option for reuse of the FSRU discharge water was no longer available. A full refinery shut down was assumed as a worst case for modelling this scenario. However, in reality, the maintenance regime at the refinery involves one half of the refinery being taken offline for 2-3 months every second year with the other half of the refinery remaining operational. When in a maintenance period with half of the refinery offline, cooling water demand is still in the range of 200-250 ML/day. Based on the projected FSRU seasonal production rates (refer to **Table 8-4**), it is likely that the FSRU would still be the primary source of refinery cooling water even during maintenance periods as winter is the only season where FSRU discharge materially exceeds the refinery cooling water demand of 200-250 ML/day. However, refinery maintenance is typically conducted in spring and autumn, not winter, so it is unlikely that there would be surplus FSRU discharge water during winter. As such, the diffuser is likely to be used on limited occasions.

Notwithstanding the above, in this modelled worst-case scenario the FSRU would operate in open loop mode using 350 ML/day and would discharge all of the cooled seawater (approximately 7°C below ambient temperature) through a 300 m long diffuser with 100 small high-velocity ports and located 0.5 metres below Lowest Astronomical Tide (LAT) under the new pier extension.

The diffuser would be designed to achieve high dilution and to ensure that the diluted discharge has a temperature change of less than 0.4°C from ambient (refer to MM-ME10). The high-velocity ports would discharge the seawater at around 5 metres per second (m/s) and at an angle of 30° away from the underside of the pier. The cool seawater would be spread out across a number of outlets rather than being concentrated directly from a single point of discharge on the FSRU. This configuration would result in greater mixing and dilution. The predicted dilution in this case is 20:1 which means that there would be 20 parts of seawater for every1 part of discharge.

As the diluted plume is cooler water, it is slightly more dense than ambient seawater and would form a plume of diluted effluent, about 3 m thick, on the seabed in the dredge shipping channel. **Figure 8-62** shows the predicted 50-percentile (median) temperature difference at the seabed for the future peak diffuser discharge case. The temperature of the plume on the seabed would be between 0.4

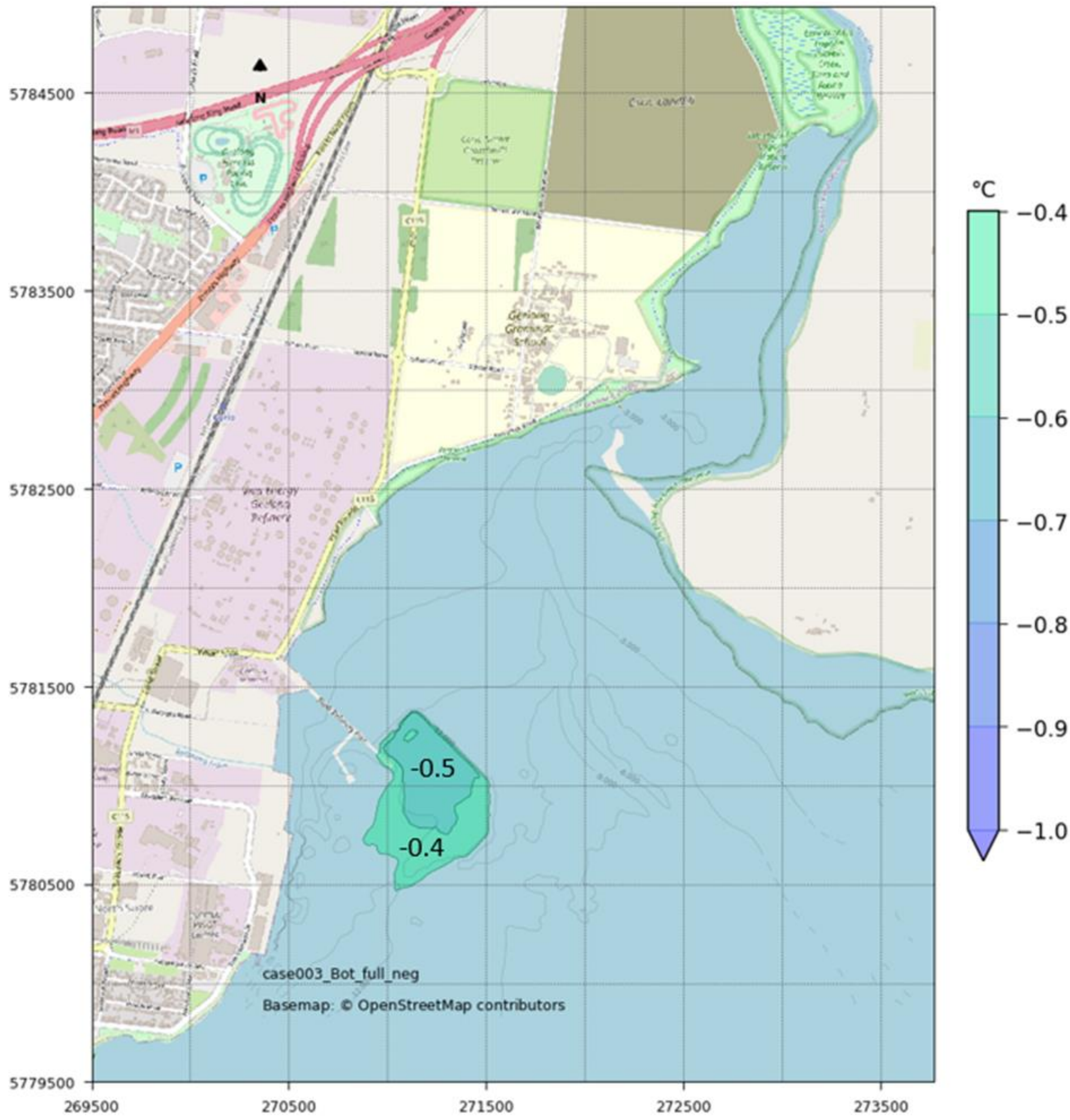


Figure 8-62 Predicted 50th percentile (median) temperature change – future peak diffuser discharge case

to 0.8°C below ambient temperature and the plume would form over an area of approximately 65 ha on the seabed at 10-13 m water depths. There would be negligible change in water temperature on the surface and at mid-depth of the water column. The temperature plume does not reach the Ramsar site including Limeburners Bay.

Predicted temperature plumes – closed loop operation

The FSRU can also operate in closed loop mode where seawater is recycled within the FSRU rather than being discharged. Closed loop mode would only ever be used in the event that the discharge water was unable to be piped to the refinery due to FSRU maintenance or an issue with the pipeline, pumps or similar. Closed loop would be used in this instance as the EES has not assessed both the refinery and FSRU operating in parallel with separate water intakes and discharges.

Closed loop regasification would use gas-fired steam boilers to heat a closed loop of circulating seawater within the FSRU as an intermediate heating medium for heat exchange in the LNG regasification trains. Around 500 m^3 of seawater from Corio Bay would be required to fill the FSRU heat exchange piping. The seawater would then be continually circulated in the heat exchange process instead of being discharged from the FSRU as per open loop mode. Seawater would only be discharged to Corio Bay through two small pipes at the rear of the FSRU when switching back to open loop when the issue preventing discharge to the refinery was rectified. Discharged seawater from the closed loop process would be around 5 °C warmer than the ambient water temperature.

Figure 8-63 show the predicted 90-percentile (peak) temperature difference at the surface for the future closed loop operation scenario. The temperature contours plotted are 0.6°C, 0.7°C, 0.8°C and 0.9°C above ambient temperature. The maximum predicted temperature rise for operation in closed loop mode would be less than 1°C. In summary, the temperature plume for the closed loop operation is smaller than the existing plume from the refinery discharge and less intense, as the maximum temperature rise is less than 1°C outside a small mixing zone. The temperature plume does not reach the Ramsar site including Limeburners Bay.

Threshold limits for seawater temperature change

The Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) list temperature as a stressor of aquatic ecosystems and the potential effects as a "*Loss of native biota*".

Aquatic ecosystems are regulated by temperature. Biota, and physical and chemical processes, such as oxygen solubility and hydrophobic interactions, are sensitive to temperature changes. Large changes in temperature occur naturally as part of normal diurnal (daily) and seasonal cycles.

Growth, metabolism, reproduction, mobility and migration patterns can be altered by changes in water temperature. Fauna endeavour to remain near the centre of their tolerance range. High temperatures (usually over 40°C) and low temperatures (usually under 5°C) are considered deleterious. Current discharges from the refinery do not enter the deleterious ranges and the modelled discharges from the project for any of the FSRU operating modes/discharge locations would not enter the deleterious ranges. As such, the marine discharges associated with the project are not considered to have any material adverse impacts on marine biota. The temperature plumes both from the current refinery operations, and from the project, do not extend to the Ramsar site or have any impact on ambient water temperature within the site.

A mixing zone is an area where an effluent discharge undergoes initial dilution close to the point of the licenced discharge point and where threshold or guideline values would be exceeded. The size and extent of the mixing zone would be designated in the EPA licence. The Australian and New Zealand Environment and Conservation Council (ANZECC) 2000 Guidelines were used to derive appropriate threshold temperature change limits at the edge of the mixing zone as a function of depth. The limits were derived based on the natural temperature variations within Corio Bay. Table 8-10 summarises the adopted threshold limits for seawater temperature change as a function of water depth. The limits are widest at the water surface (the intertidal zone) at -3/+3°C and decrease to -2/+2.5°C in shallow water (0 to 2 m depth). The adopted threshold limits are more stringent in deeper water at -1/+2°C in water between 2 to 5 m depths and +1/-1°C for depths beyond 5 m.

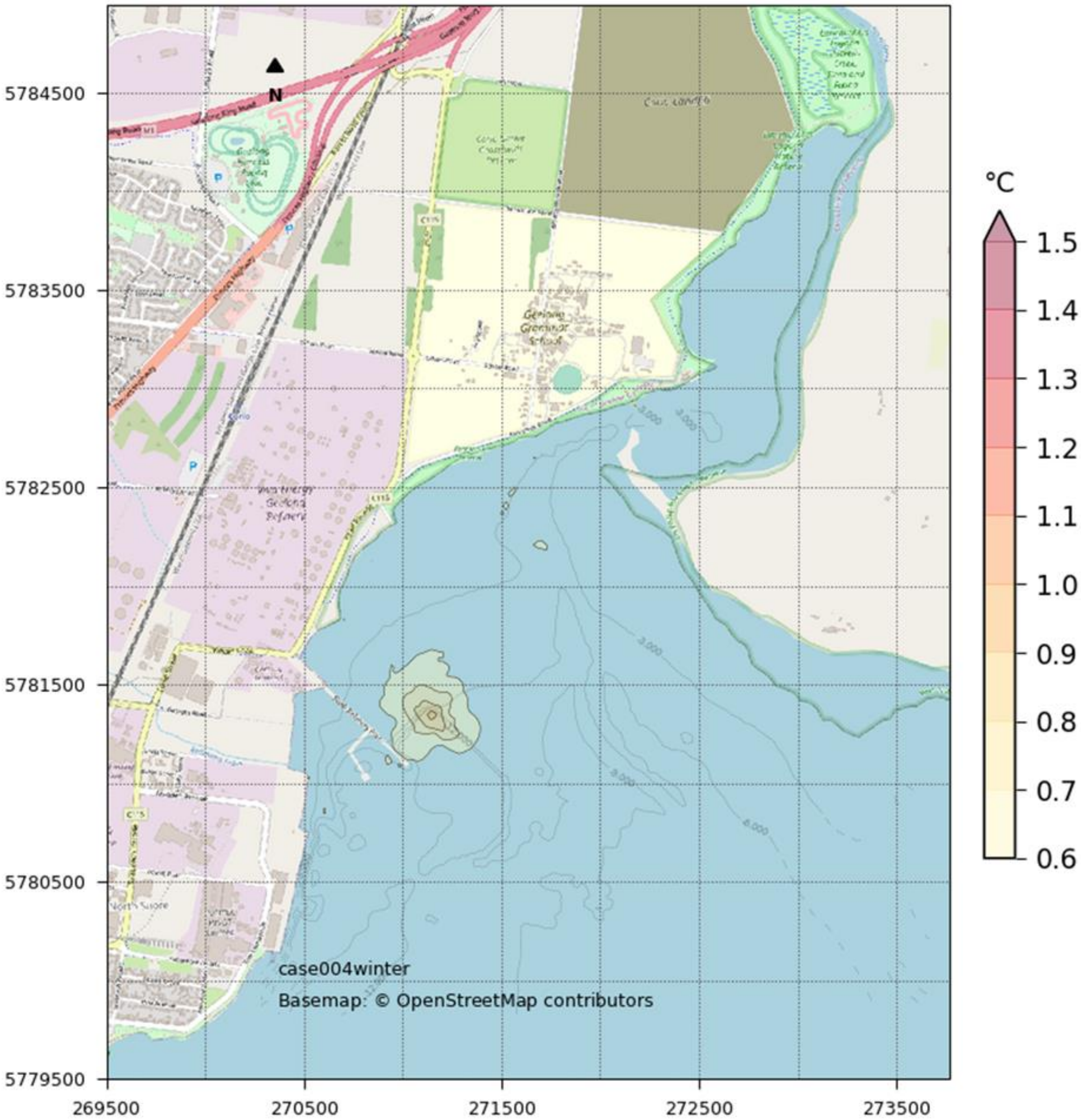


Figure 8-63 Predicted 90th percentile (peak) temperature change – future closed loop operation case

Table 8-10 Threshold limits for seawater temperature changes

Depth	Cooling limit (°C)	Warming limit (°C)
Intertidal	-3	+3
0 – 2 m	-2	+2.5
2 – 5 m	-1	+2
5 – 15 m	-1	+1

The warm water plumes for this project would occur in shallow water where the +2.5°C would apply at the edge of the designated mixing zone. The predicted temperature changes for the peak and average flow scenario with reuse of FSRU discharge in refinery and discharge through the four existing refinery discharge outlets would satisfy the derived threshold limits at the edge of the existing refinery mixing zones. The cool diffuser plume would sit in deeper waters where the -1°C would apply at the edge of the designated mixing zone. The predicted temperature within the 65ha cool plume on the seabed for discharge through the diffuser would be between 0.4 to 0.8°C below ambient temperature and would therefore satisfy the derived threshold limits during project operation.

This section has outlined the results of modelling undertaken to predict the temperature plume associated with the operational modes of the FSRU. Under all operational modes, the discharge water meets guideline values. The proposed open loop operating mode with FSRU discharge water being reused in the refinery as cooling water results in a temperature plume which is closer to ambient conditions in Corio Bay when compared with the current refinery discharges due to the influence of the chilled FSRU water in the cooling water. Empirical evidence from studies undertaken within the existing refinery plume suggests that marine biota is not adversely affected by the warm water discharge which has been occurring for more than 60 years. The studies show that the offshore area has healthy seagrass and marine biota comparable to Corio Bay generally. The ability to evaluate potential warm water discharges from over 60 years of refinery operation provides confidence that the temperature discharges from the project would not have adverse impacts on the marine environment including Limeburners Bay and the Ramsar site, and in fact, would be an environmental improvement due to a lower discharge temperature than currently experienced.

8.8.2 Chlorine

This section describes the potential impacts on the marine environment associated with chlorinated discharges into Corio Bay during operation of the project. Chlorine is used to control biofouling in the refinery cooling water system at present and would also be used in the FSRU for the same purpose. The chlorine would be converted by natural chemical transformation to other chlorine produced oxidants (CPO) such as bromoform through a series of rapid reactions as it travels through pipes and heat exchanges and would be subsequently discharged at low concentrations to Corio Bay. The residual chlorine discharged into Corio Bay from the project would be at the same levels as currently discharged from the refinery as the FSRU discharge water would be reused in the refinery as cooling water with the same amounts of chlorine dosing and discharged from the existing refinery discharge points.

Guideline value of chlorine in the marine environment

As described earlier, a mixing zone is an area where an effluent discharge undergoes initial dilution close to the point of the licensed discharge point and where threshold or guideline values would be exceeded. The size and extent of the mixing zone would be designated in the EPA licence. The guideline value for chlorine was determined by considering the Victorian EPA Environment Reference Standard (ERS), the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) and a recent Commonwealth Scientific and Industrial Research Organisation (CSIRO) paper specifically addressing the chlorine limit in marine waters (Batley and Simpson, 2020).

The ERS is a fundamental component of the *Environment Protection Act 2017* (Vic) (EP Act). While the ERS does not specify a limit for chlorine, the EP Act introduces a new permissions scheme including the requirement for a development licence and operating licence for the operation of the FSRU where chlorine limits could be specified. The

ANZG lists a chronic guideline value for chlorine in freshwater of 3 µg/L, however, does not list a guideline value for chlorine in marine water.

Batley and Simpson (2020) published a Guideline Value for chlorine in seawater in 2020 using the method of derivation described in ANZG. Batley and Simpson plotted a species sensitivity diagram as shown in Figure 8-64, using data from short-term (mostly 48-hour or 96-hour) toxicity tests in marine waters with renewal of chlorine. The exposure period to chlorine in the tests was mostly 96 hours, but some tests with a lower exposure time were also included.

The tests with the two lowest CPO levels were for sea urchins. Threshold CPO concentrations which would apply over a period of 24 hours were determined to be

- CPO of 3.7 µg/L for 99% species protection
- CPO of 12 µg/L for 95% species protection
- CPO of 21 µg/L for 90% species protection

To convert the Lethal Concentration 50 (LC50) (i.e., the concentration of CPO in seawater that would be lethal to 50% of species in a single exposure) to a no or low effect concentration (Lethal Concentration 10 (LC10)), a factor of 0.6 was applied by Batley and Simpson.

According to the guidelines, the level of species protection that applies to an aquatic ecosystem depends on the existing conditions (current or desired health status of an ecosystem relative to the degree of human disturbance. The 95% species protection applies to Corio Bay as it is classified as a slightly to moderately modified environment. The guideline value for CPO in Corio Bay at the edge of the designated mixing zone is therefore 7.2 µg/L (95% species protection 12 µg/L x 0.6).

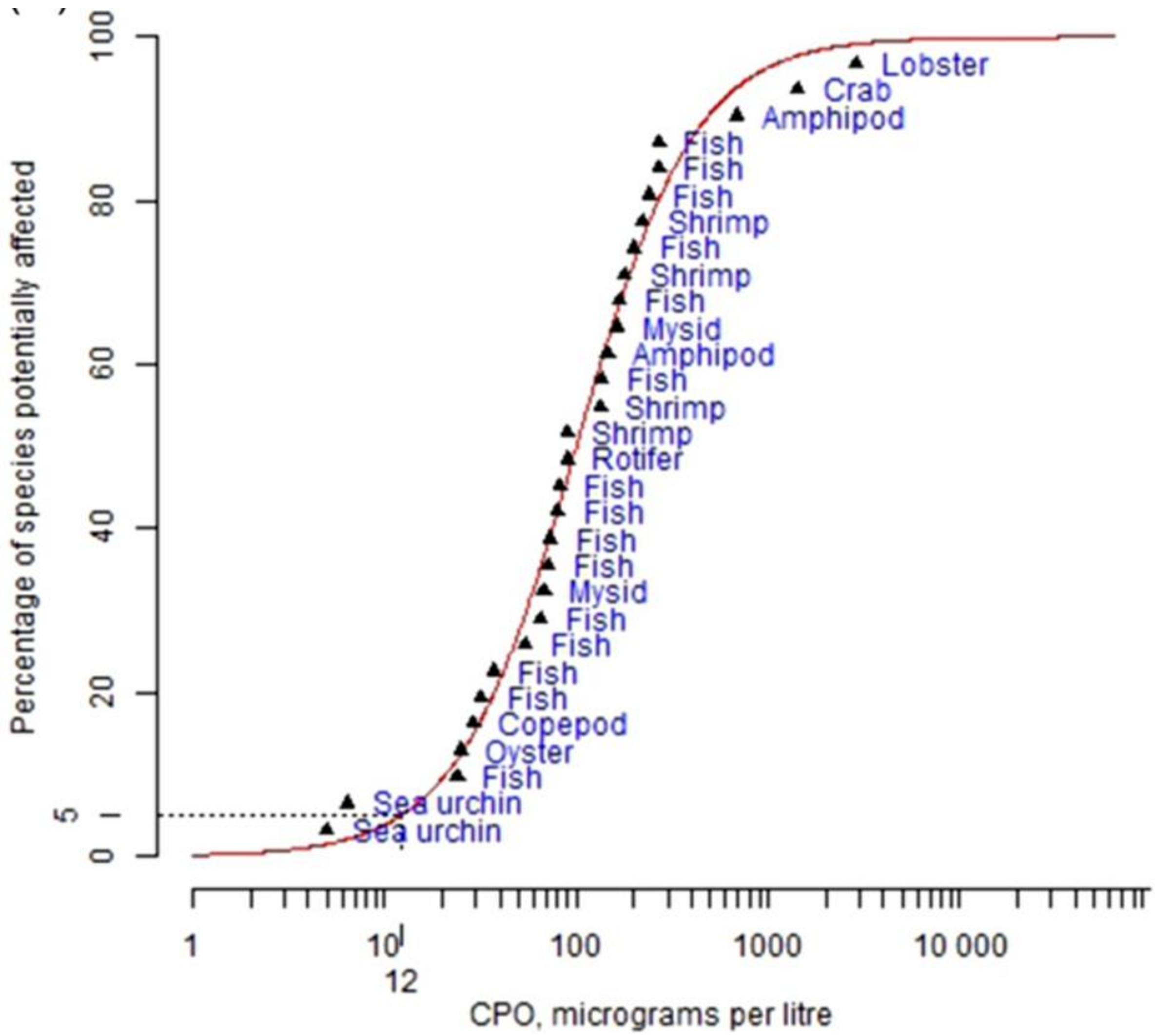


Figure 8-64 Species sensitivity diagram for effects of chlorine

Figure 8-65 Sea urchins in Corio Bay under the refinery plume

As the Geelong Refinery has been discharging chlorine into Corio Bay for more than 60 years, it provided an opportunity to assess the potential impacts on the marine environment from these existing discharges. This is particularly relevant as the chlorine discharge from the project, after the FSRU water is reused in the refinery for cooling water, will be at the same levels as the current refinery discharges.

Field surveys in Corio Bay conducted for this study show very large numbers of sea urchins breeding in the current refinery mixing zone in waters with 5 to 10 µg/L of CPO (see **Figure 8-65**). This is of interest in that sea urchins are considered to be the most sensitive sea animal to chlorine as outlined above in the discussion on toxicity. It is possible that the laboratory test does not represent what happens in nature, and that the sea urchin results in the species sensitivity diagram are artificially low. The impact assessment for the project has been conducted on the basis that the guideline value for CPO in Corio Bay is 7.2 µg/L.

Existing chlorine plumes

The refinery has been using seawater from Corio Bay for over 60 years for cooling water purposes. Chlorine is added to the seawater as it enters the refinery to prevent and control the accumulation of microorganisms, plant, algae or small animals in the pipes, pumps and heat exchangers. An average of 400 µg/L of chlorine is added to the seawater used in the refinery as cooling water.

The chlorine and CPO convert back to natural salts through chemical transformation during passage through the refinery pipes and heat exchanges and chlorine concentrations decline to less than 100 µg/L (except for the existing refinery discharge point W3, which discharges seawater that has not passed through a heat exchanger and therefore has a higher residual chlorine concentration of 180 µg/L). The average chlorine concentration in the refinery discharge is 60 µg/L as described in **Section 8.4.19**.

Figure 8-66 shows the predicted 50th percentile (median) CPO concentration at the water surface for the existing refinery discharges. The chlorine guideline value is the tidally averaged value (over 12 hours), therefore 50th percentile CPO concentrations are shown. The plumes are warm and form a layer on the water surface extending 500 m north along the shore from W1 and 800 m north along the shore from W4 and W5. The existing chlorine plume does not extend to Limeburners Bay or the Ramsar site. Three CPO contours are shown in **Figure 8-66** for 7.2 µg/L, 5.4 µg/L and 3.6 µg/L. In each case, the plume is confined to an area within 200 m of the shoreline and is located in shallow water near the refinery. The existing chlorine plume does not extend to the Ramsar site including Limeburners Bay.

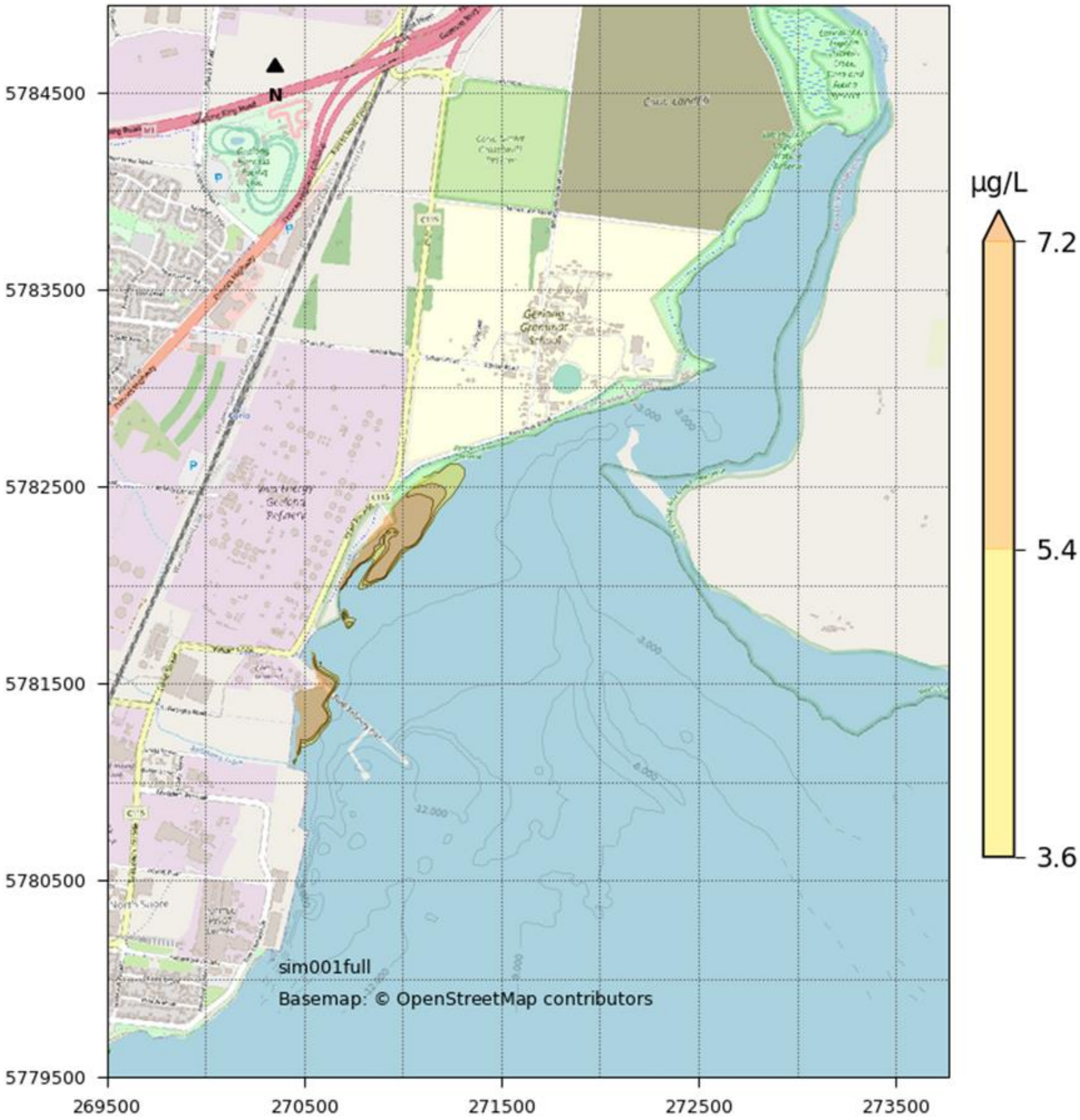


Figure 8-66 Predicted 50th percentile (median) chlorine plumes – existing refinery chlorine plumes

The current discharges have been occurring for over 60 years and surveys of the seagrass beds beneath the existing plumes show that seagrass grows prolifically in close proximity to all refinery discharge points and there is no detectable change in seagrass conditions due to the chlorine plumes.

To investigate whether the existing chlorine discharge from the refinery was producing significant levels of residual chemicals in marine life, mussels were collected from six sites in northern Corio Bay and analysed for a wide range of chlorine residuals including trihalomethanes (THMs), haloacetic acids and bromophenols. Figure 8-67 shows the locations of the mussel samples.

The sites include Refinery Pier and directly within the dispersing plume as well as samples from navigational markers around the dredged channel and two reference sites further out in the Bay.

The results for mussels from sites M1, M2 and M3 showed no detectible levels of THMs, haloacetic acids and bromophenols in the mussels. The same results were obtained for mussels from reference sites M4, M5 and M6. The results indicate that the chlorine discharged from the refinery either decays or is volatilised in a short period, and there is no accumulation of toxic by-products in mussels or, by inference, other marine life in Corio Bay.

Figure 8-67 Locations of mussel samples in north Corio Bay

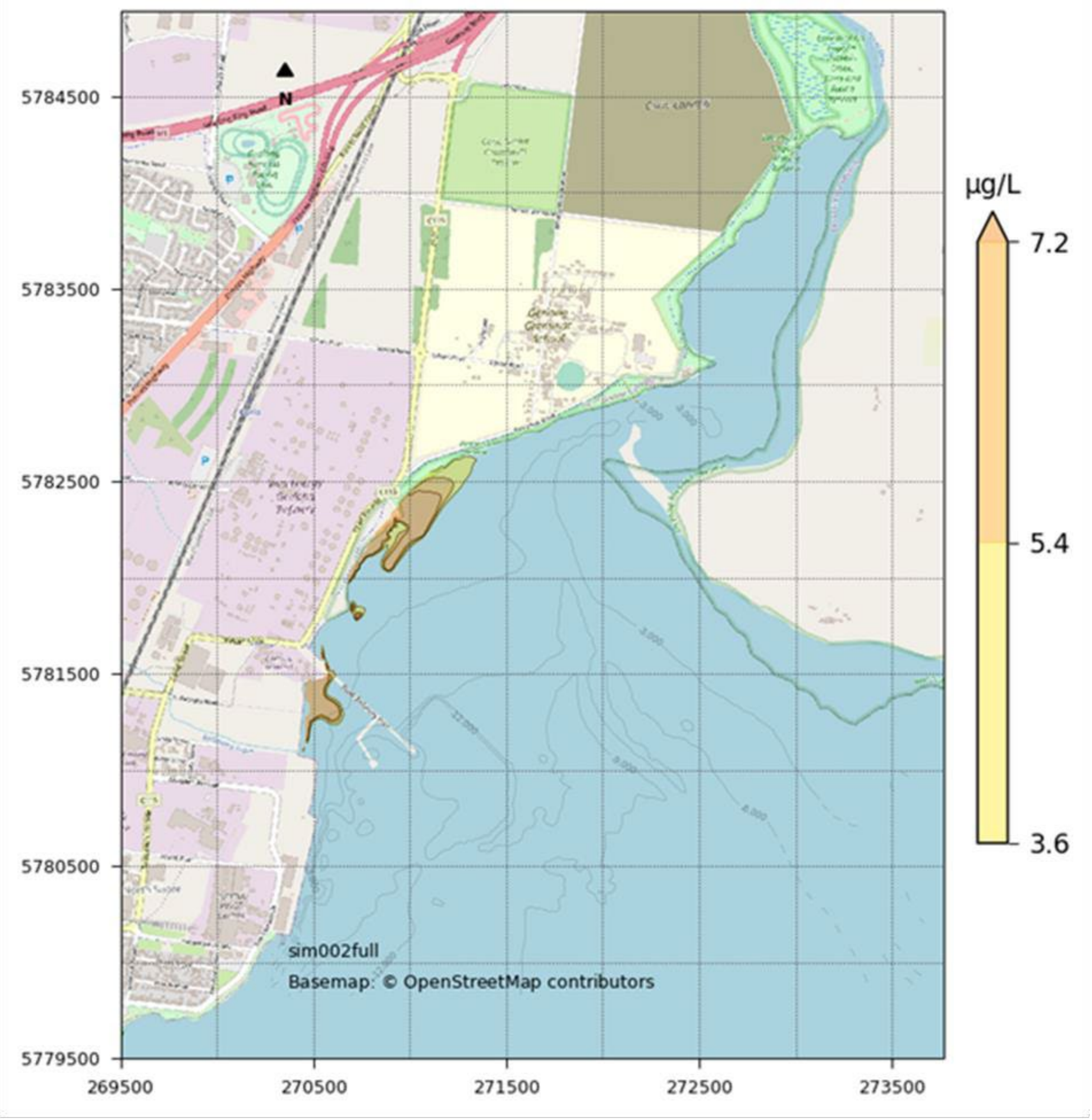


Figure 8-68 Predicted 50th percentile (median) chlorine plumes – future peak flow case

Predicted chlorine plumes – peak flow

This scenario would occur when the FSRU is operating in open loop mode using 350 ML/day and transferring all of the cooled discharge water from the FSRU (with a residual CPO concentration of up to 100 µg/L) to the existing refinery seawater intake for reuse in the refinery as cooling water. The refinery would add chlorine at inlet to bring the concentration up to the current intake chlorine concentration of 400 µg/L. The chlorine and CPO would convert back to natural salts through chemical transformation during passage through the refinery pipes and heat exchanges and would be discharged to Corio Bay though the four existing discharge points (W1, W3, W4 and W5) with the same residual chlorine concentrations as the existing situation described in Section 8.4.19 and 8.8.2 *Existing chlorine plumes*.

Figure 8-68 show the predicted 50-percentile (median) CPO concentrations for the future peak flow case. The pattern and CPO concentrations are similar to the existing refinery discharge plume as the same volume of seawater with the same concentration of residual CPO would be discharged. There are minor changes to the spatial extent of the plume as a result of reduced spreading due to the lower temperature of future discharge plumes. The chlorine plume would not extend to the Ramsar site including Limeburners Bay.

The reuse of discharge from the FSRU in the refinery for cooling water purposes would be maximised to ensure that chlorine discharge to Corio Bay is consistent with current operation (refer to MM-ME01).

Predicted chlorine plumes – average flow

This scenario would occur when the FSRU is operating in open loop mode using 250 ML/day and transferring all of the cooled discharge water from the FSRU (at approximately 7°C below ambient temperature and with a residual CPO concentration of up to 100 µg/L) to the existing refinery seawater intake for reuse in the refinery as cooling water. The refinery would draw the remaining volume of seawater required (100 ML/day) through the existing refinery seawater intake. The refinery would add chlorine at inlet to bring the concentration up to the current intake chlorine concentration of 400 µg/L. The chlorine and CPO would convert back to natural salts through chemical transformation during passage through the refinery pipes and heat exchanges and would be discharged to Corio Bay though the four existing discharge points (W1, W3, W4 and W5) with the same residual chlorine concentrations as the existing situation described in Section 8.4.19 and 8.8.2 Existing chlorine plumes.

The flow through the refinery would heat the seawater and it would be discharged to Corio Bay through the four existing discharge points (W1, W3, W4 and W5) at temperatures that are closer to ambient than the current situation, however, higher than the peak flow case discussed in Section 8.8.1 *Predicted temperature plumes - peak flow.*

Figure 8-69 show the predicted 50-percentile (median) CPO concentrations for the future average flow case. The plume at average production extends a similar distance offshore and along-shore as the plume under existing conditions and does not extend to Limeburners Bay or to the Ramsar site. There are minor changes to the spatial extent of the plume as a result of reduced spreading due to the lower temperature of future discharge plumes.

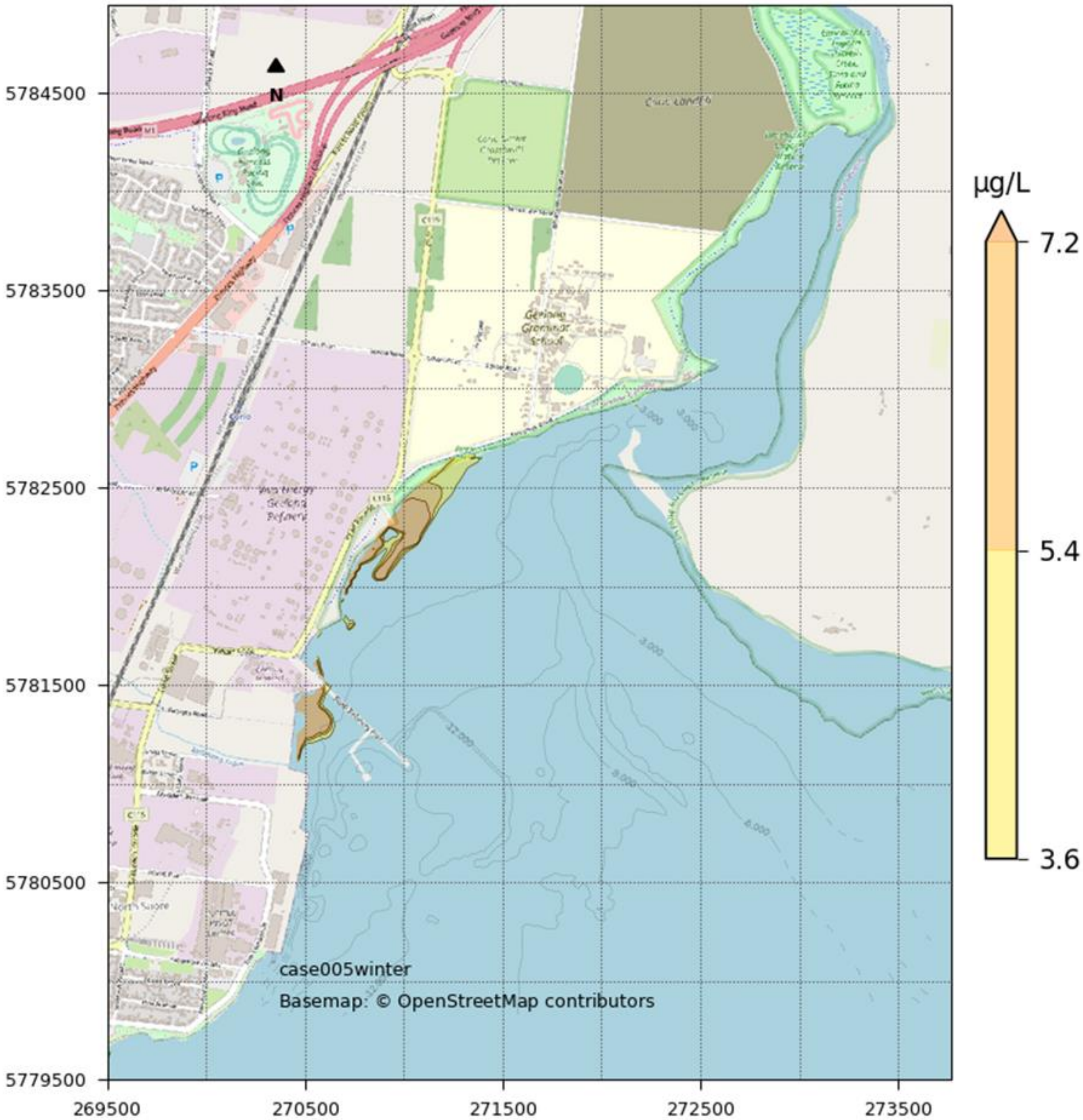


Figure 8-69 Predicted 50th percentile (median) chlorine plumes – future average flow case

Predicted chlorine plumes – peak diffuser discharge

As described in previous sections, an alternative discharge arrangement for the project would involve discharge from the FSRU directly into Corio Bay through a diffuser located under the new pier. The diffuser would be used to discharge excess seawater during refinery maintenance periods in the event that the rate of FSRU discharge exceeded the refinery demand for seawater (unlikely) or in the event that the refinery was permanently decommissioned in the future and the option for reuse of the FSRU discharge water was no longer available. A full refinery shut down was assumed for this scenario which is highly conservative as refinery maintenance occurs every second year with half the refinery being taken offline and the other half operating and still requiring cooling water in the range of 200-250 ML/day. As such, it is highly unlikely that the diffuser would operate at maximum discharge rates as the FSRU will still be piping most or all of its discharge water to the refinery even during maintenance periods. Based on FSRU production rates outlined in an earlier section, the winter months are the only period when there is potential for the FSRU to generate more water than required by the refinery during maintenance. However, refinery maintenance is typically conducted in spring or autumn so the need for discharging through the diffuser in winter is unlikely.

In this scenario the FSRU would operate in open loop mode using 350 ML/day and would discharge the seawater (with a residual CPO concentration of up to 100 µg/L) through a 300 m long diffuser with 100 small high-velocity ports and located 0.5 metres below Lowest Astronomical Tide (LAT) under the new pier extension.

The diffuser for cool water discharge from the FSRU would be designed to achieve a minimum initial dilution of 20:1 to ensure that the diluted discharge has a chlorine concentration less than the guideline value.

The diffuser would be designed to achieve high dilution and to ensure that the diluted discharge has a chlorine concentration less than the guideline value of 7.2 µg/L (refer to MM-ME10). The high-velocity ports would discharge the seawater at approximately 5 metres per second (m/s) and at an angle of 30° away from the underside of the pier. This configuration would result in greater mixing and dilution. The predicted dilution in this case is 20:1 which means that there would be 20 parts of seawater for every 1part of discharge.

Initial dilution of 20:1 would reduce the chlorine level from 100 µg/L to 5 µg/L. **Figure 8-70** shows the predicted 50-percentile (median) CPO concentration at the seabed (as the cooler seawater would sink) for this scenario. The entire plume on the seabed would have CPO concentrations below 5.4 µg/L which is well below the 7.2 µg/L guideline value for chlorine in marine waters. The chlorine plume would be localised would not reach the Ramsar site including Limeburners Bay.

Predicted chlorine plumes – average diffuser discharge

In this scenario the FSRU would operate in open loop mode using 250 ML/day and would discharge the seawater (with a residual CPO concentration of up to 100 µg/L) through the diffuser. The diffuser is 300 m long however, during the average flow scenario only 240 m of the diffuser would be used to maintain a high port velocity.

Figure 8-71 shows the predicted 50-percentile (median) CPO concentration at the seabed (as the cooler seawater would sink) for this scenario. The plume for this scenario would have chlorine concentrations in the range of 4 to 5 µg/L and would encompass a total area of 2.8 ha on the seabed. The plume would spread out in the deep waters of the channel; however, the spatial extent would be limited by the decay of chlorine compounds in the plume. As with the peak diffuser discharge scenario discussed in the previous section, the entire plume on the seabed would have CPO concentrations below 5 µg/L which is well below the 7.2 µg/L guideline value for chlorine in marine waters. The chlorine plume would be localised and would not reach the Ramsar site including Limeburners Bay.

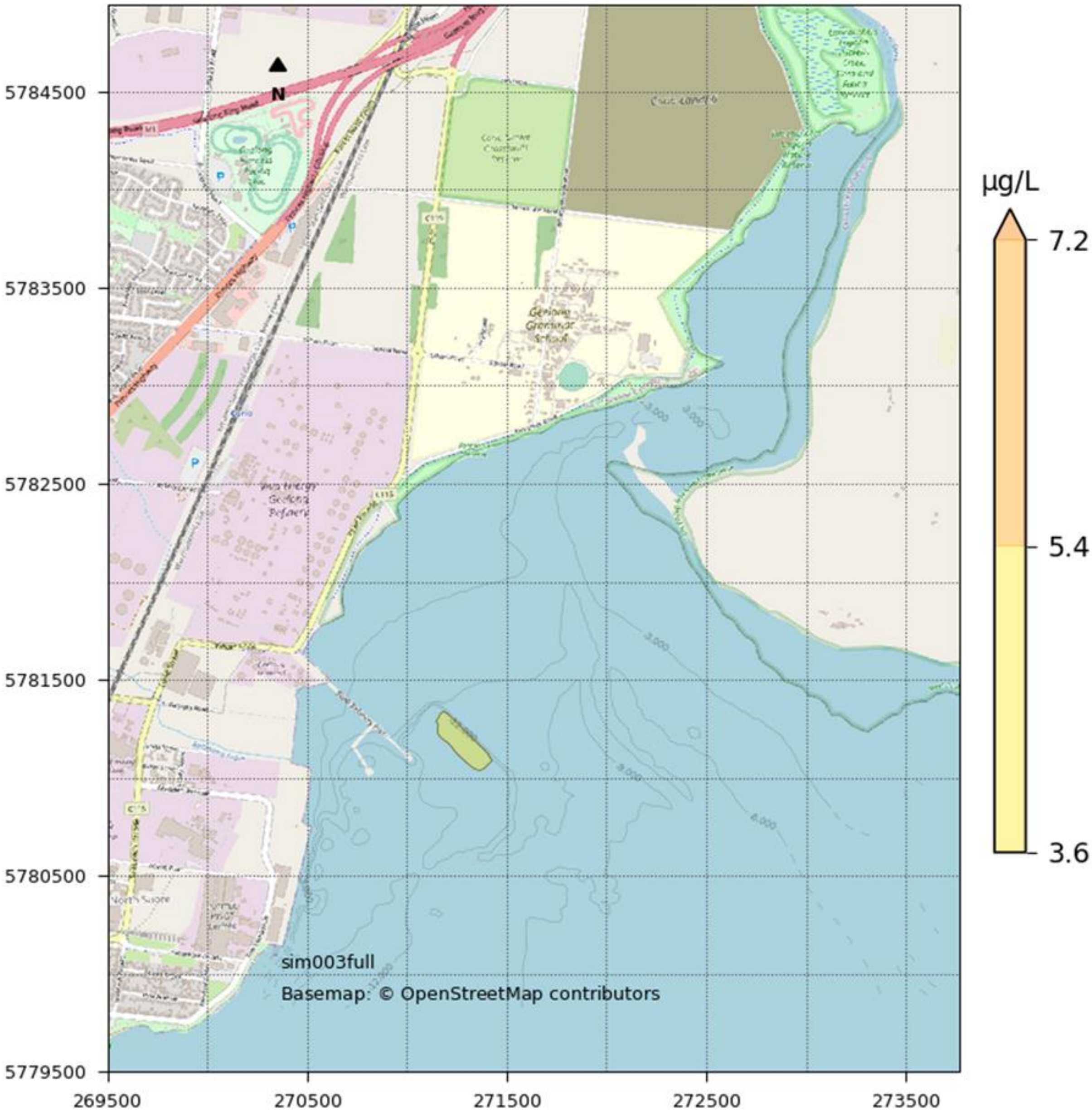


Figure 8-70 Predicted 50th percentile (median) chlorine plumes – future peak diffuser discharge

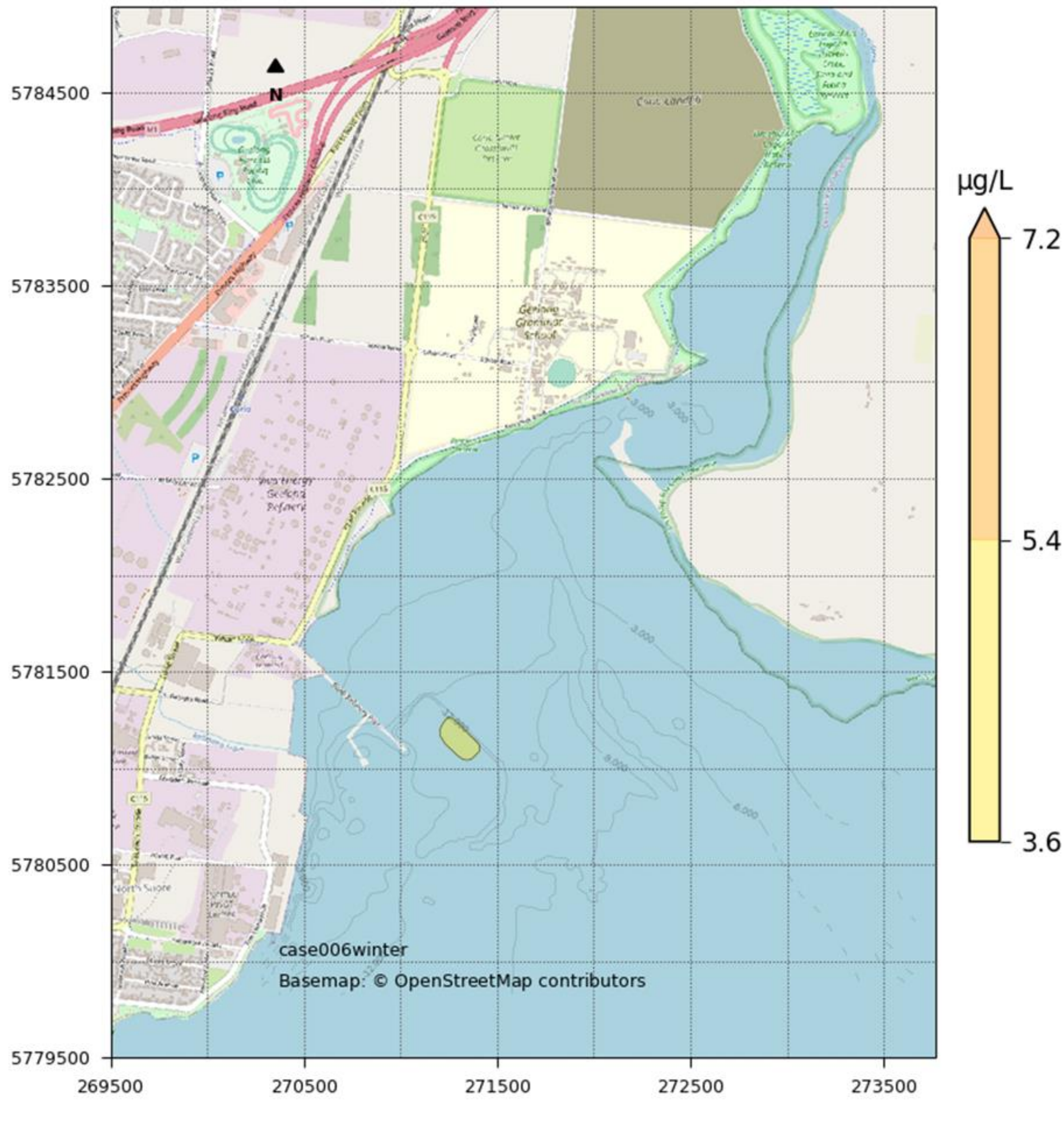


Figure 8-71 Predicted 50th percentile (median) chlorine plumes – future average diffuser discharge

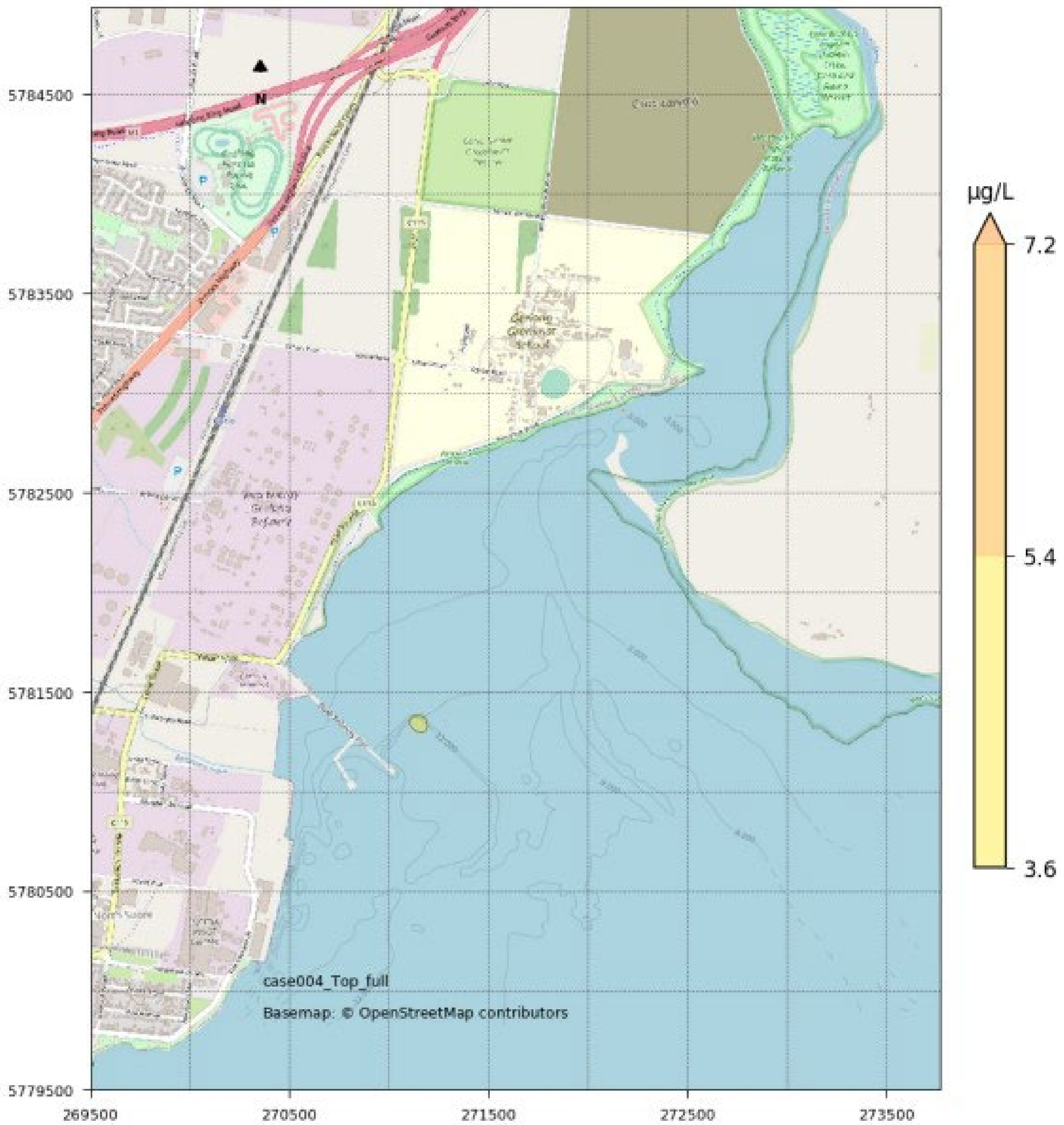


Figure 8-72 Predicted 50h percentile (median) chlorine plumes – future closed loop operation case

Predicted chlorine plumes – closed loop operation

As described in previous sections, the FSRU can also operate in closed loop mode (water recycled within the FSRU) whereby a proportion of the LNG would be regasified using LNG-fired boilers on the FSRU. This mode of operation would be used in the event that either maintenance on the FSRU or an operational issue precluded seawater to be piped to the refinery. As such, it is expected that closed loop operating mode would rarely be utilised.

In this scenario the FSRU would operate in closed loop mode as the EES has not assessed the impacts of the refinery and FSRU operating in parallel with their own seawater intakes and discharges. Closed loop regasification would use gas-fired steam boilers to heat a closed loop of circulating seawater within the FSRU as an intermediate heating medium for heat exchange in the LNG regasification trains. Around 500 m^3 of seawater from Corio Bay would be required to fill the FSRU heat exchange piping. The excess heat generated by closed loop operation would be discharged as a warm water plume at approximately 5°C above ambient temperature with residual chlorine concentrations at 100 μg/L through two small pipes at the rear of the FSRU and only at the point when the vessel was switching back to open loop operating mode.

Figure 8-72 shows the predicted 50-percentile (median) CPO concentration at the surface for the closed loop operation scenario. The maximum CPO concentration within the plume would be less than 5 μg/L which is well below the 7.2 μg/L guideline value for chlorine in marine waters. The chlorine plume would be localised and would not reach Limeburners Bay or the Ramsar site.

This section has outlined the results of modelling undertaken to predict the chlorine plume associated with the operational modes of the FSRU. Under all operational modes, the residual chlorine plume is localised and reaches the 7.2 μg/L guideline value for marine waters a short distance from the discharge points. The proposed open loop operating mode with FSRU discharge water being reused in the refinery as cooling water results in a residual chlorine discharge the same as that currently experienced from the refinery discharges. Empirical evidence from studies undertaken within the existing refinery plume suggests that marine biota is not adversely affected by the chlorine discharge which has been occurring for more than 60 years. The studies show that the offshore area has healthy seagrass, no residual chlorine found in mussels and the presence of many sea urchins within the existing plume despite sea urchins being considered the most sensitive marine animal to chlorine in toxicity testing. The ability to evaluate potential chlorine impacts from over 60 years of refinery operation provides confidence that chlorine discharges from the project would not have adverse impacts on the marine environment including Limeburners Bay and the Ramsar site.

8.8.3 Entrainment and entrapment

Operation of the FSRU would result in some entrainment of plankton, larvae and other small organisms as a result seawater being drawn into the FSRU which has the potential to result in adverse effects on populations and productivity. In addition, entrapment of small and large fish as well as other free-swimming biota (birds, squid etc.) could also occur if appropriate intake design and operational measures were not adopted. In addition to assessing overall impacts of entrainment and entrapment when compared with overall populations in Corio Bay, the potential loss of plankton and larvae as part of the food chain, and particularly for migratory waders and other shorebirds in the Ramsar site, is an important consideration.

To minimise the potential for entrapment, the seawater intake would be designed to keep the intake velocity in the horizontal plane at a speed below 0.15 m/s at the intake screen (a generally accepted US EPA guideline) to minimise capture of small and large fish and other free-swimming biota and to provide the same level of protection as the existing refinery intake. The intake would also be provided with a screen with apertures less than 100mm to prevent large objects and seagrass from being carried into the FSRU systems (refer to MM-ME08).

As discussed in **Section 8.6.3** *Entrainment during operation*, a detailed survey of plankton (phytoplankton, zooplankton and ichthyoplankton (fish eggs and fish larvae)) in Corio Bay was conducted as part of the marine ecology and water quality impact assessment from November 2020 to November 2021, to assess the spatial distribution of plankton in Corio Bay and the effects of the circulation patterns, channel deepening and refinery use of seawater for cooling. An analysis of the results show that the plankton distribution was well mixed through the Bay with no significant difference detected between plankton in North Corio, South Corio and the Geelong Arm. The data collected as part of the plankton monitoring program was incorporated into the regional model and the movement and dispersion of plankton and larvae in Corio Bay and Port Phillip Bay was modelled (using modelled particles as a proxy). The modelling examined the dispersion of larvae from various sites in Corio Bay, including the Ramsar site in northern Corio Bay and representative fish-spawning areas in northern and southern Corio Bay, and the potential for entrainment of plankton and larvae into the existing refinery intake and the proposed FSRU intake.

The following three locations were selected as starting points for the particle dispersion simulations:

1. Ramsar site along north coast of Corio Bay (including Limeburners Bay)
2. Fish breeding area in north Corio Bay
3. Fish breeding area in south Corio Bay.

A description of how the dispersion modelling was carried out and how entrainment was predicted is provided in **Section 8.6.3** *Entrainment during operation*.

Entrainment of plankton and larvae from the Ramsar site

The movement of plankton, larvae and other small biota on the day of release from the Ramsar site and 7, 14 and 28 days later is shown in **Figure 8-73**. The results show that the particles disperse widely after their initial release from the Ramsar site.

On release, the plankton and larvae would move eastwards into Port Philip Bay and after 7 days from release only 42% would remain in Corio Bay, of which 39% would be in northern Corio Bay and 3% in southern Corio Bay. The remaining plankton and larvae would move out of Corio Bay and into Port Phillip Bay in the first 7 days after release. There is very little movement down the west coast of Corio Bay. The pattern of plankton and larvae movement is consistent with the observed current patterns where there is a slow clockwise circulation in Corio Bay and a net northerly current near the western shore of Corio Bay.

There is an even wider distribution of plankton and larvae after 14 days from release and only 25% would remain in Corio Bay. Those that remain in Corio Bay would be more evenly spread between northern Corio Bay (14%) and southern Corio Bay (11%).

After 28 days from release, there would be more plankton and larvae in Port Phillip Bay than in Corio Bay, and a small percentage (2%) would have reached southern Corio Bay after travelling back in from Port Phillip Bay. After 28 days, there would be more plankton and larvae from the Ramsar site found in southern Corio Bay (17%) than in northern Corio Bay (9%).

The dispersion patterns and modelling indicate that Corio Bay and Port Phillip Bay waters are interlinked with a high degree of exchange in a14 day period. For zooplankton, which have a lifecycle of 2 to 4 weeks, there is considerable mixing of the populations in the two bays, which indicates why the two populations are similar. The majority of fish larvae that spawn in the Ramsar site (including Limeburners Bay) would move into Port Phillip Bay or

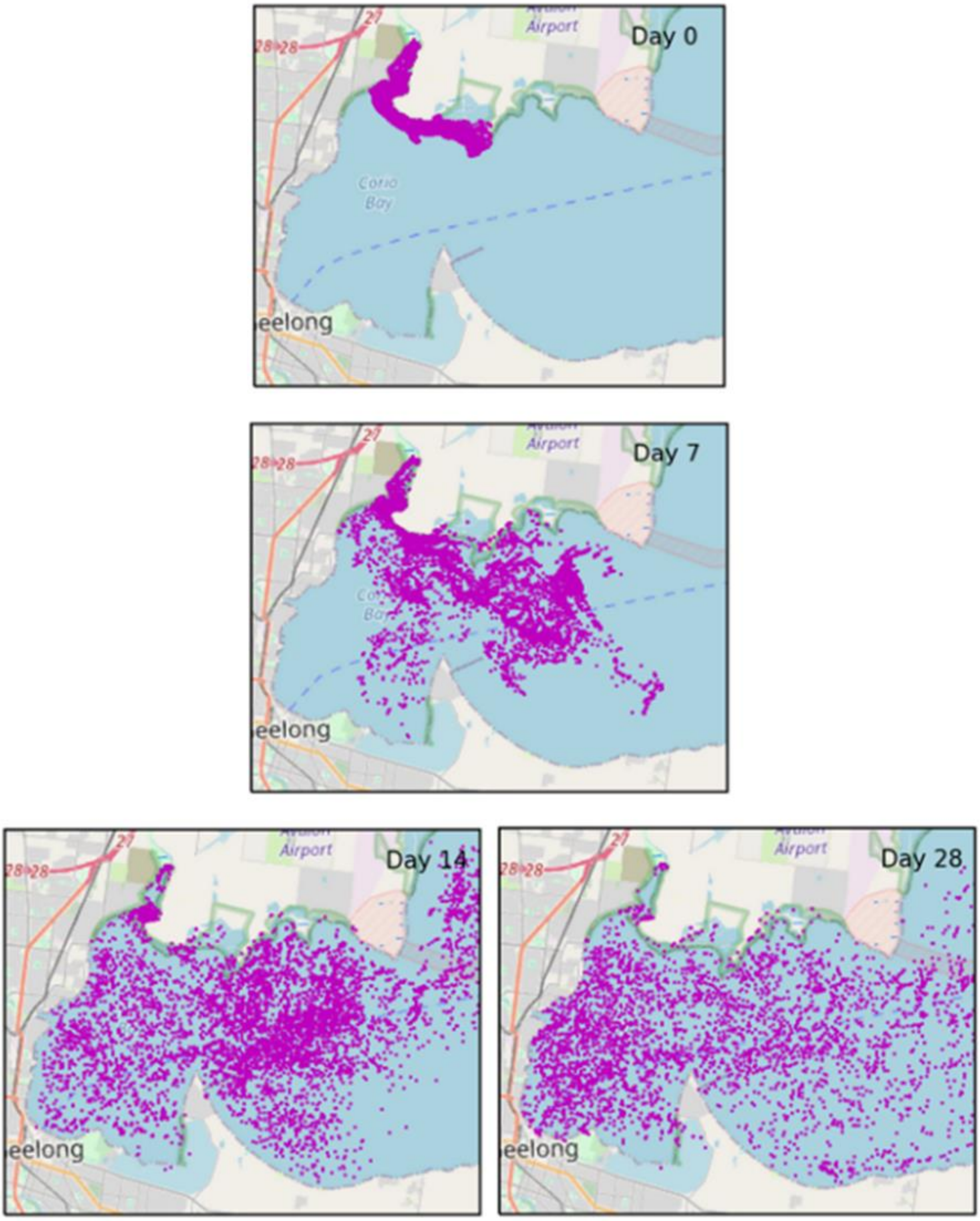


Figure 8-73 Distribution of particles from the Ramsar site after 0, 7, 14 and 28 days

southern Corio Bay and the majority of larvae that enter Port Phillip Bay would eventually move to southern Corio Bay and follow current patterns back to northern Corio Bay.

Table 8-11 shows the proportion of plankton and larvae from the Ramsar site that would be entrained in the existing refinery seawater intake and the proposed FSRU intake which would be no more than 0.13% and 0.27% respectively. There is zero entrainment of plankton from the Ramsar site in 7 days at the refinery intake and proposed FSRU intake.

Phytoplankton have a short life cycle (a day or so) and therefore phytoplankton entrained at the refinery intake and the proposed FSRU intake are likely to have developed locally and would not have travelled from the Ramsar site. Zooplankton have a life cycle of approximately 14 days and the model predictions indicate that entrainment rates are less than 0.1% in relation to natural loses of greater than 99% and therefore potential impacts of entrainment are negligible. The majority of fish larvae from the Ramsar site are dispersed into Port Phillip Bay and the potential entrainment rate after 28 days is less than 0.5% which is very small in comparison to natural predation and other losses.

Table 8-11 Entrainment of particles from the Ramsar site

Days from release	Percent entrained at high tide		Percent entrained at low tide	
	Refinery	FSRU	Refinery	FSRU
7 days	0.00%	0.00%	0.00%	0.00%
14 days	0.01%	0.06%	0.01%	0.06%
28 days	0.11%	0.25%	0.13%	0.27%

Entrainment of plankton and larvae from northern Corio Bay

The movement of plankton, larvae and other small particles on the day of release from northern Corio Bay and 7, 14 and 28 days later is shown in **Figure 8-74**. As with the plankton and larvae from the Ramsar site, the results show that the plankton and larvae disperse widely from their initial release in northern Corio Bay.

After 7 days, many of the plankton and larvae would have moved eastward into Port Phillip Bay and spread north and south in Corio Bay. They would tend to stay on the eastern side of Corio Bay, with very little movement to the west coast of the Bay. After 14 days, there would be widespread distribution within Corio Bay and Port Phillip Bay.

After 28 days, there would be more plankton and larvae in Port Phillip Bay than in Corio Bay. The distribution pattern in Corio Bay is consistent with the clockwise circulation of water in the Bay, therefore a large percentage of plankton and larvae would travel up the western coast of Corio Bay.

Table 8-12 shows the proportion of plankton and larvae released from northern Corio Bay that would be entrained in the existing refinery intake and the proposed FSRU intake which would be no more than 0.34% and 0.66% respectively.

Table 8-12 Entrainment of particles from north Corio Bay

Days from release	Percent entrained at low tide	
	Refinery	FSRU
7 days	0.05%	0.10%
14 days	0.18%	0.36%
28 days	0.34%	0.66%

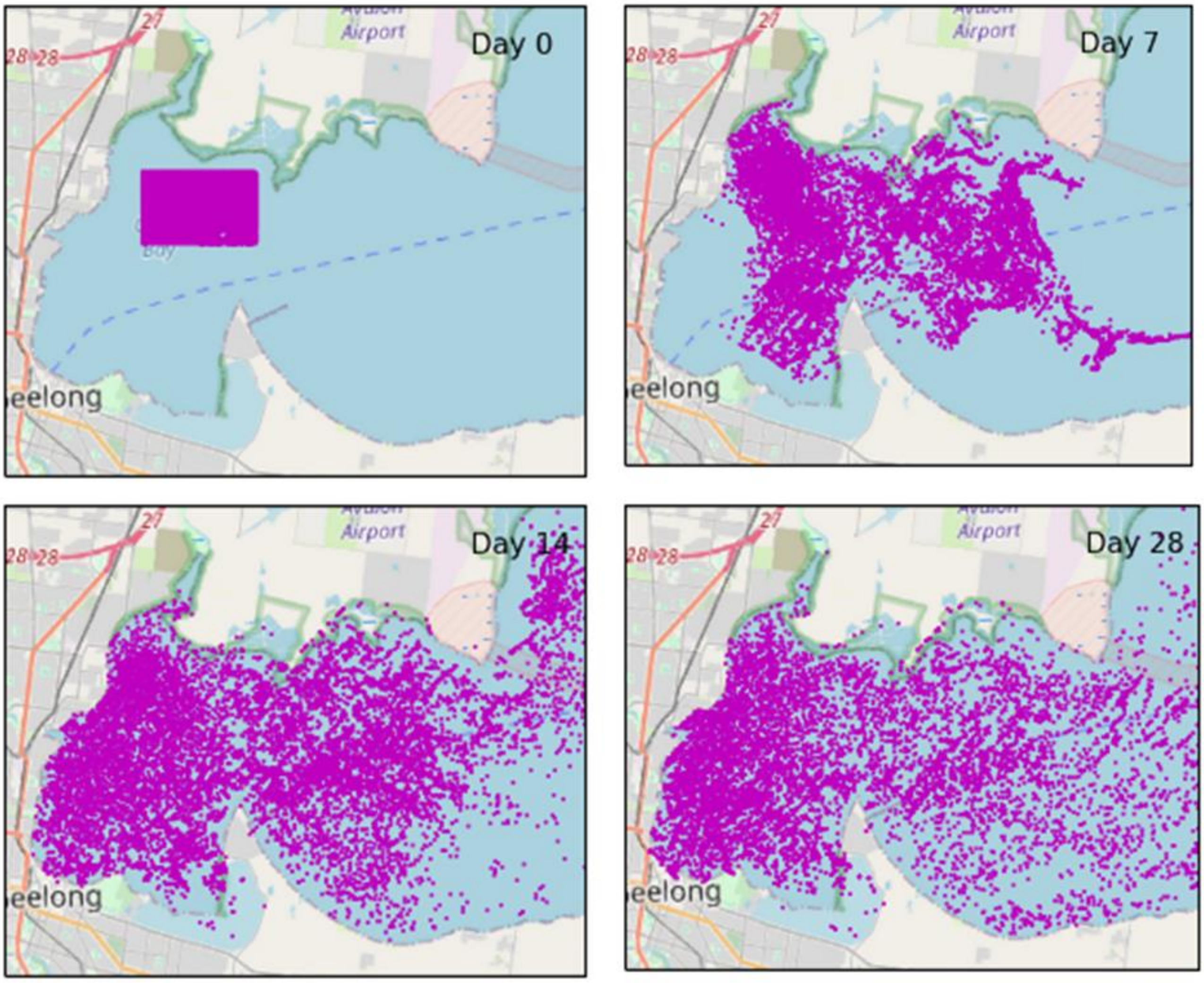


Figure 8-74 Distribution of particles from the north Corio Bay after 0, 7, 14 and 28 days

Phytoplankton have a short life cycle (a day or so) and therefore phytoplankton entrained at the refinery intake and the proposed FSRU intake are likely to have developed locally. Zooplankton have a life cycle of approximately 14 days and the model predictions indicate that entrainment rates are low in relation to natural loses and therefore potential impacts of entrainment are negligible. The potential entrainment rate for fish larvae developing in south Corio Bay after 28 days is low in comparison to natural predation and other losses.

Entrainment of plankton and larvae from southern Corio Bay

The movement of plankton, larvae and other small biota on the day of release from southern Corio Bay and 7, 14 and 28 days later is shown in Figure 8-75. As with the plankton and larvae from the Ramsar site, the results show that the plankton and larvae disperse widely from their initial release in south Corio Bay.

After 7 days, most plankton and larvae would remain close to the point of release and would spread around southern Corio Bay with a few moving into Port Phillip Bay. After 14 days, there would be a wide distribution in Corio Bay and more in Port Phillip Bay. The particle model simulation shows the slow transport of plankton and larvae from southern Corio Bay into Port Phillip Bay, with most from the southern site remaining within Corio Bay for 14 days after release.

After 28 days, there are many plankton and larvae in Port Phillip Bay, however, most are still in Corio Bay, and they are well-distributed throughout the bay. These results show that there is a longer residence time in Corio Bay for plankton and larvae starting in the southern area than larvae starting in the northern area, or in the Ramsar Site.

Table 8-13 shows the proportion of plankton and larvae released from southern Corio Bay that would be entrained in the existing refinery intake and the proposed FSRU intake. The proportion of particles from south Corio Bay entrained by the refinery intake and proposed FSRU intake would be no more than 0.10% and 0.39% respectively.

Phytoplankton have a short life cycle (a day or so) and therefore phytoplankton entrained at the refinery intake and the proposed FSRU intake are likely to have developed locally. Zooplankton have a life cycle of approximately 14 days and the model predictions indicate that entrainment rates are low in relation to natural loses and therefore potential impacts of entrainment are negligible. The potential entrainment rate for fish larvae developing in south Corio Bay after 28 days is low in comparison to natural predation and other losses.

Table 8-13 Entrainment of particles from south Corio Bay

Days from release	Percent entrained at low tide	
	Refinery	FSRU
7 days	0.00%	0.00%
14 days	0.00%	0.06%
28 days	0.10%	0.39%

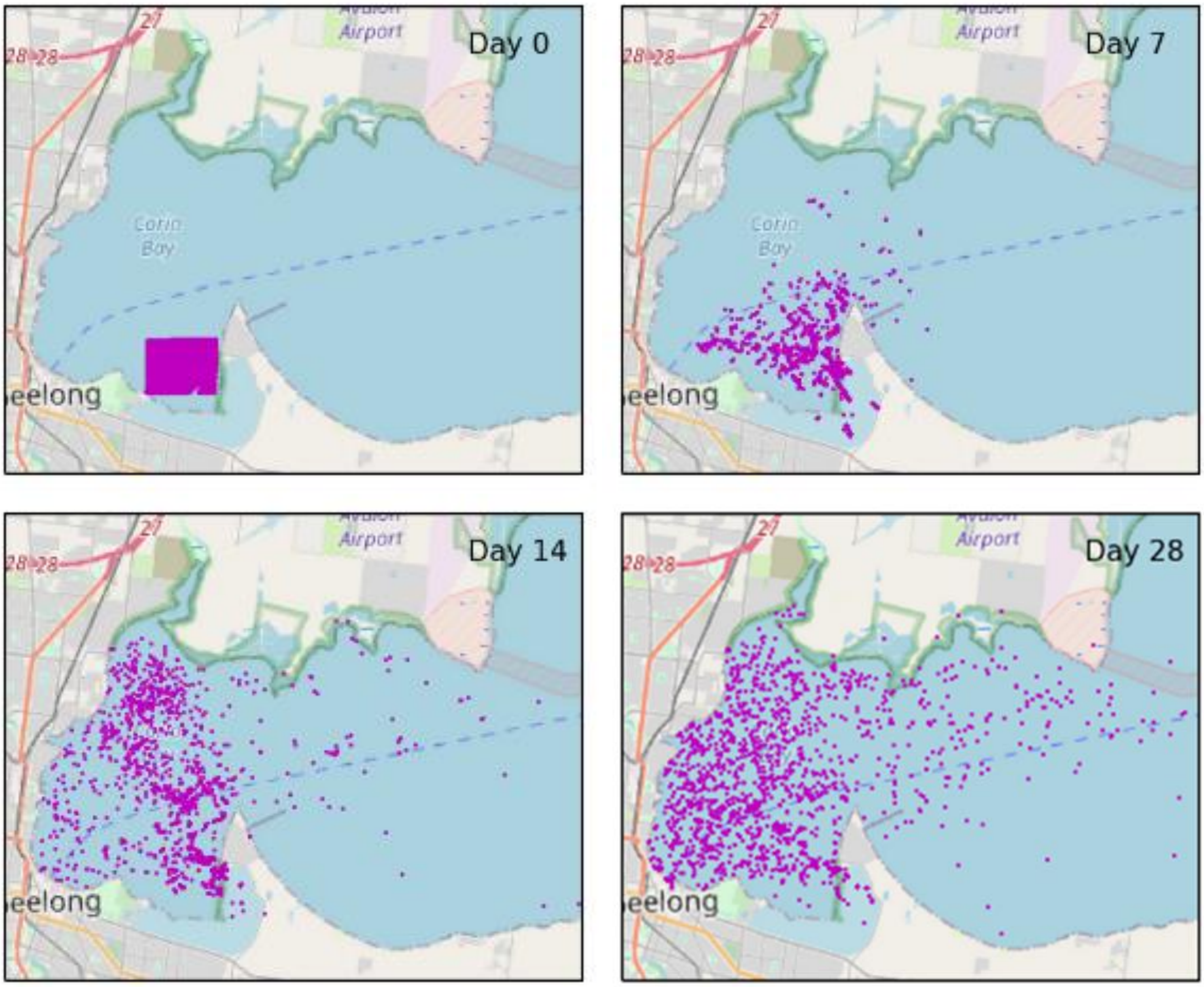


Figure 8-75 Distribution of particles from southern Corio Bay after 0, 7, 14 and 28 days

In conclusion, the predicted entrainment results and marine monitoring of existing conditions indicate that the current refinery seawater intake has negligible effect on plankton populations and fish larvae from the Ramsar site and northern and southern Corio Bay. The results indicate that the proposed FSRU intake would entrain slightly more plankton from the Ramsar site, northern Corio Bay and southern Corio Bay compared to the existing refinery intake; however, these entrainment rates are extremely low and would also have negligible impact.

To minimise the percentage of fish larvae that are entrained in spring and summer, the seawater intake on the FSRU would be located at least 2 m below the water surface to avoid entraining biota from near the surface and at least 2 m above the seabed to avoid entraining biota from near the seabed (refer to MM-ME09).

Changes to entrainment rate

Section 8.8.3 *Entrainment of plankton and larvae from the Ramsar site* to **8.8.3** *Entrainment of plankton and larvae from southern Corio Bay* show that a very small proportion of plankton and larvae from the Ramsar site and northern and southern Corio Bay are currently entrained into the existing refinery seawater intake. The remaining proportion of plankton and larvae (more than 99%) entrained into the existing refinery inlet come from the remainder of the Bay. The proposed FSRU intake would result in slight increases in entrainment of plankton and larvae from the Ramsar site and northern and southern Corio Bay (refer to summary in **Table 8-14**).

Table 8-14 Summary of proportion of particles entrained from the Ramsar site, northern Corio Bay and southern Corio Bay

Days since release	Ramsar site		North Corio Bay		South Corio Bay		Remainder	
	Refinery	FSRU	Refinery	FSRU	Refinery	FSRU	Refinery	FSRU
7 days	0.00%	0.00%	0.05%	0.10%	0.00%	0.00%	99.95%	99.90%
14 days	0.01%	0.06%	0.18%	0.36%	0.00%	0.06%	99.81%	99.52%
28 days	0.12%	0.26%	0.34%	0.66%	0.10%	0.39%	99.44%	98.69%

Phytoplankton

As discussed in **Section 8.4.8** the abundance and species richness of phytoplankton were similar over the monitoring sites in north Corio Bay. Therefore, the total number of phytoplankton that would be entrained into the FSRU inlet would be the same as the total number of phytoplankton that is currently entrained into the refinery seawater intake, however, the sources of phytoplankton entering the two intakes would differ.

At times of weak winds and average tides, the seawater entering the refinery inlet comes from a zone that extends 500 m north, 700 m south and 500 m offshore from the refinery inlet. At times of strong winds, the intake zone extends to 800 m north, 1,200 m south and 800 m offshore. The intake zone for the FSRU intake would be similar, however, it would be 700 m further offshore. As phytoplankton have a life cycle of 1 to 2 days, the majority of the phytoplankton that would be entrained in the refinery inlet and the FSRU intake would come from within the respective intake zones. Hydrodynamic modelling shows that even long-lasting phytoplankton with a life cycle of 7 days from the Ramsar site would not reach the refinery inlet zone or the FSRU inlet zone in 7 days.

In summary, changing the location of the seawater intake would move the intake zone further offshore and would slightly change the source of phytoplankton, however, there would be no change to the total number of phytoplankton entrained. Phytoplankton abundance in Corio Bay would not be reduced by the proposal.

Zooplankton

As discussed in **Section 8.4.9** the abundance of zooplankton is similar over the monitoring sites in north Corio Bay. However, abundance at the refinery inlet site was lower at 1,300 cells/m^3 compared to the east of the bay at 1,900 cells/m^3. This is most likely due to high losses of zooplankton in the refinery heat exchangers (discharged seawater from outlet W1 circulates back to the refinery seawater intake). Therefore, the total number of zooplankton that would be entrained into the FSRU intake would be higher than the number that is currently entrained at the refinery seawater intake as the FSRU intake would be located 700 m further offshore to the east.

As listed in **Table 8-14**, with the change to the FSRU intake, the proportion of plankton originating from the Ramsar site is predicted to increase from 0.01%

to 0.06%, with a similar increase from the south Bay site and a larger change from the north Bay site of 0.18% to 0.36%. These increases are very minor in relation to the natural loss rate for zooplankton of about 5% per day (Port Phillip Bay Study, 1977) and are of no ecological significance.

Zooplankton populations have a slow growth rate (20% to 50% per day, Mitchell, 1977) and therefore are slower to recover to original numbers in the existing refinery discharge plume. The growth rate of zooplankton populations depends on the phytoplankton resources available, with high growth rates (50% per day, Mitchell, 1977) in suitable conditions. The zooplankton studies in this project showed a 10-fold increase in acartia numbers in a month. Phytoplankton numbers increase quickly with distance along the refinery plume and the zooplankton population would respond to the opportunity and increase to more than 90% of the original count within 700 m of the point of discharge. By the time that the seawater travelling north from the refinery discharge points reaches the Ramsar site, the zooplankton recover to around 92% of the original count. The same scenario would occur with the introduction of the FSRU as discharge through the four existing refinery outlets would continue to occur.

In summary, changing the location of the seawater intake would move the zone of intake further offshore, however, would not alter zooplankton abundance in Corio Bay. There would be a zone extending 700 m or so in the plumes from the discharge points with lower zooplankton counts. This zone has been present for the last 65 years and would not change as the proposal involves continued discharge from the existing refinery outlets. The plume zone would move to the channel in the port when the discharge is from the diffuser.

Ichthyoplankton

As discussed in **Section 8.4.10** the abundance of ichthyoplankton is seasonal with peak numbers in spring (around 10 cells/m^3) at all monitoring sites in Corio Bay. The ichthyoplankton samples were dominated by fish eggs, which float in the water column and therefore behave is a similar manner to phytoplankton. The main fish larvae species identified were Australian Anchovy and Gobies.

Monitoring results indicate that over the year, the median numbers of ichthyoplankton were the same at all sites in Corio Bay (around 4 cells/m^3). Therefore, the number of ichthyoplankton entrained into the FSRU intake would be the same as the number that is currently entrained into the refinery seawater intake, even though the ichthyoplankton entering the two inlets would come from different intake zones. The change in the intake zone is predicted to make a marginal increase in the number of ichthyoplankton entrained into the FSRU intake from the Ramsar site, south Corio Bay and north Corio Bay.

The main factors reducing the fish larvae population are starvation and predation (approximately equal proportions, according Reynolds, 2002 and Shann et al, 2008). About 99 % of fish eggs and larvae die in the month after hatching (Kawano, 2017). The extra loss from entrainment is small in comparison to the natural loss rate of 99.99%.

As the plankton abundance per megalitre of water is relatively uniform in all waters in the area of the refinery intake and Refinery Pier, it is anticipated that the number of plankton entrained in the future at the FSRU intake would be the same as now. The sources of plankton would differ marginally and there would be a slightly higher proportion of plankton from the Ramsar site, northern Corio Bay and southern Corio Bay entrained in the FSRU intake compared to the refinery intake. However, entrainment rates are negligible and there would be no anticipated adverse impacts on plankton and larvae populations, species diversity and the food chain within Corio and Port Phillip Bays. The potential food chain impacts on migratory waders and other waterbirds are discussed in Section 10.1.5 of Chapter 10: *Land environment* and indicate that no adverse impacts would be expected.

8.8.4 Removal of soft sediment habitat

As described in previous sections, 490,000 m^3 of soft sediment would be dredged over an area of approximately 12 ha during the construction phase to create a new berth for the FSRU and a swing basin for visiting LNG carriers to turn. The seabed depth would increase from 4-8 m depths to 12.7-13.1 depths. The following potential impacts could occur as a result of the increase in depth of the seabed:

- Reduced light received by the MPB that develops on the seabed in the 12-ha dredged area. It is estimated that there is 2,000 ha of MPB cover in muddy sediments in Corio Bay.
- The existing sediments on the seabed consist of soft silt or clay. The sediments at the base of the dredged area are likely to be hard clay, with a shallow layer of fine silt. It is likely that there would be a shift in the infauna community in the 12-ha dredged area as a result of this change in sediment composition. It is estimated that the infauna community covers an area of approximately 3,000 ha in the muddy sediments of Corio Bay.

The impact of removal of soft seabed habitat is considered minor to negligible in the context of the existing ecological systems of Corio Bay. The potential impacts on productivity as a result of reduced light and a shift in the infauna community is quantified and discussed in **Section 8.8.5**.

8.8.5 Plankton and productivity

The majority of aquatic ecosystems depend on conversion of carbon, nitrogen and phosphorous into plant tissue by photosynthesis. This process is carried out by phytoplankton in the water column and MPB and large marine plants on the seabed including seagrasses and seaweeds.

The total primary productivity of Corio Bay is estimated to be10,600 tonnes of carbon per year (tC/year), which is 3.4% of the estimated primary production in Port Phillip Bay. Phytoplankton and seagrass are the major contributors, each providing approximately 40% of total productivity. MPB and seaweeds are smaller contributors, each providing approximately 10% of total primary productivity in Corio Bay. Detailed calculations of how these figures were derived are shown in Technical Report A: *Marine ecology and water quality impact assessmen*t.

The refinery has been using seawater from Corio Bay for cooling purposes for over 60 years. As discussed in previous sections, the seawater is then returned to Corio Bay via four licensed discharge outlets at 8-10°C above ambient seawater temperature and with residual chlorine levels. The combined temperature and chlorine plumes travel over seagrass beds adjacent to the shore in front of the refinery. With implementation of the project, there would be no change to the maximum volume of water drawn from Corio Bay (350 ML/d) and there would be a reduction in temperature in the refinery discharge which would range from 1°C to 10°C depending on the volume of discharge from the FSRU but not exceed the current refinery temperature discharge. It is likely that the discharge temperature when FSRU water is being discharged through the refinery will always be lower than the current refinery discharge as the refinery still requires between 200-250 ML/day of cooling water even when half the refinery is offline for maintenance every second year. The residual chlorine concentrations in the discharge would remain the same. No effects on primary productivity are anticipated as a result of the reuse of FSRU discharge in the refinery for cooling purposes.

In the event that the FSRU discharge is not able to be fully used in the refinery (i.e., if FSRU water production exceeds refinery cooling water demand or if the refinery was decommissioned in the future), the surplus cooled seawater would be discharged directly into Corio Bay via a 300 m long diffuser located under the new pier extension. As the diffuser would be designed to achieve high dilution (20 parts seawater to 1 part discharge) the entire plume on the seabed would have a CPO concentration below 5.4 µg/L which is well below the guideline value of 7.2 µg/L for chlorine in marine waters. The temperature difference in the plume on the seabed would be less than -0.5°C which is within the -1°C limit. Although peak discharge through the proposed diffuser is not anticipated to be common, modelling shows that there would be a high dilution of the discharge and the resulting chlorine and temperature plumes on the seabed would be well below guideline limits and away from the photic zone. No effects on primary productivity are anticipated as a result of discharge of seawater through the diffuser.

MPB is present in waters from 5 to 12 m depths and would be unaffected by the shoreline plumes or the diffuser plumes. However, the ongoing productivity of the MPB within the 12ha dredged area would be reduced as a result of the increased depth in the new berth and the swing basin.

Table 8-15 shows the estimated impacts on primary productivity from operation of the project. The estimated reduction in primary productivity due to operation of the project is 7 tC/year due to the reduced productivity of MPB on the dredged seabed. This is equivalent to 0.07% of the annual productivity and is within the range of natural variability from month-to-month and year-to-year, and therefore does not constitute a significant impact.

8.8.6 Spills of fuels and chemicals

The Port of Geelong has over 600 ships arriving and departing each year from 2 bulk berths south of Corio Quay, 5 berths at the Corio Quay precinct, 3 berths at Lascelles Wharf and 4 existing berths at Refinery Pier. Many more small boats used for recreational activities are launched from numerous boat ramps around Corio Bay or moored at recreational facilities at Limeburners Cove, Royal Geelong Yacht Club and public moorings at Western Beach.

Table 8-15 Estimated change in primary production – operations

Primary producer	Corio Bay (tC/year)	Reduction in area (%)	Reduction in productivity (tC/year)
Phytoplankton	4,400	-	-
MPB	1,200	0.6 %	7
Seagrass	4,000	-	-
Seaweeds	1,000	-	-
Total production	**10,600**		**7**

There are regular deliveries of crude oil for processing in the refinery and tankers taking on various types of fuel for delivery elsewhere in Australia and overseas. Bulk and break-bulk freight carriers deliver or load a range of freight at the other wharves and piers in north-western Corio Bay.

There is at present, and has been for decades, a potential for spills of oil, fuel and chemicals in northern Corio Bay. The consequences of an oil or other spill are well known and understood and are addressed through spill management plans that are in place within the Port of Geelong.

The FSRU would store very few chemicals that have the potential to spill into the marine environment, including:

- 800 tonnes of diesel (backup fuel and pilot fuel)
- 200 L of boiler water additive (e.g., Ameroyal)
- 350 L of cleaning liquid (e.g., Envirocare 370)
- 350 L of rust inhibitor (e.g., Liquide)
- 1,200 L of paints and thinners.

Up to 45 LNG carriers would enter Corio Bay a year as a result of the project. This represents 1% of the existing 4,000 large vessels which use ports around Port Phillip Bay each year. LNG carriers are modern vessels which are fueled by LNG and carry less oil and fuel than existing ships and carry much less oil than existing tankers which use Corio Bay. LNG carriers have six diesel tanks at different locations in the vessel, spaced over about 100 metres, with total volumes of approximately 250 tonnes to 1,000 tonnes. Normally the tanks are less than half full.

When the project is operational, the FSRU would be permanently moored at Refinery Pier. Therefore, the only risk of a spill is due to a potential collision with an LNG carrier or another vessel visiting Refinery Pier. The FSRU and LNG carriers are double-hull vessels and fuel storage tanks are separated from the hull by either ballast tanks or cofferdams (void spaces). No tanks on the vessel (or the LNG cargo) are in direct contact with the outer hull of the vessel.

For a significant loss of diesel to occur, the outer and inner hull of the vessel would have to be breached at the point where a storage tank is located on the vessel. In the unlikely event of this happening, there are also multiple bunker tanks meaning that fuel can be transferred to intact tanks and it would be unlikely that a large complement of diesel fuel would be lost. Overall, the potential risk for a large spill of diesel is considered to be very unlikely.

In the unlikely event that one tank is ruptured, and 30 tonnes of diesel is lost over a period of 3 hours (maximum credible spill), given the weak tidal currents in Corio Bay, an oil slick that is approximately 500 m long and 300 m wide would form within 2 hours of the loss of containment. It is likely that by this time, spill management operations would have been initiated to contain and collect the spill.

Diesel spreads rapidly over the surface. Some evaporates, but most mixes into the surface water layer. The concentration in an oil slick would exceed 1000 mg/L. Diesel fluid has a 72-hour effect concentration (EC50) of 22 mg/L for algae, 65 mg/L for fish and 210 mg/L for daphnia. While EC50 concentrations are higher for short-term events, major short-term effects would occur to biota within the area of the oil slick.

The extent of adverse impacts would depend on the rate of leakage, the time before leakage was stopped, the response time to deploy a boom and skimmer and the weather. In favourable weather, the spill could be contained in the port area.

In unfavourable weather, the spill would travel, most likely to the north in the prevailing currents. Some damage to the seagrass and seaweed on the refinery shore could occur, depending on whether the spill occurred at high or low tide. Within a kilometre, and before the boundary of the Ramsar site, the residual concentration would reduce to 50 mg/L, without including the reduction due to spill skimming, which would not cause short term impacts at a distance.

Minor short-term effects could be expected within a distance of 1 km. Beyond this distance, there would be no visible slick, and little effect on birds or intertidal biota. The effects are likely to persist for up to 1 km from the spill for weeks to months. Longer term, there would be full recovery. Thus, the estimated effects of the maximum credible spill would occur within 1 km of the site of the FSRU. An oil spill of this nature has not occurred in Corio Bay.

Worldwide, LNG facilities have an excellent safety history. This includes the processing plants, marine terminals and LNG shipping. LNG has been produced and transported for over 50 years in increasing quantities. The excellent safety record is due mainly to competent, technically trained professionals; a thorough and detailed LNG design process; multiple risk studies for LNG plant design; controlled construction, operation and decommissioning; and stringent regulatory bodies and regulations. Over the last 50 years, LNG ships have covered more than 205 million kilometres without a major accident and with no collisions, fires, explosions or hull failures resulting in a loss of containment in ports or at sea. None of the spills resulted from a failure or breach of a containment system.

Viva Energy and Ports Victoria have a well-established spill management plan, and this would continue to be used during operation of the project. The existing plan would be updated as required and implemented. Where new and improved monitoring procedures are identified these would also be implemented (refer to MM-ME14).

Further detail on the potential likelihood and consequence of LNG release is discussed Chapter 12: Safety and Technical Report N: *Safety, hazard and risk assessment*.

8.8.7 Additional light spill

This section discusses the potential impacts from light spill on marine biota as a result of the new and additional light sources on the FSRU and the pier extension as well as LNG carriers. Potential light spill impacts on migratory waders and shorebirds are discussed in Technical Report D: *Terrestrial ecology impact assessment.*

The refinery and the urban Geelong shoreline are substantial sources of the existing and extensive lighting in the area (see **Figure 8-76**). The refinery requires extensive lighting as a safety measures and to ensure that tall structures and stacks are visible to aircraft. There is also existing lighting along the western shore and southern shore of Corio Bay from port facilities, the urban area, shoreline roads, buildings, recreational facilities, cars on the road and offshore piers and marinas.

It is important to understand the potential impacts of light spill as lighting has the potential to affect fauna behaviour. Lighting for extended periods could influence marine fauna behaviour including fish and other pelagic species (e.g., zooplankton, larval fish etc.) that are attracted to light and in turn encourage predatory fish behaviour.

The additional light spill contributed by the pier extension, the FSRU and LNG carriers is calculated in Appendix A – Light spill impact assessment of Technical Report J: *Landscape and visual impact assessment*.

The lighting on the pier extension would be designed in accordance with the National Light Pollution Guidelines for Wildlife Including marine turtles, seabirds and migratory shorebirds (January 2020 Version 1.0) (refer to refer to MM-ME11). Light spill from night-time use of the proposed pier extension would be contained within the immediate vicinity of the pier. Light spill from the pier would be obstructed and masked by the light spill from the FSRU.

Minimum lighting would be required to be maintained on the FSRU and LNG carriers for safety reasons and for navigation. All vessels in Australian waters must comply with the navigation safety requirements prescribed in the *Navigation Act 2012* (Cth) and the associated Marine Orders about workplace safety equipment (e.g., lighting) and navigation. The maximum extent of light spill would be 400 m from Refinery Pier with the FSRU and LNG carrier. This additional light spill would be localised to the area around the pier and would not reach the shore.

Given the existing levels of light, the minor increase in artificial light and application of best practice to the design of new lighting on the pier extension, it is considered that the adverse effects of extra lighting on marine biota would be negligible.

Figure 8-76 Existing lighting at the refinery and the port

8.8.8 Underwater noise

Due to the existing acoustic condition in Corio Bay dominated by continuous noise mostly emitted by vessels, it is very probable that the marine animals are already accustomed (habituated) to living in a noisy environment and those individuals more sensitive to noise have long left the area. It is unlikely that the operation of the new facility will lead to behavioural responses by marine fauna on an ecologically relevant level.

Operational noise is expected to induce behavioural responses in marine mammals, most likely an avoidance of a relatively small area surrounding the sound source(s). The behavioural impact ranges for operational FSRU and LNG carrier noise extend to 1.46km for marine mammals, and TTS ranges are limited to a maximum of 40m. The predicted ranges of exceedance of the behavioural threshold are however an overestimation of the true extent, given that the average ambient noise level already exceeds that threshold (animals in Corio Bay, in other words, are exposed daily to sustained noise levels supposed to elicit behavioural responses), and the behavioural impact from the FSRU and LNG carrier will not extend as far as modelled.

For the most acoustically sensitive fish species in Corio Bay, the Australian anchovy, there is a moderate likelihood for behavioural responses within the nearfield (tens of meters) of the sound source(s) while there is a low likelihood for other fish species to show behavioural responses.

TTS is unlikely to occur in marine mammals, fish species or diving birds from exposure to operational noise as the impact range is small and, moreover, this criterion is highly conservative as it is based on assuming a receiver being stationary in this sound field over 24-48 hours.

The potential noise-induced impacts for marine fauna arising from the proposed project activities are not considered severe. A well-designed mitigation concept, such as choosing the quietest operational technique possible or reducing noise at the source (refer to MM-UN01) and deterring marine animals from the construction area (refer to MM-UN02), would reduce or even eliminate the risk of behavioural responses except for the immediate vicinity of the activities. Based on the relatively small acoustic and impact footprint of the proposed activities, it is considered that the ecological effects of underwater noise would be restricted to individuals and not affect populations negatively, particularly if mitigations are adopted.

8.8.9 Vessel strikes with wildlife

Vessel strike refers to an event in which a vessel in motion connects with marine fauna causing injury or death. Deaths usually arise from strikes with vessels such as cargo ships, tankers or large yachts. The main victim of vessel strike is usually whales, and in the waters of Victoria, the main species at risk are Humpback whales and Southern Right whales.

Approximately 20 whales are seen each year just inside the entrance to Port Phillip Bay and an average of five whales per year venture into Port Phillip Bay beyond Dromana.

Given the shallow bathymetry of Corio Bay, it is not visited by larger whales such as Killer Whales, Blue Whales or Southern Right Whales. Corio Bay is not known as an important area for large marine mammals as it is not an established breeding or feeding ground for whales. Aggregation areas for Southern Right whales are distant from Corio Bay (from Portland to Port Campbell and in waters east of Warnambool). Whale strikes are very unlikely to occur in Corio Bay but could occur in Bass Strait or anywhere along the coast of Australia.

There were 87 whale strikes (all species of whales) by ships reported in Australian waters between 1997 and 2017. Tankers make up around 10% of whale strikes. In Victorian waters, this could correspond to one whale strike involving a commercial tanker every 300 years.

The project would increase the typical number of large vessels using Victorian coastal waters. Assuming that all vessels have an equal potential for causing a whale strike, the potential impact is an additional 0.005 whale strikes (i.e., a probability of 1 in 200 over a 25-year period). As such, a whale strike from LNG carrier movements is unlikely. If a vessel strike were to occur, whale population dynamics would not be affected by the loss of an individual. Nonetheless, a precautionary approach with implementation of all practical mitigation measures is warranted.

The National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (DEE, 2017) lists three main mitigation measures - keeping vessels away from whales, slowing vessel speeds and avoidance manoeuvres. Measures to reduce the risk of whale strikes would be implemented for LNG carriers in or approaching Port Phillip Bay and Corio Bay as they would be restricted to the shipping channel and would need to adhere to Port's Victoria's vessel speed requirements (refer to MM-ME15).

8.8.10 Turbidity from tugs

The wake from tugboats operating in the shipping basins causes local turbidity as sediments from the seabed are eroded and dispersed. There are around 1,120 tug operations each year near Refinery Pier at present, and the project would introduce an additional 180 tug movements to bring the LNG carriers into and out of the port.

Propeller wash from tugs in the dredged channels has the potential cause a depth of scour of 2 mm over a maximum area of 0.2 ha, so the amount of sediment suspended is approximately 8 tonnes per tug mobilisation. The sediment resuspended by tugs would settle within approximately 100 m of the tug operations, with the sediment transport determined by the tidal currents.

Seagrass areas are well away from the operating zone for tugs and the re-suspended sediment would settle well before reaching the seagrass areas. Effects on phytoplankton are transitory and minor. Overall, the effects of turbidity from tugs associated with the project would be localised and minor.

8.8.11 Vessel grounding

Vessel grounding has the potential to cause damage to habitats or result in spills. Three vessels have grounded at Port Phillip Heads over the last 20 years. It is possible that one LNG carrier may ground in Corio Bay over a long period (say 25 years).

Temporary disturbance of seabed habitats in the shipping channel due to vessel grounding would have minimal effect on biodiversity values in Corio Bay. In the event that an LNG carrier turned from the axis of the channel, it would ground on the side of the channel. The seabed along the Corio Bay shipping channel is not vegetated as it is too deep to provide light for plants such as seagrasses and there is no rocky seabed for attachment of macroalgae. A grounded LNG carrier would likely be able to be pulled free by tugs on a subsequent high tide, most likely without damage to the vessel or any leaks.

The risk of vessel grounding would be minimised as LNG carriers would be under the control of a local pilot, travelling at defined speed limits and would be assisted by tugs when entering and leaving Port Phillip and Corio Bay (refer to MM-ME15).

The consequences of an LNG carrier grounding on the edge of the channel would be minor as the channel seabed is not vegetated, and the vessel could be returned to the channel on the following high tide. In addition, the vessel has a double hull, reducing the risk of spills (refer to **Section 8.8.6**).

Further detail on the potential likelihood and consequence of LNG release is discussed Chapter 12: Safety and Technical Report N: *Safety, hazard and risk assessment.*

8.8.12 Imported pests

The project has the potential to introduce pest species into Corio Bay which are attached to the hull or in the ballast water of an international project vessel. No ballast water would be released into Corio Bay from the LNG carrier as it would be taking in ballast water while unloading LNG at the pier. The potential impact of marine pest introduction to Corio Bay or Port Phillip Bay is the same for all international vessels entering the ports. The likelihood of introducing pest species into Corio Bay from the project relates to the increase in the number of vessels and the risk profiles of the individual vessels (port of origin, vessel design, vessel purpose, hull antifoul management systems).

There are well-established measures to control and minimise the introduction of marine pests (see MM-ME12). These include:

- Carriers have an antifoul coating to prevent biota encrusting on the hull
- Vessels from certain ports will be cleaned before entry is allowed
- International vessels will empty ballast water in accordance with the latest version of the Australian Ballast Water Management Requirements (DAWE, 2020)
- If an imported pest is identified or suspected, then the vessel would be managed in accordance with biosecurity requirements of the Biosecurity Act 2015
- Vessel management activities would adhere to the *National System for the Prevention and Management of Marine Pest Incursions.*

Based on the use of these measures, the additional 45 vessels entering the port each year would not pose a significant increase in the potential for pest species to enter Corio Bay.

8.8.13 Summary of residual impacts

Continuous mooring of an FSRU at the new Refinery Pier berth for approximately 20 years, the use of seawater as the heating medium for regasification, discharge of seawater into Corio Bay and receipt of up to 45 LNG carriers per annum have the potential to impact the marine environment during operation of the project.

The existing Geelong Refinery has been discharging warm water and low levels of chlorine into Corio Bay for over 60 years. This enabled the marine study to assess the impacts of this discharge as a baseline for assessing potential project impacts.

The field studies found a healthy marine ecosystem offshore from the refinery discharge. With the reuse of FSRU discharge in the refinery for cooling water during operation, there would be no change to the maximum volume of water drawn from and discharged into Corio Bay (350 ML/day) except when refinery maintenance occurs every second year and there would be a reduction in temperature in the refinery discharge (environmental improvement). The residual chlorine concentrations in the discharge would remain the same. On this basis, there is strong empirical evidence to suggest that the project discharge would not have adverse impacts on marine ecology and water quality.

Potential impacts from use of the diffuser on the pier extension for discharge of water into Corio Bay were also assessed. The diffuser would be used infrequently to discharge excess FSRU seawater during refinery maintenance periods in the event that the rate of FSRU discharge exceeded the refinery demand for seawater or in the event that the refinery was permanently decommissioned in the future and the option for reuse of the FSRU discharge water was no longer available. As the diffuser would be designed to achieve high dilution, modelling shows that the resulting chlorine and temperature plumes on the seabed would be localised and contained within the shipping channel and well below temperature and chlorine guideline limits.

The study also concluded that there would be a slight increase to the number of plankton entrained from the Ramsar site and northern and southern Corio Bay as a result of the project. Detailed plankton and larvae surveys conducted over 12 months indicated that plankton abundance per megalitre of water is relatively uniform throughout Corio Bay. There would, however, be a slight increase to the proportion of plankton entrained from the Ramsar site, northern Corio Bay and southern Corio Bay in the FSRU intake compared to the refinery intake, however, the entrainment rates of less than 0.66% are considered low to negligible in comparison to natural predation and other losses.

Other potential impacts to the marine environment such as spills of fuels and chemicals, additional light spill, vessel strikes with wildlife, vessel grounding, turbidity from tugs and imported pests could occur during operation, however, these potential impacts can be adequately managed through implementation of mitigation measures discussed in the sections above.

8.9 Combined stresses

This section describes the potential cumulative effects of combined stresses during construction and operation of the project on the marine environment in combination with continued operation of the port, continued urbanisation of the catchment and climate change.

8.9.1 Combined stresses during construction

Construction would commence with dredging for a period of 8 weeks followed by pier construction which would occur over approximately 12 months. There would be no overlap between these construction activities. However, combined stresses during construction could result from overlapping footprints and corresponding environmental recovery times for the impact pathways described in previous sections.

The refinery would continue to operate during construction; therefore, some construction stressors (particularly dredging) could have cumulative effects on the marine environment in combination with existing operations. There is potential for the predicted turbidity plume from dredging and dispersion to overlap with the existing temperature and chlorine plumes from refinery operation. There may be some overlap in the extremities of each plume under episodes of strong and persistent onshore winds. However, the strength and duration of the combination of the stressors (particularly turbidity) on these occasions is likely to be undetectable from background concentrations. The key environmental receptor in these areas would be shallow water seagrasses. A key outcome of the turbidity monitoring and management program would be to protect seagrass beds from the effects of turbidity. Where trigger and/or action thresholds are exceeded, action would be taken to reduce turbidity. Actions taken would most likely involve reducing the overflow period from barges to zero and slowing the dredging cycle of the backhoe dredger. This would ensure potentially detrimental combined effects of stressors on seagrasses are avoided.

Existing shipping operations and port activities would continue to occur adjacent to the project area. The existing soundscape in North Corio Bay is noisy due to the area being an industrialised port zone. Animals in the area would be accustomed to the existing soundscape and construction related underwater noise would result in temporary and localised impacts. Animals may avoid the immediate area during construction, although they would return after construction has been completed.

8.9.2 Combined stresses during operation

As described in previous sections, the refinery discharges seawater at elevated temperatures and with residual levels of chlorine. The current discharges have been occurring for over 60 years and surveys of the seagrass beds beneath the existing plumes show that seagrass grows prolifically in close proximity to all refinery discharge points and there is no detectable change in seagrass conditions due to the combined stresses of the temperature and chlorine plumes. With the project in operation, the discharge temperature would be closer to ambient temperature and the total chlorine output in the discharge would remain the same. Therefore, no adverse effects are anticipated due to combined temperature and chlorine stresses during operation.

During operation, the FSRU and the LNG carrier would occupy an area of 3 ha at different times of the day and would shade an area of 4-5 ha. Within this localised zone, there could be combined stresses due to discharge from the diffuser (if and when it occurs), shading and scour of sediments (periodically due to tugs). Shading is expected to reduce the amount of light received in the low water column and also reduce the marine biota in the water column occupied by the vessels and thereby potentially reduce the food supply to infauna in the seabed below the vessels. There could also be a superimposed effect in the area related to ship and/or tug scour.

The field studies of the infauna community in different areas observed that there was lower infauna abundance in the deeper channel seabed, which was attributed to the change in sediment character from soft silty sediment to hard clay. It is considered likely that there would be an altered infauna population in the 12 ha of seabed deepened by dredging and subject to combined stresses described above. However, as described in previous sections, it is estimated that the infauna community covers an area of approximately 3,000 ha in the muddy sediments of Corio Bay and the potential impacts from combined stresses during operation is considered minor to negligible in the context of the existing ecological systems of Corio Bay.

The projected 45 LNG carriers would add up to an extra 90 ship movements each year to the current 1,200 ship movements in the main channels of the Port of Geelong. The current shipping movements equate to an average of 4 ship movements per day and therefore the effects of the increase from the project are expected to be minor. There would be a slight increase in the likelihood of spills as a result of the additional ship movements, however, this increase can be adequately managed through mitigation measures discussed in **Section 8.8.6**.

The project area is adjacent to the existing Geelong Refinery and the Port of Geelong which are brightly lit. The industrial area adjacent to Corio Bay is a major source of lighting which spills into the nearshore waters. Although the project is anticipated to introduce new light sources to the area, the light spill from the project would be localised and contained within the port zone. The project would not result in significant light cumulative light spill impacts.

Sea level in Corio Bay has increased by 1.6 mm per year since 1965 and seawater temperature has increased by 1.5°C since 1942. Steadily increasing sea level and seawater temperature are anticipated to have effects on the mangroves and saltmarsh in the perimeter of Limeburners Bay. The project would involve either a reduction in the temperature increase above ambient in the plume along the refinery shoreline, or a small reduction in temperature on the seabed near the diffusers. Therefore, increased temperature stress due to the project and climate change is not anticipated.

Climate change would result in slightly deeper water in Corio Bay; however, this would not affect the operation of the FSRU. Deeper water would slightly increase dilution. For example, an increase in mean sea level of 40 mm (2 mm per year for 20 years) would increase the dilution of the plumes by about 0.2 %. Infauna are unlikely to be affected by rising sea level.

8.10 Integrated risk assessment (FeAST)

In May 2021, the Biodiversity Division of DELWP published a new marine risk assessment methodology called the Feature Activity Sensitivity Tool (FeAST). The FeAST methodology evaluates the vulnerability of marine biotopes (habitats), features and species to proposed developments and activities. Use of FeAST is intended to meet the objectives of the *Marine and Coastal Act 2018* (Vic) and Marine and Coastal Policy 2020, *Environmental Effects Act 1978* (Vic), *Environment Protection Act 2017 (Vic), Flora and Fauna Guarantee Act 1978 (Vic), Wildlife Act 1975 (Vic) and Environment Protection and Biodiversity Conservation Act 1999 (Cth)*; as well as statutory plans such as the Port Phillip Bay Environmental Management Plan 2012-2027. The FeAST methodology is described in the Marine and Coastal Knowledge Framework (MACKF) published by DELWP in 2021.

As requested by DELWP, the vulnerability of marine biotopes (habitats), features and species to the project were evaluated in accordance with the FeAST to test and consider the applicability of this new and emerging tool to projects of this nature.

The tool is being continuously refined and is being tested with a number of proposed projects in Victoria.

The outcomes from the FeAST integrated risk assessment are summarised in Table 8-16. The outcomes are considered conservative and precautionary as the methodology assumes a two-year duration for all activities and assumes that impacts would occur over specified buffer distances.

While the FeAST assessment framework provided another tool for consideration of potential marine impacts, the detailed assessment undertaken in the EES is considered to be a refinement of the framework and has taken the FeAST approach to a further level of detail. As such, the assessment outlined in detail in the EES is considered to be a more detailed representation of the potential impacts of the project as the assessment is based on the results of field studies, computer modelling of turbidity, chlorine and temperature plumes which show the predicted and current extent of potential impacts and considers the actual duration of activities proposed for the project. The EES outcomes shown in Table 8-16 are consistent with the results that are obtained when using the EPA risk evaluation table in the *Environment Reference Standard.*

A more detailed description of the methodology of this tool is provided in Technical Report A: *Marine ecology and water quality impact assessment.*

As mentioned above, the FeAST outcomes are considered extremely conservative and precautionary. For example, the dredging program would occur for 8-weeks, however, the minimum duration that can be selected for an activity in FeAST is 2 years. Regional modelling of the sediment plumes during the dredging program shows that the turbidity plumes would not reach the Ramsar site including Limeburners Bay, however, use of the FeAST tool assumes that the Ramsar site would be impacted as there is a minimum 'buffer' distance from the activity area where impacts are assumed.

Table 8-16 Outcomes from the FeAST integrated risk assessment

Biotope description	FeAST outcome	EES outcome / results obtained when using the EPA risk evaluation table in the ERS
Sublittoral Mud	Medium	Low
Sublittoral Seagrass	High	Low
Sublittoral Seaweed	Medium	Low
Biogenic reef	Medium	Unaffected

8.11 Assessment of impacts on Ramsar site

This section assesses the potential for adverse effects on the components, processes and services (CPS) that characterise the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site, located approximately 1.3 kilometres to the north of where the proposed FSRU mooring location. A detailed discussion of potential impacts to the Ramsar site is also provided in Attachment IV: *Matters of National Environment Significance*.

The information in this section summarises information contained in earlier sections of this chapter and in Technical Report A: *Marine ecology and water quality impact assessment* which should be referred to for more detail.

The initial risk screening conducted to inform the assessment identified the following impact pathways for marine ecology impacts on the Ramsar site:

- Plumes of turbid water generated during dredging impacting on environmentally sensitive areas within Corio Bay
- Changes to the availability of food for water birds
- Changes to water quality (chlorine) and temperature via water discharge into Corio Bay
- Operational activities (including noise and lighting) impacting marine fauna.
- Introduction/spread of imported species during construction or operations from vessels.

8.11.1 Dredging and sediment mobilisation

Seagrass mapping within and around the project area was undertaken following the seagrass surveys that were conducted during the 12-month marine monitoring program. The results of the investigations and mapping show that no seagrass would be removed as a result of the proposed dredging (refer to **Figure 8-77**). While the maximum depth of seagrass for the whole of Corio Bay is approximately 4.5 m, video tows in the northwest of Corio Bay in January and February 2021 show that *Zostera* meadows were confined to depths less than approximately 3 m. No medium or dense *Zostera* was recorded beyond 2.5 m. The waters that are being dredged are deeper than the extent of seagrass.

The pathway for an impact of dredging on the Ramsar site is an increase in turbidity and light attenuation over the seagrass beds within the Ramsar site boundary. A large proportion of the seabed in the Ramsar site has sediments and water depth suitable for seagrass. Retaining healthy seagrass is essential to meet the ecological functions of the site with respect to fish nursery and habitat, as well as a wide range of other marine organisms.

A second consequence of an increase in turbidity and light attenuation in the waters of the Ramsar site could be a reduction in phytoplankton populations with flow-on effects in the marine food chain such as reduced zooplankton numbers (as they feed on phytoplankton), and reduced populations of small fish (as they feed on zooplankton).

Metals and nutrients would also be released into the water column during dredging, as described in **Section 8.7.1** *Mobilisation of contaminants and nitrogen*. The assessment concluded that metal concentrations would be within acceptable levels close to the dredging zone and there would be negligible increase in metal concentrations in the Ramsar site. There is a small possibility that favourable weather conditions at the end of dredging could instigate a small, localised phytoplankton bloom. Monitoring of plankton during dredging (commencing 4 weeks prior and continuing for 8 weeks after) is proposed to monitor for toxic algal blooms and enable appropriate notifications to be made if required (refer to MM-ME07). However, if a bloom did occur, this would not alter the ecological character of the Ramsar site as such blooms occur periodically due to natural events.

Figure 8-77 Zones of existing seagrass in relation to the dredging zone

The area predicted to be impacted by the dredging is shown in Figure 8-78. The red outline indicates the 12-hectares of seabed that would be dredged and the 550 m long trench for the seawater transfer pipe from the FSRU to the refinery inlet. The orange indicates the area predicted to be affected by 20 milligram per litre (mg/L) median suspended solids (40 hectares) and the pink indicates the area affected by 5 mg/L median suspended solids (160 hectares). The background level of suspended solids in Corio Bay is 5 mg/L which increases regularly to around 12 to 20 mg/L when waves re-suspend sediment near the shore. and this is why the 20 mg/L contour is shown.

The median 5 mg/L suspended solids contour would not extend into the Ramsar site, although modelling suggests that there is a localised part of the Ramsar site that would experience an increase in median suspended solids concentration of around 1 mg/L during the short duration of the dredging program. Hydrodynamic modelling indicates that the area affected by dredging would not extend into Limeburners Bay. The Ramsar site would have only a minor increase in turbidity, similar to the increase in turbidity recorded in the 1996-1997 Corio Bay Channel Improvement Program.

There would be no reduction in the area of seagrass in the Ramsar site. The predicted increases in turbidity would occur for short periods within the limited 8-week dredging period. This could have a minor effect in slowing seagrass growth and productivity for a day or two, but the impact would be too small to be measured and of no ecological consequence.

While it is unlikely that dredging would impact fish populations present in seagrass habitat in the Ramsar site, as a precautionary approach, the timing of dredging would avoid spring (September to November), where key fish species are potentially in a more vulnerable stage of development (early in their lifecycle) (refer to MM-ME02). Furthermore, if dredging does not occur in spring, early seasonal growth of *Zostera nigricaulis*, the most extensive seagrass in the Ramsar site, would not be impacted by potential increases in turbidity.

In addition, a silt curtain is proposed to be installed to reduce the opportunity for sediment to reach the intertidal zone of the western shoreline of Corio Bay adjacent to the refinery (refer to MM-ME04).

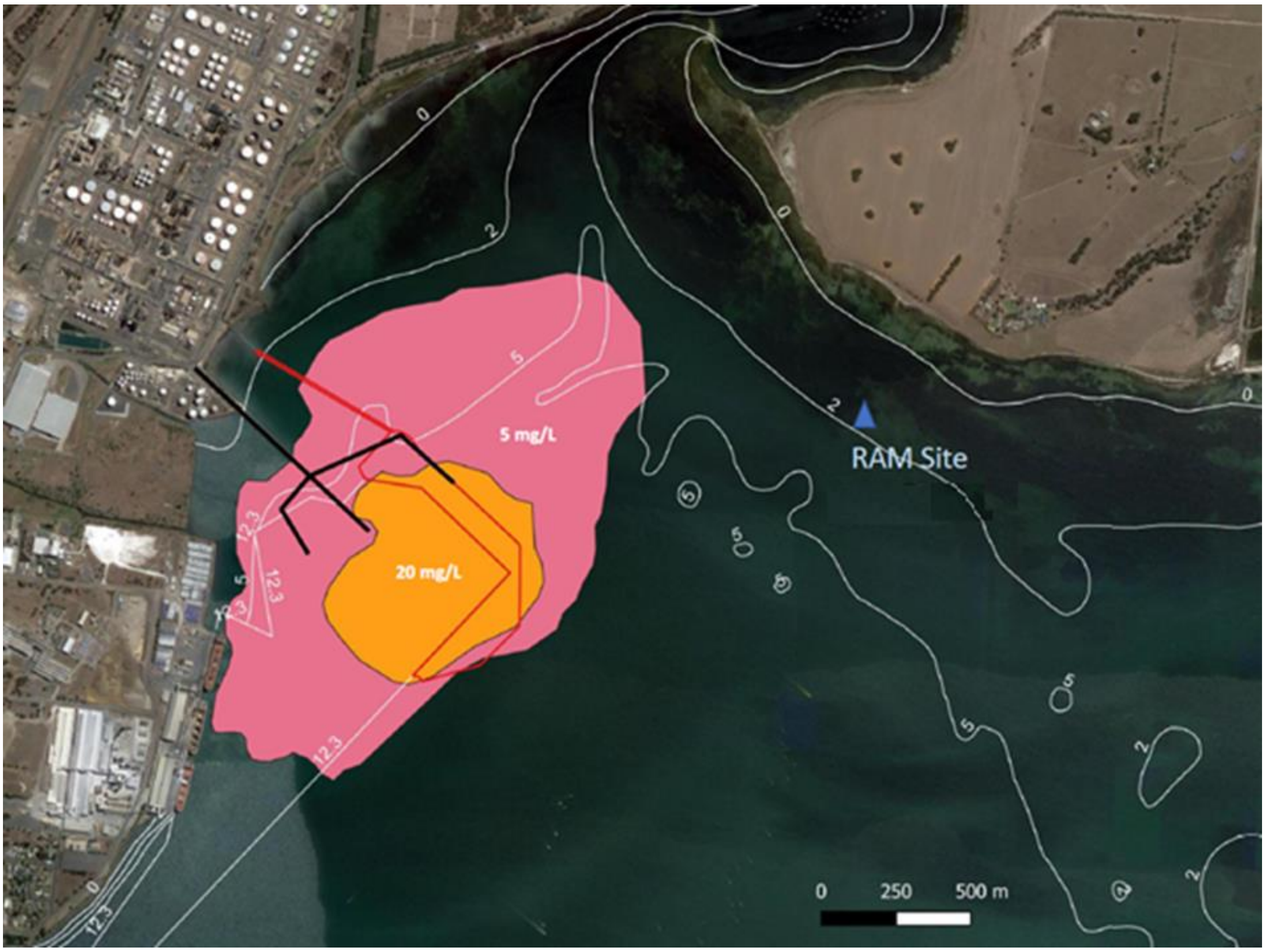


Figure 8-78 Predicted area of impact from proposed dredging

8.11.2 Entrainment

As discussed in **Section 8.6.3** *Entrainment during operation,* a detailed survey of plankton (phytoplankton, zooplankton and ichthyoplankton (fish eggs and fish larvae)) in Corio Bay was conducted as part of the marine ecology and water quality impact assessment from November 2020 to November 2021, to assess the spatial distribution of plankton in Corio Bay and the effects of the circulation patterns, channel deepening and refinery use of seawater for cooling. An analysis of the results show that the plankton distribution was well mixed through the Bay with no significant difference detected between plankton in North Corio, South Corio and the Geelong Arm. The data collected as part of the plankton monitoring program was incorporated into the regional model.

As described in **Section 8.8.3**, plankton and larvae from the Ramsar site have been modelled and shown to disperse widely from the Ramsar site. The modelling of entrainment of plankton and larvae from the Ramsar site in the existing refinery intake or the proposed FSRU seawater intake indicates there is zero entrainment in 7 days. The proportion of plankton and larvae from the Ramsar site that would be entrained in the proposed FSRU intake after 14 days would be no more than 0.27%, compared to the entrainment rate at the existing refinery seawater intake of 0.13%. Both the current and the proposed FSRU intake would have a negligible impact on plankton populations.

Phytoplankton mostly have a short life cycle (a day or so) and any entrained at the refinery inlet or the FSRU intake are likely to be developing locally and not from the Ramsar site. Zooplankton have a life cycle of around 14 days and the results show that entrainment rates are negligible in comparison to natural factors (> 99 % loss). The majority of fish larvae from the Ramsar site including Limeburners Bay are dispersed into Port Phillip Bay and the potential entrainment after 28 days is less than 0.5%, which is very small in comparison with natural predation and other losses.

The assessment concludes that entrainment as a result of the current refinery seawater intake has a negligible effect on plankton populations in Corio Bay and the proposed FSRU intake also would have negligible impact. Therefore, there would be negligible impact on food availability for shorebirds that eat zooplankton, or animals that consume zooplankton.

8.11.3 Water discharge

As indicated in **Section 8.8.1** and **8.8.2**, the warm plumes formed by the existing discharges from the refinery travel to the north and reach the mouth of the Limeburners Bay but are within the acceptable temperature limits and within the existing refinery discharge licence limits. Recycling of the chilled FSRU discharge through the refinery for cooling water would reduce the temperature in the refinery discharge (the reduction dependent on the production rate of the FSRU) and therefore reduce the discharge temperature within the project mixing zone. As the temperature plumes under any of the FSRU operating modes do not reach the Ramsar site including Limeburners Bay, there would be no effect of the temperature change on the Ramsar site. Chlorine levels in the water discharge from the refinery after the FSRU discharge water is recycled through the refinery would be the same as the existing levels as the refinery would add chlorine to the FSRU water to maintain the dosage levels currently used. As such, there would not be additional, or a change in environmental impacts associated with the discharge water.

Plumes formed by direct discharges from the FSRU (cooling water via the diffuser in the event that FSRU discharge water exceeds the refinery cooling water demand, ballast water or heated water released in closed loop operations) are well away from the Ramsar site, and the saltmarsh and mangroves that form components of the site.

The existing shoreline plume (temperature and chlorine) formed from the four existing refinery discharges has been occurring for over 60 years with no detectible impact on seagrass beds near the refinery or in the Ramsar site. Surveys of the seagrass beds under the plumes did not detect any significant change due to the plumes, mussels sampled contained no residual chlorine and sea urchins (considered the most sensitive sea animal in toxicity testing for chlorine) were found in abundance within the existing refinery mixing zone.

Based on detailed studies conducted for the EES, it is considered that the water discharges associated with the project would not impact on the Ramsar site or seagrass in Corio Bay.

8.11.4 Additional noise, vibration and light

Underwater noise generated during construction is discussed in **Section 8.7.1** *Underwater noise*, **8.7.2** *Underwater noise* and **8.7.3** *Underwater noise* and underwater noise generated during operation is discussed in **Section 8.8.8**.

Additional light spill as a result of the project is discussed in **Section 8.8.7**. Light spill modelling shows that the maximum extent of light spill from the FSRU and LNG carriers moored at the pier extension would be 400m.

The Ramsar site is too distant from the construction zone or the operations area for any fauna to experience any direct impacts from additional noise, vibration or light. Indirect effects may involve avoidance reactions by fish and marine mammals close to the construction zone, during the period of dredging and pier construction. Large marine corridors for these species to access the Ramsar site would remain, and it is considered that there would not be any adverse impact to the Ramsar site from additional noise, vibration or lighting.

8.11.5 Introduction of pest species

Marine pest introduction to Australian waters from shipping is rigorously managed by the Commonwealth Department of Agriculture and Water through the implementation of the National Plan for Marine Pest Biosecurity 2018-2023 (DAWR, 2018). There are well-established measures to control and minimise the introduction of marine pests and they would continue to be implemented for all vessels involved in the construction or operation of the project to reduce the potential for marine pest introduction to the Ramsar site.

8.11.6 Summary of impacts on the Ramsar site

The main potential impacts addressed in this section are for direct impacts of chlorine, temperature and turbidity on seagrass habitat and fish breeding and dispersal, and indirect impacts on the habitat or food supply for waterbirds in the context of the components, processes and services which make up the ecological character of the Ramsar site. Other causes of indirect impacts are spills of fuel and chemicals; extra light; underwater noise and imported pests.

The assessment undertaken of the impacts on the components, processes and services which make up the ecological character of the Ramsar site indicates that the project would have minimal impact on the ecological character of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site. The potential impacts on the components, processes and services of the Ramsar site are summarised in

Table 8-17. A detailed discussion of potential impacts to the Ramsar site is also provided in Attachment IV: *Matters of National Environment Significance*.

Table 8-17 Summary of impact assessment on Ramsar site

Components processes and services	Conclusion of assessment	Mitigation and monitoring
Wetland bathymetry	No change in intertidal mudflat area	No mitigation needed
Geomorphology	No significant change in sedimentation patterns	No mitigation needed
Marine invertebrates	Chlorine and temperature plumes below guideline limits well before they reach the Ramsar site, so no effect in Ramsar site	No mitigation needed Note: Infauna monitoring recommended close to dredging site
Seagrass	No loss of seagrass in Ramsar site	No mitigation needed Note: Turbidity monitoring recommended for boundary of Ramsar site
Mangroves	No loss of mangroves	No mitigation needed
Saltmarsh	No loss of saltmarsh	No mitigation needed
Fish	Minor change in entrainment of fish eggs and larvae, no effects on adults	No mitigation needed
Water bird abundance and diversity	No effect due to dredging or operation of FSRU	No mitigation needed
Water bird breeding	No effect due to dredging or operation of FSRU	No mitigation needed
Threatened bird species	Addressed in Chapter 10: *Land environment*; no significant impact pathway from marine operations.	No mitigation needed
Migratory birds	Addressed in Chapter 10: *Land environment*; no significant impact pathway from marine operations. No change in zooplankton availability.	No mitigation needed
Threatened fish species	No effect	No mitigation needed

8.12 Mitigation measures

The mitigation measures to avoid, minimise and manage potential marine ecology and water quality impacts associated with the project are outlined in **Table 8-18**.

Table 8-18 Marine ecology and water quality mitigation measures

MM ID	Mitigation measure	Project phase
MM-ME01	**Reuse of discharge from the FSRU in the refinery** The reuse of discharge from the FSRU in the refinery for cooling water purposes will be maximised to ensure that: the volume of seawater withdrawn from Corio Bay is consistent with current operations the seawater discharge volume to Corio Bay is consistent with current operations the residual chlorine discharge to Corio Bay is consistent with current operation there is a reduction in temperature plume from existing refinery discharge	Design and Operation
MM-ME02	**Avoid dredging in spring growth season** The 8-week dredging program will avoid the spring season (September, October and November) as this is the period of the year where there is a high growth of seagrass and phytoplankton and key species of fish are in larval or juvenile stage.	Construction
MM-ME03	**Limit duration of overflow from barges** To limit the extent of the turbidity plume in Corio Bay during dredging, the overflow period for barges associated with a small or medium-size backhoe dredge will be limited to 20 minutes while the overflow period for barges associated with a large size backhoe dredge will be limited to 14 minutes. This will limit the sediment spill rate to below 9 kg/sec and the extent of the turbidity plume.	Construction
MM-ME04	**Install silt curtain between dredging and refinery intake and seagrass** A temporary silt curtain will be installed between the dredging site and the existing refinery seawater intake and seagrass bed to minimise the number of days with elevated suspended solids concentration.	Design and Construction
MM-ME05	**Monitor turbidity and light attenuation during dredging, with threshold limits** Turbidity will be monitored during the dredging program continuously at four sites in north Corio Bay, with three sites along the 3 m depth contour at the offshore boundary of the main seagrass beds, and one near the refinery intake. The following limits are proposed as thresholds for action to restrict turbidity releases: 12-hour concentration above 15 NTU (trigger warning) 24-hour concentration above 12 NTU (action required) Turbidity will be monitored continuously at two sites 600 m inshore of the Point Wilson DMG to confirm that there is not regular transport of turbidity from barge disposal into shallow water near Point Wilson.	Construction

MM ID	Mitigation measure	Project phase
	Light attenuation will be monitored at the same six sites. Actions that will be taken will most likely involve reducing the period of overflow from barges to zero and slowing the dredging cycle of the backhoe.	
MM-ME06	**Seabed biota monitoring in dredged area and Point Wilson dredged material ground** Two baseline surveys will be made with a 3-month gap prior to dredging, and four post-commissioning surveys in the same locations every 3 months for 2 years of benthic fauna abundance, diversity and composition to detect any significant changes to infauna communities in the dredged area and the recovery of the Point Wilson DMG.	Construction and operation
MM-ME07	**Monitoring of plankton during and after dredging** Plankton populations will be monitored at four sites in north Corio Bay (as used in the 2020-2021 plankton surveys) before, during and after the dredging period, at two weekly intervals. The purpose is to identify if there is a bloom of toxic phytoplankton as a result of release of nitrogen or toxic algal spores during dredging. The phytoplankton surveys will commence 4 weeks before dredging and will continue for 8 weeks after dredging has been completed. The standard notifications to EPA and aquaculture will be made in the event that there is a bloom.	Construction
MM-ME08	**Design seawater intake to minimise entrapment** The seawater intake will be designed to keep the intake velocity in the horizontal plane at a speed below 0.15 m/s at the intake screen to minimise capture of small and large fish and other free-swimming biota and provide the same level of protection as the existing refinery intake. The intake will also be provided with a screen with apertures less than 100mm to prevent large objects and seagrass from being carried into the seawater cooling system.	Design and Operation
MM-ME09	**Locate seawater intake to minimise entrainment** To ensure that a very low percentage of fish larvae are entrained in spring and summer, the seawater intake on the FSRU will be located so that it is at least 2 m below the water surface (to avoid entraining biota from near the surface) and at least 2 m above the seabed (to avoid entraining biota from near the seabed).	Design and Operation
MM-ME10	**Design diffuser to achieve high dilution** The diffuser for cool water discharge from the FSRU will be designed to achieve a minimum initial dilution of 20:1 to ensure that the diluted discharge has a chlorine concentration less than the guideline values and a temperature change from ambient of less than 0.4°C	Design and Operation
MM-ME11	**Design lighting to minimise adverse overspill** Best practice will be used in the design of the lights on the pier extension and will meet the requirements of AS 4282: 2019 Control of the Obtrusive Effects of Outdoor Lighting and the National Light Pollution Guidelines for Wildlife (Jan 2020).	Design and Operation

MM ID	Mitigation measure	Project phase
MM-ME12	**Implement biosecurity measures on all vessels** There are well-established measures to control and minimise the introduction of marine pests in Corio Bay and all applicable measures will be implemented, including: Antifoul coating to prevent the encrusting of biota on the hull; Vessels from certain ports will be cleaned before entry; Manage ballast water in accordance with the Australian Ballast Water Management Requirements (DAWR, 2017); Manage vessel activities in accordance with the National System for the Prevention and Management of Marine Pest Incursions.	Operation
MM-ME13	**Manage cleaning and antifouling system on FSRU to avoid contamination** The anti-foul coating on the FSRU will be cleaned and maintained periodically. There are established procedures to collect scrapings from the hull and prevent them from accumulating on the seabed. Only approved antifoul coatings will be used for maintenance.	Operation
MM-ME14	**Continue to use and upgrade spill management procedures** Viva Energy and Ports Victoria have a well-established spill management plan. The existing plan will be updated as required and implemented. Where new and improved monitoring procedures are identified these will be implemented.	Operation
MM-ME15	**Use pilots, tugs and comply with vessel speed restrictions** All vessels will be under the control of experienced and qualified captains and pilots and will only be operated in the dredged channel or for smaller vessels, within the defined operation area. The dredge spoil transport barges and LNG carriers will adhere to Ports Victoria's vessel speed requirements to limit the risk of whale strikes. All vessels and tugs will slow down or stop where necessary if notified of a whale sighting or if a whale is sighted.	Construction and Operation
MM-ME16	**Minimise chlorine concentration at the discharge points** The seawater chlorination process at the FSRU and the Refinery will be managed to minimise the concentration of chlorine in the seawater discharges, consistent with good practice while also achieving the purpose of chlorination (which is to avoid internal biofouling).	Operation
MM-ME17	**Monitor rates and characteristics of all FSRU wastewater discharges** The flow rate, temperature and residual chlorine concentration of all discharges from the FSRU (excluding fire water, water curtain and ballast water) either from the refinery or directly to Corio Bay will be monitored and recorded. Monitoring will be conducted to keep a record of all discharges, confirm that the discharge rate, temperature and chlorine concentration are within the values stipulated in the licence conditions of the refinery EPA Licence and FSRU EPA Licence and, if not, provide the trigger for remedial action.	Operation

MM ID	Mitigation measure	Project phase
MM-UN01	**Minimise underwater noise impacts** Choose the quietest operational technique possible and reduce the number or duration of sound exposure periods to the absolute minimum necessary to achieve the construction targets: Reduce the rate of penetration and the number of piles installed per day (hammer strikes). Use noise dampening technologies at the source to reduce the initial sound production (primary noise mitigation) or placed in the path of propagating sound to reduce intensity (secondary noise mitigation).	Construction and Operation
MM-UN02	**Deter marine animals from construction area** Implement procedures to deter marine animals from the construction vicinity, including methods such as: Using Acoustic Harassment Devices (AHDs) during (noise-) critical activities such as the onset of impact pile driving Implementing a safety zone around loud sound sources by visual monitoring of the surrounding area prior to commencing loud activities and implement activity delays of 20 minutes based on time of last sighting Using soft-start or ramp-up procedures.	Construction
MM-UN03	**Noise awareness training** Train construction workers to understand potential for underwater noise impacts and endorse measures to reduce emissions (e.g., switching off machinery or equipment not required on a vessel while moored).	Construction and Operation

8.13 Conclusion

Construction and operation of the project is considered unlikely to have adverse impacts on the chemical and physical attributes of the marine environment, habitat conditions and the ecological character of Corio Bay, including the Point Wilson/ Limeburners Bay section of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsular Ramsar site.

Localised dredging, excavation of a trench for the installation of the seawater transfer pipe, construction of a temporary loadout facility at Lascelles Wharf and construction of the extension to Refinery Pier have the potential to cause impacts to the marine environment during the construction phase of the project. The study concluded that potential impacts related to these activities, such as turbidity, light attenuation, habitat modification and underwater noise would be temporary and localised and would not result in significant impacts to nearby populations and communities. It is likely that any altered conditions (e.g., turbidity, light availability) would return to original conditions within a short period of time after the construction activity ceases.

The existing Geelong refinery has been discharging warm water and low levels of chlorine into Corio Bay for over 60 years. This enabled the marine study to assess the impacts of this discharge as a baseline for assessing potential project impacts. The field studies found a healthy marine ecosystem offshore from the refinery discharge. With the reuse of FSRU discharge in the refinery during operation, there would be no change to the maximum volume of water drawn from and discharged into Corio Bay (350 ML/day) except when refinery maintenance occurs every second year and there would be a reduction in temperature in the refinery discharge (environmental improvement). The residual chlorine concentrations in the discharge would remain the same. On this basis, there is strong empirical evidence to suggest that the project discharge would not have adverse impacts on marine ecology and water quality.

Potential impacts from use of the diffuser on the pier extension for discharge of water into Corio Bay were also assessed. The diffuser would be used infrequently to discharge excess FSRU seawater during refinery maintenance periods in the event that the rate of FSRU discharge exceeded the refinery demand for seawater or in the event that the refinery was permanently decommissioned in the future and the option for reuse of the FSRU discharge water was no longer available. As the diffuser would be designed to achieve high dilution, modelling shows that the resulting chlorine and temperature plumes on the seabed would be localised and contained within the shipping channel and well below temperature and chlorine guideline limits.

The study also concluded that there would be a slight increase to the number of plankton entrained from the Ramsar site and northern and southern Corio Bay as a result of the project. Detailed plankton and larvae surveys conducted over 12 months indicated that plankton abundance per megalitre of water is relatively uniform throughout Corio Bay. There would, however, be a slight increase to the proportion of plankton entrained from the Ramsar site, northern Corio Bay and southern Corio Bay in the FSRU intake compared to the refinery intake, however, the entrainment rates of less than 0.66% are considered low to negligible in comparison to natural predation and other losses.

In response to the EES evaluation objectives potential impacts on marine ecology and water quality from construction and operation of the project have been assessed and mitigation measures have been identified to avoid, minimise and manage potential impacts where required.