CONTENTS

LIST OF TABLES

12. ENVIRONMENTAL IMPACT ASSESSMENT: MARINE

This chapter presents the assessment of the potential biological and physical impacts to the nearshore marine environment associated with Project activities.

For this impact assessment the nearshore marine environment is broadly defined as including the foreshore, littoral zone (between about 0 to 1.2 m water depth given the local tidal range, therefore including intertidal and only occasionally inundated habitats) and subtidal habitats present within the portion of the Application for Petroleum Processing Facility Licence (APPFL) located within Caution Bay to an approximate depth of 30 m. Chapter 8 Receiving Environment: Marine, Figure 8.1 and Figure 8.8, show the main marine habitat features and their relationship to Project facilities.

The potential impacts of Project activities in the nearshore marine environment related to social and cultural values are assessed in detail in Chapter 13 Social Impact Assessment. Air emissions from shipping are addressed in Chapter 15 Greenhouse Gases and Climate Change and Appendix F Greenhouse Gas Assessment.

12.1 APPROACH TO IMPACT ASSESSMENT

The general approach and method used to assess environmental and social impacts in this EIS is described in detail in Chapter 5 Overview of Impact Assessment Method. The nearshore marine impact assessment process includes the following steps:

- **Baseline characterisation:** Describing the existing marine environmental values and sensitivities, and aspects of those values and sensitivities that could be impacted by the Project. Baseline information is presented in detail in Chapter 8 Receiving Environment: Marine and Appendix E Nearshore Marine Baseline.
- **Defining magnitude and sensitivity:** Describing the magnitude of an impact considering the severity, geographical extent and duration of an impact that could potentially occur, and the sensitivity of an environmental value in terms of its susceptibility to change, including its capacity to adapt to, or accommodate, the changes that may be caused by the Project.
- **Identifying potential impacts:** Identifying and describing Project related activities that will impact on nearshore marine environments, i.e., mechanisms that cause a change in a value status that can be attributed to the Project. The identification of impacts was based primarily on assessing Project activities described in Chapter 2 Project Description.
- **Mitigation measures:** Identifying and assessing the significance and magnitude of the potential impacts of Project activities and developing management measures that reduce the significance level.
- **Residual impact assessment:** Assessing the impacts of the Project following the assumed successful implementation of mitigation measures.

For most impacts, significance depends on the sensitivity (or vulnerability) of the value to change, as well as the severity (or magnitude) of the impact. The significance assessment method is a function of the sensitivity of a value and the magnitude of impact on that value, which are combined to determine the level of significance. The method also assumes that an identified impact will occur, avoiding any subjectivity about which impacts will or will not materialise. Definitions of the sensitivity of the environmental value (i.e., the receptor in the marine environment) and the types and magnitude of impacts relevant to the Project are described in the sections below.

12.1.1 Sensitivity of environmental value

The sensitivity of an environmental value is its susceptibility to change, including its capacity to adapt to, or accommodate, the changes that may be caused by the Project. It also considers the intrinsic importance of that environmental value. In the marine environment, the sensitivity of an environmental value has been determined by evaluating the following attributes:

- Formal conservation status, i.e., a regionally, nationally, or internationally recognised site or environmental value.
- The level to which the environmental value supports the ecological function of other environmental values, subsistence and/or commercial resource use.
- The existing condition of the environmental value, i.e., intactness.
- The distribution, extent, or rareness of the environmental value and its replacement potential, considering both the local and regional context.
- The vulnerability of the environmental value to material damage or loss and capacity to adapt to change or regenerate.

The definitions used for assigning sensitivities to environmental values are described in Chapter 5 Overview of Impact Assessment Method, Table 5.1.

12.1.2 Magnitude of impact

The magnitude of impact to an environmental value requires the level of severity of potential impacts to be determined. In general, the magnitude of potential impacts on a value considers the extent of the impact and how quickly the effect materialises or is felt, whether it is sustained, and the duration of the effect, as follows:

- Geographic extent: The geographic extent where project activities may directly or indirectly impact the value.
- Intensity: The scale, degree and/or severity of change or disturbance experienced by the value, including the rate of change. This change can be positive or negative.
- Temporal extent: The timing of when the impact materialises and its duration (project phases and post-project phase), whether the impact will be immediate or delayed, occur during the day or at night and in which season, is a once-off, periodic, cyclical or is continuous.

Magnitude criteria for the nearshore marine impact assessment are described in Chapter 5 Overview of Impact Assessment Method, Table 5.4.

12.1.3 Assessment of significance

A matrix of significance was developed which combines the definitions of the magnitude of impacts with the various scales of sensitivity. The matrix assigns a significance of impact for each of the possible combinations between the magnitude of impact and sensitivity of environmental value (resource or receptor). Only the magnitude of an impact can be reduced by mitigation: the sensitivity, as assessed, is fixed and is not changed by project activities. The resultant significance, therefore, reflects the reduction in magnitude that can be achieved by the proposed mitigation. The matrix is provided in Chapter 5 Overview of Impact Assessment Method and reproduced below in Table 12.1.

Table 12.1 Significance-based assessment matrix

Magnitude of the impact	Sensitivity of the value				
	Extremely sensitive	Very sensitive	Sensitive	Not very sensitive	Not sensitive
Very high	Major	Major	Major	High	Moderate
High	Major	Major	High	Moderate	Low
Moderate	High	High	Moderate	Low	Low
Low	Moderate	Moderate	Low	Low	Very low
Very low	Moderate	Low	Very low	Very low	Very low

12.2 OVERVIEW OF PROJECT ACTIVITIES, IMPACTS AND ENVIRONMENTAL VALUES

Additional marine facilities are required to accommodate the increased LNG Plant production rates and subsequent increase in the number of vessels. Project infrastructure required to be constructed in the marine environment will include the following:

- Installation of a catenary anchor leg mooring (CALM) buoy to delink the non-LNG liquids (naphtha and condensate) from LNG offloading at the existing berth.
  - The CALM buoy will also require installation of a pipeline end manifold (PLEM) and approximately 6 km of export pipeline(s) for naphtha and condensate. These pipelines will connect the LNG Plant with the offshore CALM buoy, where tankers will be moored to receive the product. The construction of the pipelines and PLEM are outside the scope of this impact assessment; however, the operation of this infrastructure is a component of the Project.

Additional information describing the proposed Project marine facilities is provided in Chapter 2 Project Description.

In the context of the marine infrastructure components described above, various Project activities during construction and operation, several of which represent incremental changes to pre-existing conditions that are already occurring as a result of the PNG LNG Project, have the potential to affect marine environmental values including:

- Seabed disturbance occurring during CALM buoy installation and operation.
- Additional wastewater discharges including those from the LNG Plant retention ponds (existing and expansion) and other sources that may cause contamination (e.g., hydrotesting, surface run-off, wastewater, and brine concentrate from desalination).
- Additional illumination from lights installed in association with the LNG Plant, CALM buoy, vessels or other marine infrastructure.
- Increased vessel traffic.

These Project activities and components have the potential to result in the following effects:

- Direct physical impacts to and degradation of coastal and marine habitats.
- Increased volumes of suspended sediment and sedimentation rates.
- Contamination of sediments and a reduction in water quality.
- Generation of light and underwater noise.

- Introduction of invasive species.

These effects associated with Project activities can impact the following marine environmental values:

- Coastal and marine habitats including coral reefs, seagrass, macroalgae and mangroves.
- Marine fauna.

These aspects are discussed in greater detail in the following sections.

12.3 POTENTIAL IMPACTS

This section describes the potential impacts to marine environmental values arising from construction and operation of the Project marine facilities.

12.3.1 Coastal and marine habitats

Proposed Project activities have the potential to cause direct habitat loss in marine and coastal environments through removal, coverage, or burial during construction activities, or by altering hydrological regimes.

12.3.1.1 CALM buoy

The CALM buoy installation that facilitates the seaward connection of the naphtha and condensate pipelines, will affect the benthic habitats in this area due to seafloor placement and associated mooring and anchoring activities.

Habitats adjacent to the direct disturbance footprint associated with the CALM buoy could also be affected by varying degrees of Project-induced increases in suspended sediments and sedimentation (potentially causing habitat deterioration).

There is the potential for the mobilisation of seabed sediments during movements of export vessels (such as LNG tankers) during operations, principally via ships' propwash. However, there is reportedly no evidence of this at the existing LNG berth and, given the even greater depth of water at the proposed CALM buoy location (approximately 20 m compared to 13 m), any effects are not expected to be a credible impact able to be detected above natural variation. This potential impact has not been considered further on this basis.

12.3.1.2 Wastewater discharges

There is the potential for nutrient and chemical contamination to impact the quality of habitats due to the discharge of wastewaters, particularly in the event this occurs without appropriate management prior to discharge.

Project-related sources of wastewater discharge that could impact the nearshore marine environment include:

- Brine water from desalination facilities, including brine concentrate, backwash and rinse water that may contain traces of chemical additives
- Treated sanitary wastewater
- Clean surface run-off
- Process area surface run-off
- Thermal oxidizer spent water
- Hydrotest water (construction only).

Wastewater from most sources will be sent to the LNG Plant retention pond for final settling in the mixing pit (see Figure 2.8 in Chapter 2 Project Description), to meet the required water quality criteria before final discharge into Caution Bay. Wastewater discharges are anticipated to be discharged into the marine environment at chemical concentrations as close to ambient seawater conditions as possible and in compliance with Environment Permit criteria. Project-induced changes related to elevated salinity concentrations in retention pond discharge may arise, potentially due to the additional desalination plant, the highly demineralised water system, and associated brine waste flows.

Brine is currently discharged to the existing LNG Plant retention pond where it is mixed with process area run-off prior to being discharged into the sea, at a flow rate of approximately 23 m^3/h. The discharge of brine water and other treated wastewater from the retention pond will increase to approximately 284 m^3/h during construction of the Project and 82 m^3/h during operation in a no-rain scenario.

The brine component of the wastewater discharge may have localised effects on salinity with associated impacts to habitats such as mangroves, seagrasses, coral reefs, as well as the composition and abundance of species in affected areas (Lattemann and Höpner 2008). This can also lead to ecological health disruptions and reduced disease resilience in nearby communities (see Chapter 8 Receiving Environment Marine and Appendix E Nearshore Marine Baseline).

Hydrotest water will be required during construction activities for integrity testing of pipes and storage tanks and will use freshwater sourced from desalination facilities. Following the completion of testing procedures, it is possible that hydrotest water will be discharged directly to Caution Bay. Hydrotest water will contain traces of substances potentially including oxygen scavengers and biocides, used to protect infrastructure from risks associated with corrosion and fouling.

12.3.2 Marine fauna

12.3.2.1 Water and sediment quality

The release of low volumes of contaminants, such as those derived from operating vessel engines, is most likely to have undetectable impacts on habitats but may affect individual animals. The susceptibility of marine fauna to the potential physical or toxic effects of contaminants will depend on various factors including the contaminant type and concentration, the fauna type, and length of exposure.

Disturbance of the seabed during CALM buoy installation activities could result in elevated concentrations of suspended sediments. Elevated amounts of suspended sediments can clog filter feeding mechanisms, irritate the gills of fish, smother benthic fauna, and affect communication, feeding, mating, and predator/prey interactions. Free-swimming mobile fauna species are likely to be less affected by suspended sediments as they can actively avoid plumes. Less mobile species, and sediment epifauna and infauna are more susceptible to increased sediment impacts. Localised impacts to sediment quality associated with direct seabed disturbance, such as changes in particle sizing, may result in changes to infaunal community composition. As discussed in Section 12.3.1.1, sediment-related issues related to vessel movements (due to propwash) during operations are not likely to occur.

Disposal of wastes (including dredged material, should dredging be required during operations) could lead to the deterioration of water and sediment quality. If this occurs, direct impacts to marine fauna may occur.

Discharge of sewage and other organic galley wastes from vessels into the coastal waters of Caution Bay has the potential to cause localised elevation of nutrient levels within the receiving waters, which can lead to the accelerated growth of algae and plankton. Discharge of solid or liquid chemicals cause more serious contamination within the marine environment.

12.3.2.2 Underwater noise

Underwater noise will be generated by several different sources during construction and operations. Vessels associated with construction and operation activities include lay barges, tugs, LNG carriers and condensate carriers. These vessels will contribute to existing underwater noise levels. Project-related sources of underwater sound include propeller noise (e.g., cavitation, blade frequency, blade passage forces), main engines, other machinery, and hydrodynamic hull flow. The lay barge is likely to use anchors but may be dynamically positioned, with consequent noise emissions because the underwater noise created by dynamically positioned vessels is generally greater than from other sources. Underwater noise can cause physical damage to body tissues resembling decompression sickness, and create acoustically induced stress in marine fauna, which can consequently influence certain behaviours, including modifications in breathing patterns, the cessation of vocalisations, and active efforts to avoid or escape from regions with elevated sound intensities (NRC 2003). An additional key auditory effect is the increase in background noise levels, such that the ability of an animal to detect a relevant sound signal is diminished, which is known as 'auditory masking'. Masking marine mammal vocalisations used for finding prey, navigation and social cohesion may compromise the ecological fitness of populations (Compton et al. 2008).

12.3.2.3 Effects of lighting on marine fauna

The LNG facilities are currently lit for safety and security purposes during operation. A relatively small amount of additional lighting will be required for safety, navigation, and maintenance purposes associated with the CALM buoy. It is anticipated that the CALM buoy will be illuminated at night given the marine facilities will be designed for 24-hour mooring and loading operation. Light as a stressor can be broadly categorised as either discrete sources of light, such as individual lamps or buoy lights, and skyglow. Skyglow is the diffuse scattered light that brightens the night sky, particularly the anthropogenic portion of skyglow associated with human settlements or industrial facilities. The increased intensity or changed spectrum/colour caused by discrete lighting sources can alter species behaviour, physiology, and ecosystem structure beyond the alterations caused by skyglow, with potential subsequent impacts related to the predation of marine fauna, turtle nesting, and turtle hatchling survival.

12.3.2.4 Vessel collision with marine fauna

Direct impacts from vessels and dredging operations resulting in physical harm are well recognised (e.g., massive injuries, fractures, crushed tissues, haemorrhage, and mortality).

The presence of the marine facilities construction vessels and the ongoing arrival and departure of additional LNG carriers and condensate tankers for loading and export present both a temporary (during construction) and ongoing (during operations) risk of collisions occurring with marine species, particularly mammals and turtles.

The proposed navigational shipping channel from the entrance of Caution Bay to the CALM buoy will not need to be dredged during construction. During operations, maintenance dredging may occur. Hopper dredge dragheads (as opposed to cutter-suction pipeline, bucket or clamshell, and trailing-suction hopper that generally present less risk) are slow-moving and nearly silent while suctioning bottom sediments, thereby potentially causing injuries or death to sea turtles that are entrained into the draghead (Dickerson et al. 1991; Banks and Alexander 1994; Dickerson et al. 2004; Fitzpatrick et al. 2006).

The risk of vessel collision is multifactorial and includes the fauna type and abundance, vessel type, vessel speed and location. Large vessels such as dredges, tankers and barges are slow-moving and may allow marine fauna time to evade an approaching vessel. Large vessels typically also have sizeable/powerful propellers and a lower draft, potentially presenting a risk to slow moving fauna in the upper water column. Slow moving fauna, such as turtles floating on the water surface, may be unable to evade fast moving watercraft such as support vessels.

12.3.2.5 Accidental spillage of hazardous substances

Hazardous and dangerous goods that will be associated with Project activities include LNG liquids, diesel fuel, solvents (for repair of corrosion coatings on the pipe), oxyacetylene gas (for welding), paints, oxygen-reducing agents, hydraulic fluids, and X-ray sources (for radiography of pipeline welds).

These sources may generate contamination due to accidental spills of these products, or during vessel operations and loading. Contamination may result in impacts to water and sediment quality, subsequently affecting marine fauna and habitats. Subsequent effects may include adverse physiological responses in nearshore marine fauna, particularly those that are less mobile or unable to move from or avoid the affected area. These effects include clogging of gills with suspended solids, direct ingestion of contaminants including hydrocarbons or metals at toxic concentrations, adsorption of contaminants to the surfaces of organisms, and bioaccumulation in the tissues of organisms.

Large-scale release and accidental spillage of hazardous substances is not expected as part of Project activities, with these being non-routine events that generally result from upset conditions that will be mitigated through engineering design controls and adherence to standard operating procedures and established mitigation measures (including those provided in Attachment 3 of the EIS and also documented in the Project ESMP and appended Spill Prevention and Response Plan).

These events can also constitute scenarios or incidents that may cause adverse, off-site impacts in terms of human health issues or major impacts to the natural environment. Therefore, these aspects are discussed further in Chapter 17 Environmental Hazard and Risk Management.

12.3.2.6 Introduction of invasive aquatic organisms

Marine invasive species are recognised as one of the major direct causes of biodiversity loss and changes in ecosystem provisioning and supporting services. Invasive species are transported to new environments via vectors and pathways. Marine pests may impact ecosystems through predation, competition with existing native species for resources, habitat alteration and modification of physical environments, disease introduction and alteration of localised gene pools. Non-native organisms may be present in ballast water discharged into the waters of Caution Bay or on the hulls of improperly cleaned ships including construction vessels, LNG carriers and condensate tankers.

The installation and ongoing operation of the CALM buoy provides a potential pathway in addition to that of the existing LNG Plant facilities for the introduction of non-native marine flora and fauna into PNG waters.

12.4 MANAGEMENT MEASURES

This section describes the management measures to be implemented to mitigate impacts on marine environmental values arising from construction of the CALM buoy and operations of the Project marine facilities.

12.4.1 Coastal and marine habitats

The direct loss of marine habitat will occur to the extent of the areas that will be occupied by the Project structures, which is unavoidable, regardless of the routes and locations of those facilities. Considerable planning and assessment of the options has included measures that have limited the extent of the most sensitive habitats directly or indirectly impacted and considered other engineering and archaeological constraints (see Chapter 3 Assessment of Project Alternatives). Direct disturbance works will be limited in spatial extent and restricted to the areas required for the installation of Project facilities and conducting associated activities. Where required, adaptive management will be implemented to minimise impacts on sensitive habitats and species. This could include micro-siting and making localised adjustments during construction works to avoid certain locations and potential disturbance areas, such that selection of identified alternatives would result in a lower degree of impact.

12.4.1.1 CALM buoy

Industry good practice will be adhered to, to minimise the sediment release resulting from installation (mooring) of the CALM buoy and associated hoses. Works will be prohibited from exceeding the design disturbance width, and boundaries will be communicated through distribution of worker awareness information. Direct marine habitat and seafloor disturbance will therefore be limited to the area of the CALM buoy installation footprint, hoses, and their movements. As the sedimentation and noise-related impacts associated with CALM buoy installation are low (on account of the low intensity pile driving that will occur at the seafloor as opposed to on the water surface, and the small disturbance footprint), specific mechanical mitigations such as silt or bubble curtains are not proposed.

Construction of the CALM buoy will be linked to the separate construction of the associated export pipelines, to be completed for the Upstream component of the Papua LNG Project; therefore, consideration of the impacts of pipeline installation is outside the scope of this assessment.[1] Impacts due to sedimentation and direct disturbance from pipeline installation are expected to be more substantial than those corresponding to CALM buoy installation, and the pipeline construction timeframe will be longer. Overlapping effects are anticipated due to spatial proximity, potentially presenting challenges in terms of distinguishing between the sedimentation-related effects of the Upstream and Project activities. Given this context, a combined sedimentation monitoring program is proposed to be completed part of Upstream works during construction for both the CALM buoy and pipeline installation.

Subsequent monitoring required during operations will be in accordance with the Project operations ESMP for the integrated LNG Plant that will be developed prior to commissioning. Monitoring may include the deployment of settlement tubes / sediment traps, sediment quality monitoring and benthic habitat monitoring, similar to that prescribed in Table 3 and Annex 2 of Appendix 28 (Environmental Monitoring Plan) of the PNG LNG Project ESMP.

While not currently predicted to occur, any required maintenance dredging will be managed and mitigated as described for sea water and sediment quality.

Apart from monitoring the effectiveness of these measures, no further mitigation measures are proposed during operations.

12.4.1.2 Management of wastewater discharges

Wastewater streams entering the retention pond will be mixed within the mixing pit to assist with dilution. The outfall of the retention pond mixing pit is designed to disperse the discharge into Caution Bay to achieve compliance with the required Environment Permit (see Chapter 2 Project Description).

During Construction, associated Project discharges will be managed by EMPNGA under a Construction Environment Permit and existing production discharges will be managed under the EMPNG Environment Permit EP-L3(210). Although overlap is anticipated, criteria is expected to remain similar otherwise the most stringent criteria will apply. All discharge water post-start-up will be managed under an updated Environment Permit for the integrated LNG Plant, and the CEPA approved environmental and social management plan (ESMP) (see Chapter 18 Environmental and Social Management, Monitoring, and Reporting). The Project will work to meet the International Finance Corporation (IFC) guideline criteria for emissions, effluent and waste levels from onshore oil and gas development, subject to facilities design optimisation.

[1] The effects of pipeline installation will be addressed in a separate Combined Impact Assessment for the Papua LNG Project, and in a forthcoming addendum to the Papua LNG Project – Upstream EIS.

Hydrotest water treatment procedures will be finalised during FEED and managed under the Project construction ESMP and associated Hydrotesting Management Plan. Hydrotest water will be reused for testing whenever practicable, to reduce overall demand and associated quantities of wastewater requiring discharge. The Project will model the dispersion characteristics of the hydrotest water that will be discharged in Caution Bay prior to discharge. If necessary, additional options such as diffusion and disposal of hydrotest water through the retention pond mixing pit may be implemented as necessary to meet Environment Permit conditions.

Project wastewater discharge characteristics will be finalised during FEED. EMPNGA will inform CEPA of any material changes to the predicted level of residual impact at this time.

12.4.2 Marine fauna

12.4.2.1 Water and sediment quality

Validation monitoring and evaluation of water and sediment quality will be conducted. Particular attention will be given to water near discharge points and at sensitive receptors to confirm that measured water and sediment quality parameters are within permitted environmental limits. A response plan to halt or remediate impacts that exceed predicted conditions will be developed.

It is not expected that maintenance dredging of the navigational channels or export pipelines will be required during the life of the Project. Should sedimentation occur to an extent that requires dredge-removal, the Project will adhere to the relevant requirements of the *Marine Pollution* (*Sea Dumping*) *Act 2013*, with respect to dredging and disposal of dredged material. This includes protocols for investigating contamination and suitability material for disposal, alternative options for use of material, management of dredging options and site selection. Dredging equipment will be selected with the objective of minimising the creation of plumes and reducing the risk of entraining or otherwise impacting marine fauna. The PNG LNG Project previously identified and utilised offshore disposal locations for dredged material and determined that dredged sediments in Caution Bay were not classified as contaminated. It is likely that the established disposal locations would be revisited if required.

12.4.2.2 Management of underwater noise

To minimise the potential for exposure and disturbance to marine fauna caused by underwater noise during installation of the CALM buoy, the Project will adopt ‘soft start’ or ‘ramp up’ procedures (i.e., gradual increase in intensity from lower noise emissions to higher noise emissions). ‘Soft start’ procedures deter and reduce the likelihood of impacting nearby marine fauna (e.g., larger fauna such as dolphins and turtles) and allow mobile marine fauna in the vicinity the opportunity to move away before sound levels reach a maximum where potential for injury is more likely. Marine fauna observation procedures will also be maintained throughout construction to track abundance and diversity within the area, with additional management measures (such as avoidance and reduced vessel speeds, see Section 12.4.2.4) applied accordingly.

There are no practical ways to reduce the noise characteristics from vessels, and limited necessity given the existing context of the current vessel movement patterns associated with the PNG LNG Project. Therefore, extending the marine fauna observation procedures to individual vessels in Caution Bay during operations is not warranted.

12.4.2.3 Management of effects of light on marine fauna

Measures will be implemented to reduce, where practicable, artificial illumination of the marine environment, during Project construction and operation.

Lighting arrays will be designed and managed to minimise visibility of the LNG facilities (including marine facilities) from Idihi Island, a location where turtles may nest.

Good industry practice for lighting fixture design will be incorporated to include consideration of factors that can help prevent or mitigate the impacts on wildlife and the environment, including:

- Removal of excess lights
- Using intermittent or flashing lights, lower lighting intensities, and timers and/or dimmers as appropriate
- Placement of lights to reduce vertical spread of light (uplight) and water illumination
- Utilising spectrums known to be less-impactful to wildlife.

Additional research findings regarding the effects of lighting on turtles that may be considered by the Project through FEED include the following:

- Lights most disruptive to turtle hatchlings are those rich in short wavelength blue and green light (e.g., metal halide, mercury vapour, fluorescent and light-emitting diode) and lights least disruptive are those emitting long wavelength pure yellow-orange light (e.g., high- or low-pressure sodium vapour) (Pendoley 2005; Horch et al. 2008).
- Loggerhead turtles are particularly attracted to light at 580 nm, green and flatback turtles are attracted to light <600 nm with a preference to shorter wavelength light over longer wavelength light, and many species are also attracted to light in the ultraviolet range (<380 nm) (Commonwealth of Australia 2020).
- Some light types such as low-pressure sodium, LPS15, and filtered high-pressure sodium, which excludes wavelengths below 540 nanometres, do not appear to affect nesting densities (Pennell 2000).

12.4.2.4 Management of vessel collisions with marine fauna

During construction, the PNG LNG Project Ecological Management Plan (Appendix 1 of the PNG LNG Project ESMP) required a marine fauna observation procedure to be implemented, whereby all observations and encounters with marine mammals and turtles were documented. Similarly, the Project will maintain and implement a marine fauna observation procedure during construction. Implementing a protocol to minimise vessel interactions with marine fauna, including reducing speeds when potentially susceptible marine fauna (primarily turtles and marine mammals) are observed in the water, will reduce the risk of Project vessels striking fauna.

When observed, vessel crew will be notified and subsequent avoidance actions will be implemented as practicable, including reducing speed, navigating away, or waiting, until marine fauna moves well clear of the vessel path (i.e., 200 m from the vessel). Marine fauna observations will be reported to the LNG Plant environment team.

Vessels will travel safely and at appropriate speeds that allow them to take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions. Only one way traffic is permitted in the Caution Bay channel. Under the existing PNG LNG Project vessel procedures, navigational channel transit speed is limited to 8 knots in an east-west heading and 6 knots in a north-south heading, reducing to 3 knots when crossing the marked submerged gas pipeline and fibre-optic communication cable. These procedures will be adopted for the Project.

12.4.2.5 Management of discharges from vessels

The existing PNG LNG Project marine waste management plans will be reviewed and updated where necessary to capture proposed Project activities and comply with MARPOL standards (prohibiting discharges within three nautical miles of the coast) and with international port policies and procedures applying to vessels within this distance.

The Project shall adhere to the relevant requirements of the *Marine Pollution (Ships and Installations) Act 2013* and *Marine Pollution (Sea Dumping) Act 2013*. Onboard wastes produced by vessels that cannot be discharged under PNG and relevant International Maritime Organization legislation, guidelines and standards should be stored and transferred to an approved onshore facility for treatment, reuse, recycling or disposal.

12.4.2.6 Management of invasive aquatic organisms

The existing Project-wide quarantine management plan will be updated and continue to be enforced, and include requirements for Project vessels to adopt industry practices complying with PNG legislation (e.g., *Marine Pollution* (*Ballast Water Control*) *Act 2013*), and relevant MARPOL and International Maritime Organization guidelines and standards applicable to ballast discharge, hull cleaning and antifouling requirements to prevent unintended pest introductions.

IFC Performance Standard 6 also sets forth the following requirements that will be met by the Project under the requirements of the ESMP:

- The client will not intentionally introduce any new alien species (not currently established in the country or region of the Project) unless this is carried out in accordance with the existing regulatory framework for such introduction, if such framework is present, or is subject to a risk assessment (as part of the client’s Social and Environmental Assessment) to determine the potential for invasive behaviour.
- The client will not deliberately introduce any alien species with a high risk of invasive behaviour or any known invasive species and will exercise diligence to prevent accidental or unintended introductions.

12.5 RESIDUAL IMPACT ASSESSMENT

This section assesses residual impacts after the assumed successful implementation of the management measures outlined in Section 12.4.

12.5.1 Coastal and marine habitats

Habitat deterioration due to direct physical impact and sedimentation associated with seabed disturbance will occur during the installation and operation of the CALM buoy.

Sedimentation-related impacts can vary from obliterative to non-detectable, depending on the volume of sedimentation, type of sediment, duration of sedimentation and characteristics of the habitat. Sedimentation rates are anticipated to be proportional to the distance from their source, with higher concentrations occurring closer to the epicentre of disturbance/mobilisation and diluting progressively with distance. Sedimentation will be driven by ambient currents, winds, and waves, with larger materials settling out of the water column sooner than fine materials.

During operations, impacts will occur incrementally and ongoing habitat loss or deterioration to marine habitats is expected to be minimal unless unplanned events such as spills, or other significant vessel-related impacts to habitat (such as groundings) occur.

The residual impacts related to specific Project activities are discussed further below.

12.5.1.1 CALM buoy

The CALM buoy will be located approximately 6 km from shore at the 20 m depth contour. The CALM buoy will require the installation of mooring chains that will be affixed to the seafloor. Installation of the CALM buoy will result in a direct disturbance area of approximately 120 m^2. This area is based on the installation of each mooring chain affecting a 20 m^2 area (assuming a conservatively estimated disturbance footprint of 5 m x 4 m per chain). Suspended sediment generation during piling is expected to be limited given the low intensity and short duration of the activity.

During operations, the lateral movement of the six mooring chains due to motion responses relative to the prevailing wave loads and hydrodynamic properties associated with the CALM buoy is anticipated to result in the chains periodically making contact with and eventually scouring the seabed, resulting in localised seabed erosion of loose sediments. Over an extended period (years), this effect may result in the development of a subsea gully or ditch. Given the 400 m length of each chain, contact may occur across tens of metres of seafloor and eventually lead to the formation of a ditch several metres in depth. The specific effect will depend on wave conditions, the motion of the mooring chains that occurs, seafloor type, and sediment deposition processes. The overall impact in affected areas is likely to be similar to that of bottom trawling. The rate of change to the seabed will be too slow to cause material impacts to surrounding habitats due to elevated suspended sediments.

Existing habitats in the direct disturbance footprint of the CALM buoy infrastructure will be lost, with mortality expected for immobile fauna present in these habitats. Data from 2019 and 2022 marine surveys indicated that most of the seabed displayed high benthic homogeneity and low structural complexity or three-dimensionality above the seafloor. Epifauna mainly comprises sea whips and sea fans, where present. Occasional exceptions were observed in the form of discrete patch reefs and other generally limited areas of hardstand rocky substrate in terms of spatial extent, though these were sometimes well-established in terms of fauna. In other locations, various gorgonians colonising otherwise bare silty sediments tended to be the main corals. Closer to shore, low-lying reef, scattered coral rubble, soft silts, muddy sediments, and sand inhabited by sparsely distributed benthos characterise the CALM buoy and naphtha and condensate export pipeline routes.

Sampling undertaken for the PNG LNG Project EIS in 2007/2008 collected a total of 725 individuals from 68 different microbenthic taxa from Caution Bay. A high diversity of fauna was indicated with 28 taxa being crustaceans followed by 23 taxa in polychaetes, with a lesser number of gastropods, bivalves, echinoderms, and six other taxa represented by one or two individuals. Comparative sampling was conducted in the 2019/2022 surveys. A total of 971 macrofauna animals were collected from 74 taxa, indicating a high diversity of fauna, similar to observations made in 2007/2008. Silty habitats in deeper water typically displayed lower numbers of individuals, with less than 40 individuals per sample. The diversity sampled from 2022 indicates that the community is an established population that has not experienced any recent environmental disturbances (for example, cyclones, freshwater inundation). Individual counts were distributed evenly among the different species and dominance was low across all sites suggesting that no individual species population dominated the study area. These findings suggest an apparently stable diversity of taxa after prior disturbances, and natural variability in microbenthic fauna communities.

The area of effect is likely to represent less than approximately 0.010% of the overall soft sediment habitat type present in Caution Bay, that is characterised by a widespread benthic infauna and a limited diversity of corals and epifauna. While loss of benthic habitats can create food web implications (HELCOM 2018), the potentially affected area represents a very small proportion of the total available habitat, is a widely available habitat type, and is of relatively low ecological value (compared to coral reefs, for instance). Therefore, impacts to food webs and related ecological processes in Caution Bay are not predicted as a result of CALM buoy installation or operation.

The habitat affected is characterised as widely available, having high benthic homogeneity and generally low structural complexity. It is also subject to the influence of suspended sediments that are likely to naturally limit the development of more complex faunal communities such as reef-building corals. Most benthic and epibenthic marine biota within the directly-impacted soft sediment seafloor area are also widely distributed across this commonly occurring habitat type. The receiving environment is therefore depicted as **Not Very Sensitive**.

The effects of direct habitat impacts will be restricted to a relatively small area in Caution Bay compared to the extent of the available habitat type, and will remain for as long as the infrastructure affects the seabed, before it is recolonised by benthic fauna. The impacts to marine habitats are therefore predicted to be of **Low** magnitude.

For comparative context, the PNG LNG Project EIS determined that impacts to the benthic environment adjacent to the footprint of the pipeline infrastructure would be low (expected to occur within 1 km and with rapid recovery within 2 years). Project impacts to sensitive ecosystems such as mangroves, fringing reefs and seagrasses are not expected given the distance from shore, and will not be as substantial compared to those of the PNG LNG Project, due to the different disturbance locations and types of disturbance activity.

Based on the assessments of magnitude and sensitivity, the residual impact significance is therefore **Low**.

12.5.1.2 Wastewater discharges

Most wastewater streams will be sent to the integrated LNG Plant retention ponds where they will combine in the mixing pit for settling, prior to discharge into Caution Bay. These waste streams will include:

- Brine water from the desalination facility
- Treated sanitary wastewater
- Clean surface run-off
- Process area surface run-off
- Thermal oxidizer spent water.

The retention pond and mixing pit system and associated treatment processes are part of the site design of the LNG Plant to manage discharges such that they meet Environment Permit conditions regarding water quality. Sampling results from 2019 displayed similar patterns to previous years (2007/2008, 2010/2011, and 2014) with most parameters either below the applicable detection limit for each parameter, or above the detection limit but below the Environment Permit EP-L3(210) criteria, ANZG (2018) 95% species protection and Schedule 1 guideline values.

Hydrotest water will also be discharged, potentially directly to Caution Bay. This discharge will be managed to meet Environment Permit conditions and avoid prolonged residence in fringing reef or seagrass areas. As the hydrotest water discharge will be short-term and not an ongoing event, it is unlikely that this will result in salinity changes resulting in adverse effects, and concentrations of additives are likely to be readily-diluted such that they rapidly reach levels where adverse effects are not expected to occur.

In 2019, salinity sampling results in Caution Bay ranged from 13.1 PSU to 34.4 PSU, with an average recorded across all sites of 33.7 PSU. This indicates natural spatial variation in terms of the degree of salinity flux that occurs in the prevailing marine environment. Various scientific literature sources indicate a typical ambient ocean salinity of 35 PSU, and that benthic environments can tolerate an increase in salinity of between 1 to 2 PSU above ambient concentrations, with slightly higher tolerance levels identified for restricted periods for certain seagrass species (Høpner and Windelberg 1996; Jenkins and Wasyl 2005; Barron 2006; Sánchez-Lizaso et al. 2008). Typically, impacts are not detected where adequate flushing capacity exists. A 10% increment above ambient ocean salinity has also been suggested as a conservative measure of aquatic life tolerance to increases in salinity (WHO 2007).

Mangrove dieback has been observed in association with discharge from the retention pond mixing pit (see Chapter 8 Receiving Environment Marine and Appendix E Nearshore Marine Baseline). Water quality samples were collected during the 2022 mangrove surveys from 25 sites where localised pooling and ponding was observed, and from the LNG Plant discharge points. In addition to the pooling of water, brackish water was observed (salinity of 12.7 ppt) close to mangrove dieback areas, as well as elevation changes (potentially influencing likelihood and duration of pooling or stagnation). Water quality results were generally similar to those typically encountered within tropical mangrove ecosystems, with evidence of freshwater intrusion in some areas, potentially from the LNG Plant or groundwater sources. This change in conditions has induced a localised transition in mangrove community composition in the vicinity of the LNG Plant retention pond discharge areas, contributing to an overall increase in mangrove coverage adjacent to the LNG Plant. Dieback of some mangroves (primarily *Ceriops* spp. based on observations to date) is expected to continue in the event of ongoing water quality and hydrodynamic fluxes caused by the retention pond discharge, with succession of *Avicennia marina* also predicted.

The sensitivity of the environmental value of marine habitats within the vicinity of the retention pond discharge is assessed as **Sensitive**, due to the mangrove and marine communities near the retention pond mixing pit discharge location providing nursery habitat for many juvenile fish species and invertebrates, buffering against sedimentation and strong weather, and acting as a natural nutrient filtration system.

Based on the findings that the existing retention pond discharge is having localised influence on the mangrove community composition but no observable effects on the ecological functions of the broader marine habitat of Caution Bay, and assuming Project compliance with Environment Permit criteria, the magnitude of impact is assessed as **Low**.

Based on the assessments of magnitude and sensitivity, the residual impact significance is assessed as **Low**.

12.5.2 Marine fauna

12.5.2.1 Suspended sediments

Suspended sediments generated due to disturbance of the seabed will have varying degrees of impact on filter feeding organisms, fish, and benthic fauna. In the case of free-swimming mobile fauna species, it is likely that exposure to localised suspended sediments will be brief as most organisms can avoid plumes of increased sediment. Localised, brief exposure can clog filter feeding mechanisms, irritate the gills of fish, and affect communication, feeding, mating, and predator/prey interactions. Less mobile species such as slow moving or sessile invertebrates and sediment epifauna and infauna will be more susceptible to being impacted by increased sediment. Benthic fauna occurring in areas of high suspended sediments will likely be smothered. Depending on the rate and volume of deposition, and the tolerance and sensitivity of fauna, effects will range from negligible to mortality.

There is substantial variability in the vertical distributions of total suspended sediment concentrations in the water column, with a distinct increase in concentration towards the seabed (RPS 2023). It is likely that the existing conditions are partially a function of the proximity to the Vaihua River, and that benthic fauna in the south of Caution Bay have a degree of natural resilience to fluctuations in suspended sediments given the ongoing variable input of terrigenous sediments from the Vaihua River.

Benthic communities associated with the CALM buoy infrastructure placement locations typically have low structural or biological complexity (see Section 12.5.1.1), compared to other locations in Caution Bay such as where reefs are well developed. Given the proposed CALM buoy location is further offshore than the existing LNG Plant jetty, and the observations from surveys indicating that benthic communities in the vicinity of the location are typically of low complexity and associated with a widely distributed habitat type (that is, soft sediments with infrequent observations of corals), the sensitivity of the marine fauna has been categorised as **Not Very Sensitive**.

The localised impacts from habitat burial and sedimentation as a result of CALM buoy infrastructure are therefore also predicted to be reversible over time, with indications of recovery likely detectable within two years following the cessation of disturbance, as deposited sediments become colonised by benthic fauna.

These factors provide the basis for prediction that the magnitude of sediment-related impacts to marine fauna will be **Very Low**.

Based on the assessments of magnitude and sensitivity, the residual impact significance is therefore **Very Low**.

12.5.2.2 Underwater noise

There are various sources that contribute to ambient ocean noise including oceanic processes, noise from shipping activities and naturally occurring biological noise. While there has been no recorded marine fauna mortality attributed to PNG LNG Project-generated underwater noise to date, the potential effects of noise from Project activities may be elevated due to the increase in vessel traffic.

Noise exposure effects are highly variable as they are dependent upon the type and intensity of noise, period of exposure and distance from the source. The potential effects of noise can be divided into five types:

- Mortality and mortal injury – immediate or delayed death either due to injury or substantially reduced fitness.
- Recoverable injury – injuries, including hair cell damage, minor internal or external bleeding, etc. None of these injuries are likely to cause direct mortality.
- Temporary threshold shift – short- or long-term changes in hearing sensitivity that may, or may not, reduce fitness due to exposure to intense sound. Temporary threshold shift is defined as any change in hearing sensitivity of 6 dB or more.
- Masking – increase in threshold levels of detection by more than 6 dB.
- Behavioural effects – substantial change in behaviour for a large portion of the animals exposed.

Commercial vessel movements are a major contributor to underwater noise, especially at low frequencies between 5 to 500 Hz (NRC 2003; Richardson et. al. 1995). Underwater noise, primarily generated during project construction activities, but also ongoing during operations, has the potential to interfere with the behaviour of marine fauna, particularly marine mammals that communicate and navigate using sound (Richardson et. al. 1995).

These will add to background levels of noise that are derived from wind, waves and surf, and existing vessel movements and log export activity in Caution Bay. In some cases, extremely high levels of sound can cause harm to air-breathing animals and fish with air-filled swim bladders. However, such impacts only occur when animals are close to sources such as powerful bow thrusters. Bow thrusters may be used by concentrate vessels, other large vessels during construction and operation, or tug boats, but the noise emissions are expected to be typical of the existing activities at the LNG Plant jetty.

Compared to fishes, much less is known about the role of sound in the lives of marine turtles. With so few data, predictions of both the physical and behavioural effects of noise on turtles are, largely, not currently possible (Piniak et al. 2016). While the biological significance of hearing in turtles remains largely unstudied, it is known that sea turtles can detect and respond to acoustic stimuli and may use sound for navigation, locating prey, avoiding predators, and general environmental awareness. Sea turtles spend much of their life underwater, but they breathe at the air-water interface and critical portions of their reproductive cycle (egg laying and hatching) take place on land. Therefore, it may be important that sea turtles are able to detect sound in both underwater and aerial environments. It is unknown if turtles detect substrate vibration, sound pressure, particle motion, or all of these.

Piniak et al. (2016) compared underwater and aerial hearing sensitivities in five juvenile green sea turtles by measuring auditory evoked potential responses to tone pip stimuli. Green sea turtles detected acoustic stimuli in both media, responding to underwater stimuli between 50 and 1600 Hz and aerial stimuli between 50 and 800 Hz, with maximum sensitivity between 200 and 400 Hz underwater and 300 and 400 Hz in air. When underwater and aerial hearing sensitivities were compared in terms of pressure, green sea turtle aerial sound pressure thresholds were lower than underwater thresholds; however, they detected a wider range of frequencies underwater. When thresholds were compared in terms of sound intensity, green sea turtle sound intensity level thresholds were 2 to 39 dB lower underwater particularly at frequencies below 400 Hz.

Noise levels that can interfere with marine fauna could occur in the event of extensive use of vessel thrusters. The relatively shallow depth and soft sedimentary seafloor[2] will partially attenuate underwater noise through refraction, reflection, and the absorption of sounds from engines and thrusters.

Furthermore, marine animals are not likely to be suddenly exposed to high levels of underwater noise from shipping or trenching without prior detection, such that this would prevent avoidance behaviour, as sounds are typically audible from a distance.

The duration of the impact during construction will be limited to the period required to install the CALM buoy. During operations, the impact will be intermittent and associated with the daily operation of export vessels and support vessels. Even then, underwater noise intensities from Project-related vessels are not expected to be substantially different from existing shipping activities and are likely to be insufficient to cause physiological harm except to animals approaching to within a few tens of metres. This finding is based on a specialist report prepared by Curtin University of Technology (provided in the PNG LNG Project EIS as Annex A in Appendix 11, Offshore Impact Assessment) describing modelling that was based on the worst-case characteristics of a dynamically positioned pipelaying vessel. The report noted that noise would be audible across a distance of more than 20 km; however, the noise levels would be too low to produce detectable physiological effects on marine fauna such as temporary hearing threshold shifts (i.e., less than an underwater noise level threshold of 180 dB re 1 μPa). The study noted that cetaceans would be aware of the vessel activity (mainly propellor cavitation) and may exhibit avoidance behaviour at ranges of between 1 and 10 km, and that the most substantial effect of the noise was predicted to be increased masking of relatively low-level signals transmitted between groups of marine animals.

A more recent study[3] in a New Zealand location in 2020 associated with offshore sand extraction in depths up to 25 m noted that during full dredging conditions (pump on, draghead down and loading the hopper), noise was not expected to induce a temporary threshold shift beyond 1 m distance due to M-weighted source levels being below the required sound exposure level thresholds. No risk of permanent threshold shift (injury) was identified for all species, including fur seals, common and bottlenose dolphins, orca and Bryde’s whale. Audibility limits were species dependent, ranging between an approximately 4 km and 6 km radius. Auditory masking effects, and the extent of such, also varied between species. The specific distances at which there was a 75% chance for some behavioural effect to occur (whether low or moderate in severity) was approximately 15 m for dolphin species and 124 m for Bryde’s whales. A 50% probability of some behavioural effect occurring was restricted within approximately 51 m and 241 m for dolphins and Bryde’s whales, respectively.

Given the intermittent nature of the noise likely to be generated, it is probable that some animals may exhibit a startle or alarm type of response; the existing environment presently experiences the sound types that will be generated by the Project (due to PNG LNG Project operations), as well as other non-Project sources.

While marine mammals are not commonly encountered in Caution Bay, some smaller marine cetaceans such as dolphins are present at various times, but these are not listed by the International Union for the Conservation of Nature (IUCN) Red List (IUCN 2023) as being of conservation significance. Marine turtle species which are internationally recognised by the IUCN Red List are known to occur in Caution Bay and therefore, the sensitivity of the environmental value is assessed as **Extremely Sensitive.**

[2] The PNG LNG Project EIS noted that sediments within Caution Bay are more consolidated and less absorptive of sound, compared to less consolidated sediments present in the western parts of the Gulf of Papua.
[3] https://www.aucklandcouncil.govt.nz/ResourceConsentDocuments/BUN60369079%20Underwater%20Noise.pdf

With the application of management measures such as 'soft start' procedures where noise-causing activities are ramped up gradually, the effects of underwater noise on marine fauna are predicted to be of **Very Low** magnitude.

Based on the assessments of magnitude and sensitivity, the significance of this residual impact is assessed as **Moderate**.

12.5.2.3 Effects of light on marine fauna

The existing LNG facilities are illuminated 24 hours a day during construction and operations. There is some direct illumination or glare from the facilities (including the marine facilities) that is visible from Idihi Island at night. The CALM buoy may also introduce another source of artificial light at sea; this will be of a lower intensity than that of the existing facilities.

Surface lights, such as the light of the moon, are used by some marine fauna for navigation. Sea turtles rely on visual cues (light of the moon) to select and navigate nesting beaches, and hatchlings migrate out to sea using the same navigational technique. Turtles may nest occasionally on Idihi Island and feed in the coastal waters of Caution Bay.

Most hatchling turtles emerge at night (Mrosovsky 1968) and must rapidly reach the ocean to avoid predation (Erb and Wyneken 2019). Hatchlings locate the ocean using a combination of topographic and brightness cues, orienting towards the brighter oceanic horizon and away from elevated darkened silhouettes of dunes and/or vegetation behind the beach (Limpus and Kamrowski 2013). They can also find the sea using secondary cues such as beach slope.

The effect of artificial light on marine fauna such as turtles has been recognised since 1911 (Hooker 1911) and since then a substantial body of research has focused on how light affects turtles and its effect on turtle populations. The physical aspects of light that have the greatest effect on turtles include intensity, colour (wavelength), and elevation above beach (Lohmann et al. 1997; Salmon 2003; Witherington and Martin 2003). Artificial night lighting on or near beaches has been shown to disrupt nesting behaviour. Beaches with artificial light, such as urban developments, roadways, and piers typically have lower densities of nesting females than dark beaches (Salmon 2003; Hu et al. 2018). On beaches exposed to light, females will nest in higher numbers than in areas that are shadowed (Price et al. 2018). Moving sources of artificial light may also deter nesting or cause disturbance to nesting females (e.g., flash photography) (Campbell 1994).

Sea-finding behaviour may be disrupted by artificial lights, including flares (Pendoley 2005), which interfere with natural lighting and silhouettes (Kamrowski et al. 2014; Pendoley and Kamrowski 2015). Hatchlings have been observed to respond to artificial light up to 18 km away during sea finding (Commonwealth of Australia 2020). Artificial lighting may adversely affect hatchling sea finding behaviour in two ways: disorientation, where hatchlings crawl on circuitous paths; or misorientation, where they move in the wrong direction, possibly attracted to artificial lights. Artificial lighting along the coast can confuse and misdirect newly emerged hatchlings by appearing brighter than the sea surface horizon, increasing their risk of death by predation, dehydration, or exhaustion (Erb and Wyneken 2019). If hatchlings reach the ocean, artificial light on and around water (e.g., boats at anchor, jetties) can continue to disorientate them, potentially causing them to linger in nearshore waters with similar results.

Brightness and elevation are recognised as important cues for hatchlings as they attempt to orient toward the ocean (Commonwealth of Australia 2020). Brightness refers to the intensity and wavelength of light relative to the spectral sensitivity of the receiving eye (Witherington and Martin 2003). Both field and laboratory-based studies indicate that hatchlings have a strong tendency to orient towards the brightest direction. The brightest direction on a naturally dark beach is typically towards the ocean where the horizon is open and unhindered by dune or vegetation shadows.

Artificial lights can also interfere with the in-water dispersal of hatchlings, by attraction to shore or fixed lighting. Additionally, light sources are associated with structures that also attract fish (such as jetties), potentially leading to increased predation (Commonwealth of Australia 2020). The impacts of artificial lighting on hatchlings are typically greater than those experienced by adult turtles, fish and larger fauna due to the increased risks of predation and exhaustion.

While there are IUCN-listed species present at various times in Caution Bay, there are no beaches suitable for turtle nesting in the immediate vicinity of the LNG facilities. Turtles may nest occasionally on Idihi Island and feed in the coastal waters of Caution Bay. The sensitivity of the environmental value is **Extremely Sensitive** because of the potential presence of the IUCN-listed turtle species within the Project area.

There have been no known light-related impacts on marine fauna caused by PNG LNG Project activities, and this suggests that these are not likely to occur because of the Project. No nesting beaches are known to be present in a reasonable proximity (<18 km) to the LNG Plant and the level of light during proposed Project activities is not expected to significantly increase beyond that already experienced at the site, the magnitude of impact is **Low**.

Based on the assessments of magnitude and sensitivity, the significance of this residual impact is assessed as **Moderate**.

12.5.2.4 Vessel collisions

The expansion of the LNG Plant will increase vessel traffic by up to 60 to 70 additional LNG carriers and 10 to 12 condensate cargos per year. As stated in Section 12.5.2.2, large marine mammals such as whales are not commonly encountered in Caution Bay. Some whale species listed as vulnerable by the IUCN (Cetacean Specialist Group 1996a, 1996b, 1996c) are found in the Gulf of Papua, but these large, widely distributed and highly mobile species are not frequently observed to enter the nearshore environment of Caution Bay. Smaller cetaceans such as the pantropical spotted dolphin and bottlenose dolphin occur in Caution Bay but are not listed as species of conservation concern. Dugong are not reported to be present, and if they are, are likely to be transient rather than resident, given the absence of observational data. In the presence of vessels, fish usually exhibit avoidance behaviour and are unlikely to be injured due to vessel strike.

Marine turtles including the green and hawksbill turtle occur in Caution Bay and are listed by the IUCN as endangered and critically endangered respectively. Given the presence, or potential presence of these IUCN-listed species, the sensitivity is **Extremely Sensitive**.

Collisions between marine megafauna (primarily marine mammals and turtles) and Project-related vessels are unlikely to occur for the following reasons:

- Marine mammals are not known to be resident in the parts of Caution Bay that are in the vicinity of the CALM buoy. Marine turtles and dolphins are highly mobile and observed sporadically but not commonly.
- Sounds associated with the CALM buoy installation activities should temporarily deter marine mammals and turtles from entering the immediate area of activity.

While support vessels (tugs and supply boats) will typically travel at greater speeds than (for example) tankers, they will travel at speeds not exceeding 10 knots in Caution Bay (see Section 12.4.2.4) and their noise characteristics enable species such as dolphins and turtles to avoid them, in a similar manner to existing shipping traffic (El-Reedy 2020). Based on the above reasons the magnitude of impact is **Very Low**. The overall significance of this impact is therefore assessed as **Moderate**.

12.5.2.5 Vessel discharge

Project activities will result in increased daily vessel movements, beyond those already occurring. The expansion of the LNG Plant will increase vessel traffic by up to 60 to 70 additional LNG carriers and 10 to 12 condensate cargos per year. Without adherence to MARPOL (IMO 1973/1978) standards, or equivalent port policies and procedures, discharges from vessels such as sewage and galley waste into coastal waters could adversely affect fringing reefs, seagrass areas and associated fauna communities. As discussed above, marine mammals are not commonly encountered and therefore will be minimally impacted by the added discharge of approximately 90 vessels per year. Other marine fauna such as turtles occurring in the area (particularly the IUCN-listed species) may be affected by discharge either directly, through contamination, or indirectly, through degradation of habitat. Fringing reefs and seagrasses will potentially be impacted by the additional vessels' discharge. Reduced transparency, nutrient and chemical inputs, and increased siltation associated with vessel traffic causes light-associated, water quality, and fine sediment disturbances to seagrass and reef communities. Eutrophication and increased siltation are major contributors to seagrass and reef loss; however, it is unlikely that the additional vessels will attribute significant impact as the Project will adhere to MARPOL standards, or equivalent port policies and procedures. MARPOL details discharge criteria, general requirements, prevention of pollution, and sets limits to protect and conserve environmental values. Additionally, seagrass communities appear to be resistant to pollution by organic and heavy metal contaminants (Borum et al. 2004).

The sensitivity of the receiving environment is **Very Sensitive** due to the characteristics of the locally occurring or potentially occurring IUCN-listed species and their key habitats. While the discharges from additional vessel traffic will likely increase disturbances to fringing reefs, seagrass areas and associated fauna communities, adherence to MARPOL will significantly reduce such impact. When appropriately detected and managed, small-scale accidental spills and leaks would have a highly localised impact and are unlikely to cause a measurable decline in marine fauna populations. The magnitude of impact is assessed as **Very Low**.

Based on the assessments of magnitude and sensitivity, the overall significance of this impact is **Low**.

12.5.2.6 Invasive organisms

The ability of an invasive marine species to become established in a different environment such as Caution Bay is difficult to predict because of the complex interaction between native and introduced exotic (i.e., non-native) species. The introduction of aquatic pests observed to have the most deleterious effects has typically been between northern and southern temperate areas. Marine animals adapted to tropical conditions generally have widespread distributions with many existing throughout the Indo-Pacific. Non-native temperate species are unlikely to survive, and the overall risk of new exotic pests becoming established is low.

The susceptibility of tropical waters, such as Caution Bay, to the introduction of non-native marine flora and fauna is lower than temperate waters. Most tropical species have a wide distribution, so the risks of local introductions of species not already there or of temperate species becoming established are low. Non-native marine pests can still be introduced into tropical waters, such as the introduction of the black-striped mussel (*Mytilopsis sallei*) to Darwin marinas in 1999 (Marshall et al. 2003).

The existing use context of the LNG Plant jetty, and the fact that field observations in 2022 (as noted in Chapter 8 Receiving Environment: Marine, and Appendix E Nearshore Marine Baseline) did not identify invasive pest species, suggests that invasive species have either not become established in the area or remain inconspicuous. The sensitivity of the environmental value is **Not Very Sensitive**.

Potential quarantine-related impacts to the nearshore marine environment in Caution Bay need to be considered within the context of the existing and future vessel traffic to the LNG Plant jetty, including existing vessel movements unrelated to the Project, which may make attribution to a particular vessel or activity difficult.

Although unlikely, if this occurred, invasive species may spread from the LNG facilities to other parts of PNG waters and remain present long-term as it is often not possible to successfully manage or eradicate introduced marine flora and fauna. On this basis, the magnitude of impact is **Moderate**.

With the implementation of Project-specific quarantine management measures and the requirements of international vessels arriving at the LNG Plant jetty and CALM buoy to comply with PNG customs and quarantine requirements, the significance of impacts related to the introduction of invasive marine species is predicted to be **Low.**

12.6 SUMMARY

Table 12.2 summarises the residual impacts on nearshore marine values, with significance ratings derived from the relevant assessments of sensitivity and magnitude.

Table 12.2 Residual impacts on nearshore marine environmental values

Impact description	Residual impact after implementation of management measures		Significance rating
	Magnitude	Sensitivity	
CALM buoy	Low	Not Very Sensitive	Low
Discharges from retention pond mixing	Low	Sensitive	Low
Suspended sediments	Very Low	Not Very Sensitive	Very Low
Underwater noise	Very Low	Extremely Sensitive	Moderate
Effects of light on marine fauna	Low	Extremely Sensitive	Moderate
Vessel collisions	Very Low	Extremely Sensitive	Moderate
Vessel discharge	Very Low	Very Sensitive	Low
Invasive organisms	Moderate	Not Very Sensitive	Low