Chapter 11

Offshore and Near Shore Environmental Impact Assessment and Mitigation

CONTENTS

11 OFFSHORE AND NEAR SHORE ENVIRONMENTAL IMPACT ASSESSMENT AND MITIGATION

11.1 INTRODUCTION

This chapter describes the potential Project-induced ecological impacts on the Offshore and Near Shore baseline marine environments resulting from the Project, as well as Project-induced changes to physical processes and water quality.

11.2 STRUCTURE OF CHAPTER

This chapter is structured as follows.

- *Section 11.3* describes the approach and methodology pertinent to the Near Shore and Offshore impact assessment.
- *Sections 11.4* to *11.8* consider Project activities that may potentially impact water quality, the seabed and marine ecology in the Offshore environment.
- *Sections 11.9* to *11.14* address the potential impacts associated with dredging activities, including disposal of dredge material in the Near Shore environment. These include the potential for increased turbidity, the remobilisation of heavy metals and organic compounds, physical disturbance and sediment deposition.
- *Sections 11.15* to *11.23* consider Project activities that potentially impact marine ecology in the Near Shore environment.

11.3 APPROACH AND METHODOLOGY

The impact assessment methodology used is explained in *Chapter 3* of this EIA Report. However, definitions of impact extent have been refined further to be more pertinent to the Near Shore and Offshore impact assessment. *Table 11.1* provides the definitions specific to this chapter.

In accordance with the UN Law of the Sea Convention (UNCLOS) (1982), Internal Waters are defined as waters landward of the Baseline, which delineates the inner (landward) limits of the territorial sea. Other Maritime Zones are measured from this Baseline. A straight baseline (1) is used in

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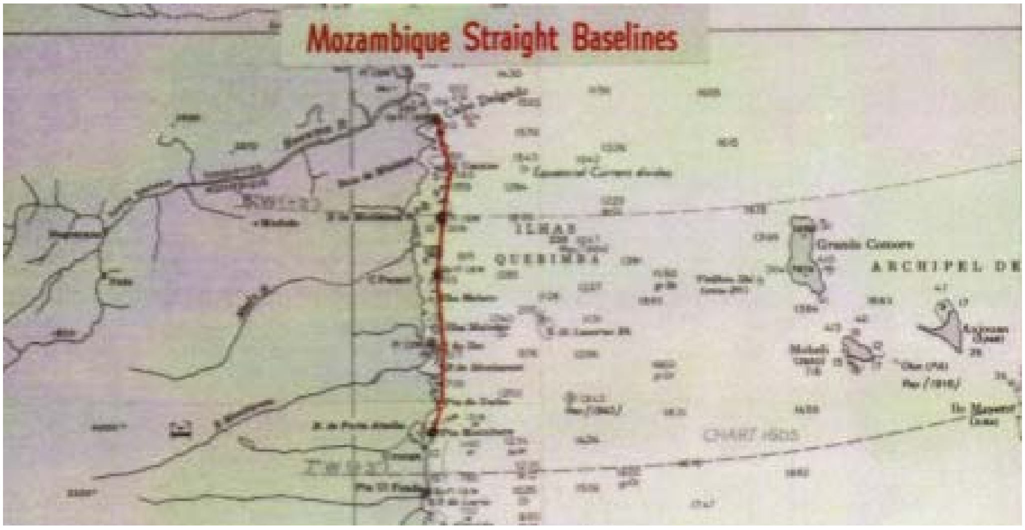
(1) A normal baseline is the low-water line along the coast, as shown on large-scale charts officially recognised by the coastal states. Straight baselines may be used where the coastline is deeply indented (bays, ports and similar enclosed areas of the sea) or if there is a fringe of islands along the coast in its immediate vicinity.

Mozambique's northern coast, which incorporates Palma Bay, extending from Cabo Delgado Peninsula in the north for 110 nautical miles along the Quirimbas Archipelago to Cabo Conducia just south of Nacala, as shown in *Figure 11.1* (1). Accordingly, Palma Bay and associated islands are within Internal Waters, where Mozambique has full sovereign powers to control all activities as if they occurred on land (2). This is set out in The Sea Act (Law No. 4/1996, January 4).

Figure 11.1 ***Straight Baseline in Northern Mozambique***



Key:
Red line shows the straight baseline from Cabo Delgado Peninsula in north to Cabo Conducia.

Source: US Department of State, International Boundary Study, Limits in the Seas, 1970.

For the purposes of this assessment, Offshore has been defined as the area beyond (or to the east of) Mozambique's Maritime Baseline. Near Shore refers to waters westward of the Maritime Baseline.

Table 11.1 provides the definitions of impact extent pertinent to the Offshore and Near Shore marine environment impact assessment. *Figure 11.2* indicates the approximate alignment of the Maritime Baseline, about 1.5km east of the islands of Rongui, Tecomaji, Queramimbi and Vamizi.

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(1) First established in 1967 under Portuguese law (Jamine, 2007), and subsequently acknowledged in a United Nations Law of the Sea delimitation agreement between Mozambique and Tanzania on 28 December 1988.

(2) These powers, including powers over pollution prevention from shipping, may be stronger than in its Territorial or other waters. Territorial Sea is an area of sea up to a limit not exceeding 12 nautical miles, measured from baselines determined in accordance with this Law of the Sea Convention.

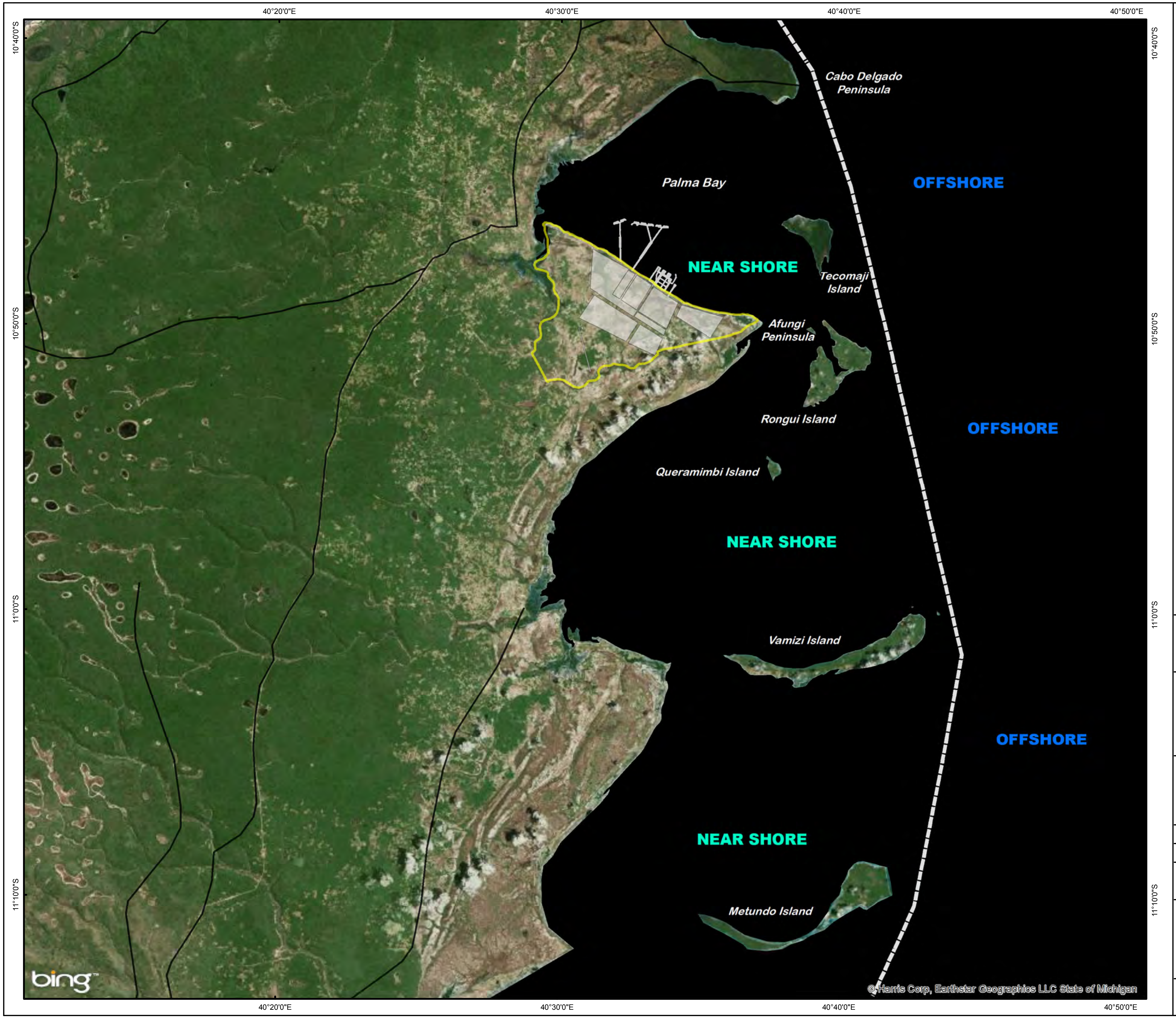
Table 11.1 Definition of Impact Extent Used for Near Shore and Offshore Marine Environment (Refer to Figure 11.2)

	Near Shore	**Offshore ***
Onsite	A 28km^2 block around the Near Shore Project infrastructure, as shown in *Figure 11.2*	An area of <5km^2 around source of Project activity
Local	The Internal Waters of Palma Bay inside the Maritime Baseline, as shown in *Figure 11.2*	5-50km^2 (~7x7km) from source of Project activity
Regional	The Internal Waters of Cabo Delgado Province inside the Maritime Baseline, as shown in *Figure 11.2*	An area of 50-500km^2 (~22x22km) around source of Project activity
National	Mozambique's Economic Exclusion Zone (EEZ), but beyond the Maritime Baseline of Cabo Delgado Province	Within Mozambique's EEZ
International	Outside of Mozambican EEZ (eg in Tanzanian or Comoros waters)	Outside of Mozambique's EEZ

Key:
* The extent defined for Offshore impacts is related to the location of Project activities (eg drilling).

The definitions used to describe impact extent in the Near Shore marine environment are illustrated in *Figure 11.3***.**

Potential impacts to marine ecology resulting from the construction and operational phases are dealt with in this chapter, where applicable. The key Project activities likely to result in impacts to the Offshore Environment will take place in the vicinity of Golfinho and Prosperidade gas fields, in Area 1, and Mamba Gas Field in Area 4, as well as in Palma Bay.



TITLE:

Figure 11.2: Mozambique's Maritime Baseline

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: KG	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 230 000

DRAWING:
Impact Extent Definitions Applied for the Near Shore.mxd

REV:
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ERM
Great Westerford Building
240 Main Road
Rondebosch, 7725
Cape Town, SOUTH AFRICA
Tel: +27 21 681 5400
Fax +27 21 686 073

Impacto Projectos e Estudos Ambientais

ERM

Projection: UTM Zone 37 S, Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation
Lwandle Technologies, 2012. Inset Map: Esri Data

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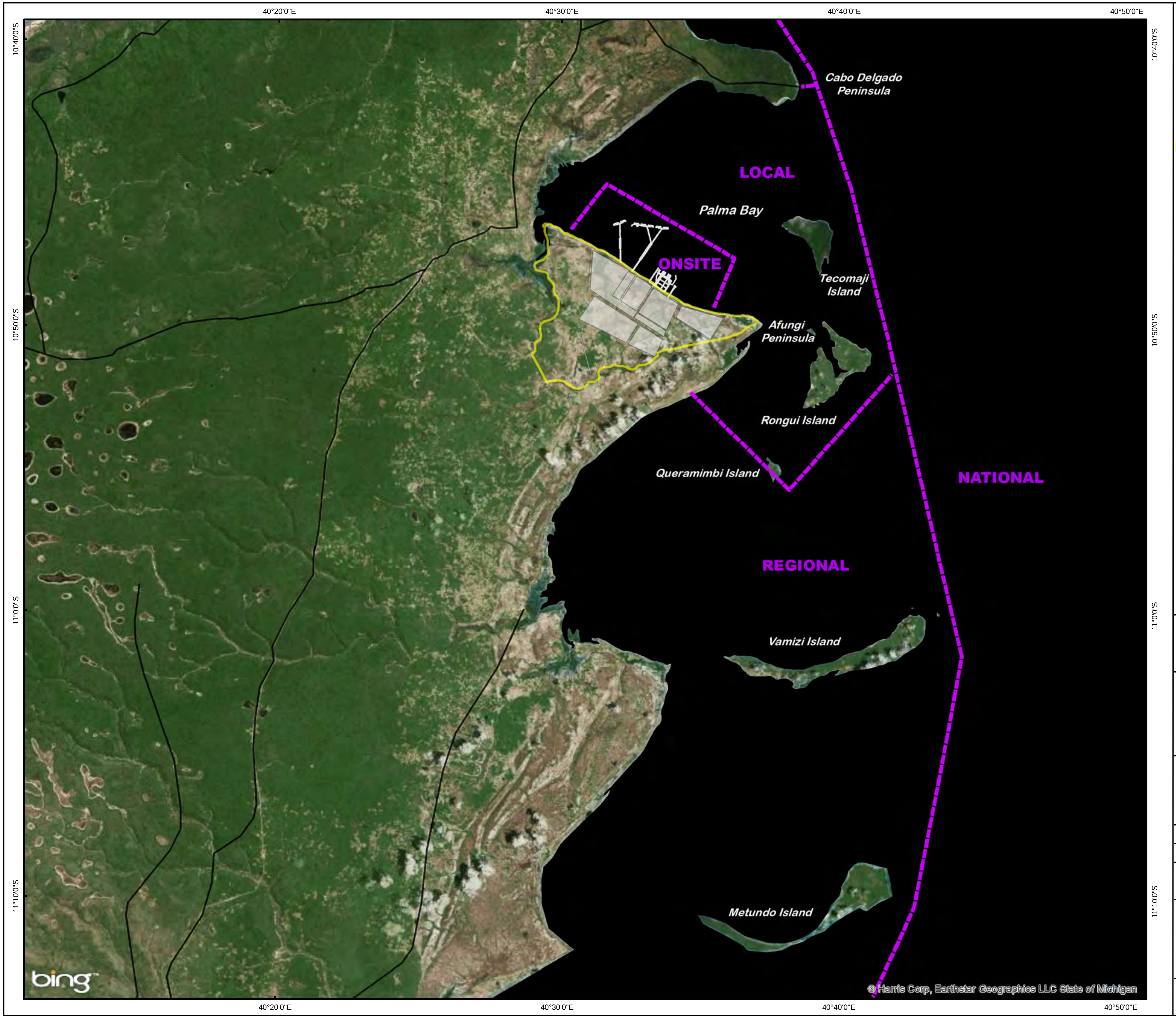
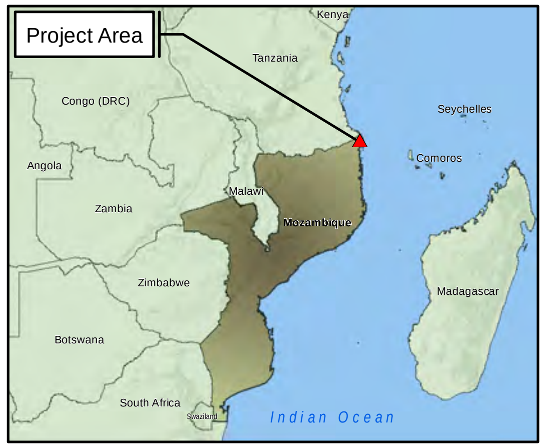


Legend

- ▬ Regional Roads
- ─ Jetty
- ▭ Onshore Layout
- ▭ Afungi Project Site
- ▬ ▬ Near Shore Impact Extents



MAIN MAP SCALE:

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Kilometers

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Figure 11.3:
Impact Extent Definitions Applied for the Near Shore

CLIENT:

Anadarko Moçambique Área 1, Lda

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DATE: Oct 2013	CHECKED: KG	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 230 000

DRAWING:
Moz Maritime Baseline.mxd

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Impacto
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Projection: UTM Zone 37 S, Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation
Lwandle Technologies, 2012. Inset Map: Esri Data

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11.4 IMPACT OF DISCHARGE OF TREATED DRILL CUTTINGS AND RESIDUAL MUDS ON OFFSHORE BENTHOS AND DEEPWATER REEF ORGANISMS

11.4.1 *Impact Assessment*

Drilling muds will be separated from the drill cuttings using shale shakers, dried where necessary and returned to the drilling fluid system. The treated drill cuttings will then be discharged to the sea together with any residual muds (1). Two types of impacts from the discharge of treated drill cuttings and residual muds into the ocean from production well drilling may occur, namely:

- physical inundation (burial and change in sediment grain size) effects on benthic marine organisms (addressed in this section); and

- chemical toxicity effects on benthic and water column marine organisms (addressed as a separate impact in *Section 11.5*).

For a robust assessment of impacts, both types of impacts require knowledge about how the discharges will be dispersed once discharged into the marine environment. Results from dispersion modelling (2) of cuttings and muds behaviour, undertaken by Applied Science Associates Inc (ASA) as part of an investigation into the offshore gas fields conducted by CSA (2012), are used in this assessment. The model predicts the behaviour of discharged treated drill cuttings (coarse fraction) and residual drilling fluids (mud, fine fraction) in terms of convective descent, dynamic collapse and far field dispersion phases of sediment plume behaviour. The model outputs include sedimentation thickness gradients with distance from the discharge points.

ASA modelled treated cuttings and residual drilling fluids discharges at two locations offshore: Atum 1 in the Prosperidade Gas Field and Golfinho O in the Golfinho Gas Field. Golfinho O has been taken to represent the expected conditions in the Golfinho Gas Field, whilst Atum 1 represents the expected conditions in the Prosperidade and Mamba gas fields.

The respective locations of Atum 1 and Golfinho O and relative to the coastline and main bathymetry are shown in *Figure 11.4*.

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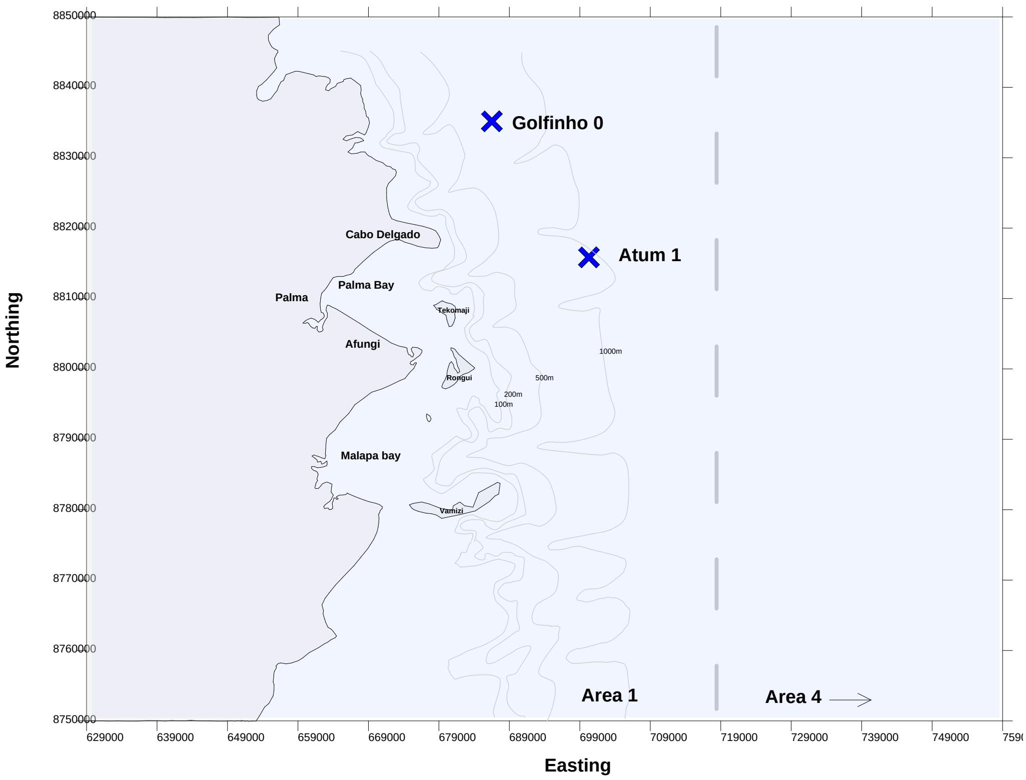
(1) The optimum alternative solution for the final disposal of cuttings will be further investigated and GIIP will be applied.

(2) The modelling platform employed for the dispersion modelling was MUDMAP. This was developed by ASA and has numerous applications in drill cuttings discharge investigations, to the point where it may be regarded as an industry standard.

Figure 11.4 *Potential Well Locations for which Treated Drill Cuttings Discharge Modelling was Conducted*



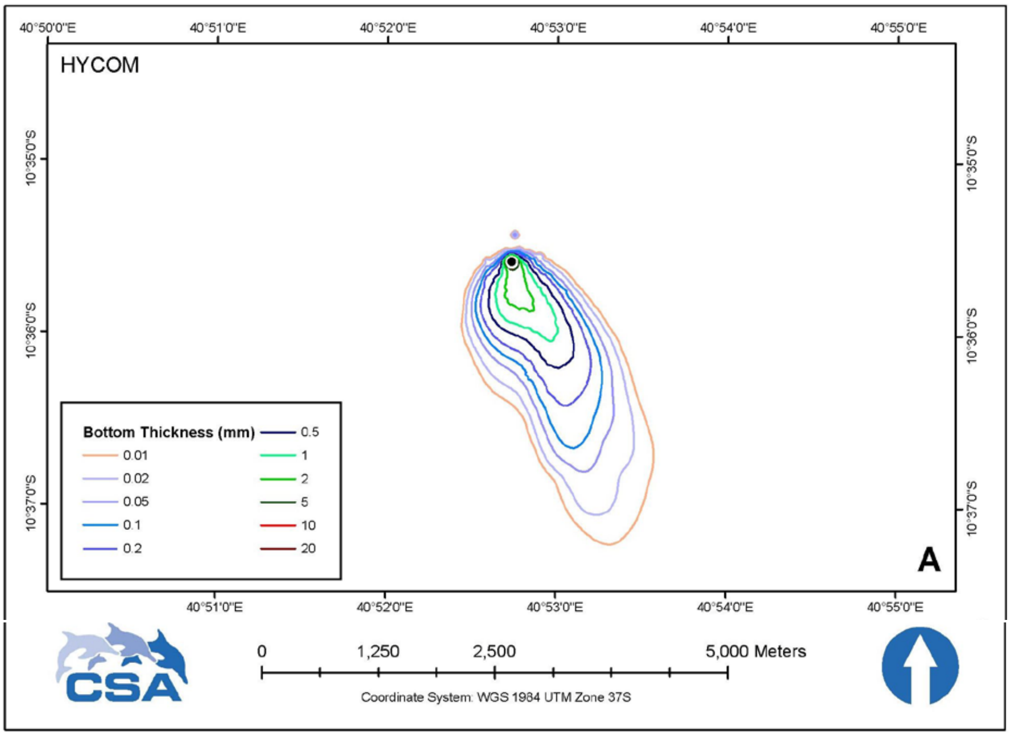
Note: The vertical dashed line delineates the boundary between Area 1 and Area 4.

Source: ASA in CSA, 2012.

Currents for each of the modelled sites were abstracted from the HYCOM data set for 2011, as detailed in *Chapter 7*. The model outputs are shown in *Figure 11.5* and *Figure 11.6* for Atum 1 and Golfinho O respectively.

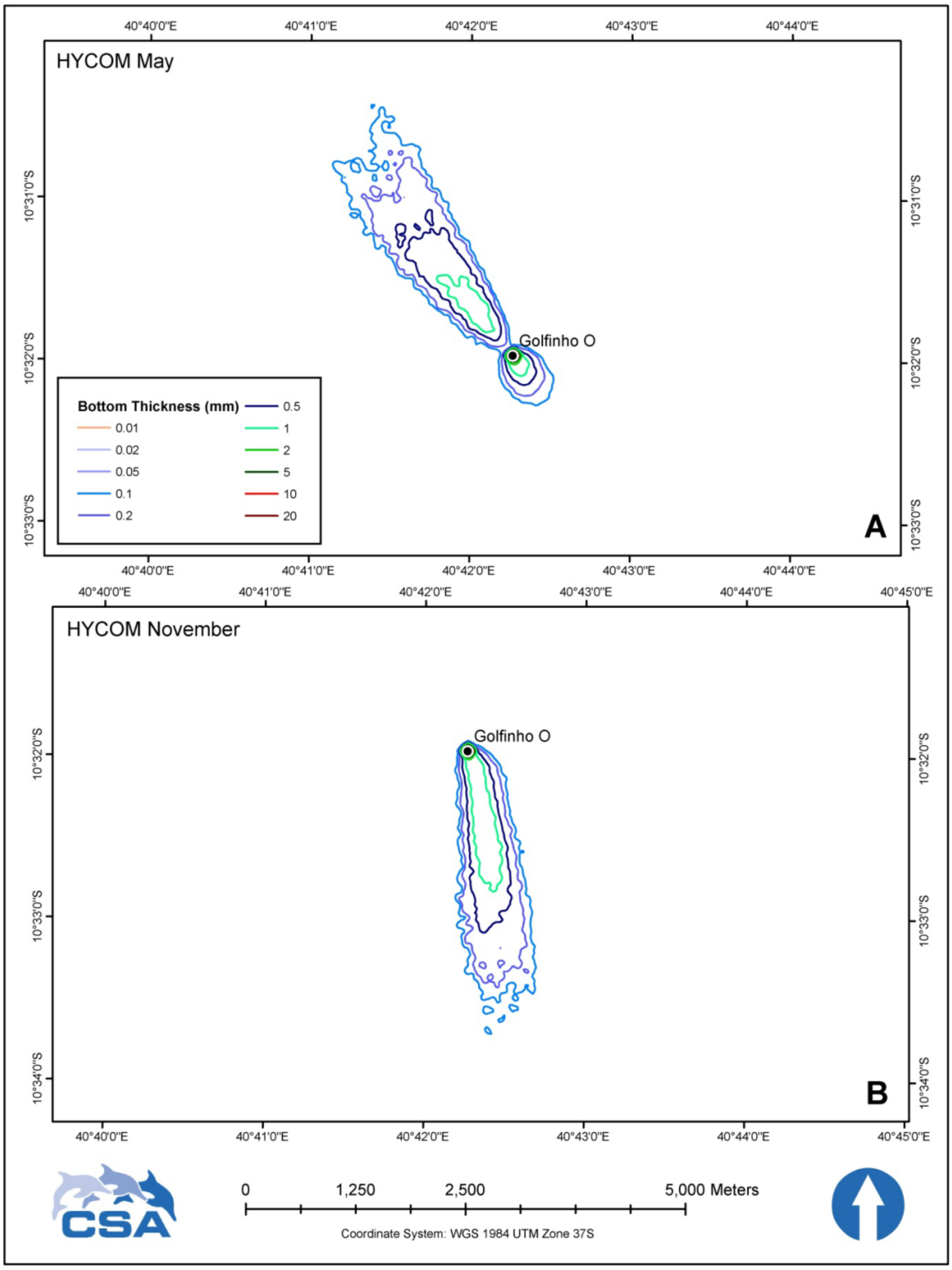
The plots of the predicted treated cuttings deposition show that the expected pattern is a narrow elipse aligned with major current vectors. This is most apparent for the Golfinho site (*Figure 11.6*), which experiences an apparent seasonality in currents, possibly due to its location near the bifurcation point of the Southern Equatorial Current (SEC) near the African landmass (described in *Chapter 7*). This results in switching between predominantly northward and southward flows, and the response is a cuttings deposition elipse aligned north-west in the period of northerly flows (May) and aligned almost due south during the period of southerly flows (November).

Figure 11.5 Modelled Drilling Cuttings and Residual Mud Deposition Footprint for the Atum 1 Well Site



Source: ASA in CSA, 2012.

Figure 11.6 Modelled Drilling Cuttings and Residual Mud Deposition Footprint for the Golfinho O Well Site in May 2011 (Top) and November 2011 (Bottom)



Source: ASA in CSA, 2012.

As shown in the above figures, the predicted total deposition footprints extend approximately 3km from the location of the well sites. There is a marked gradient in deposition depths within the footprints. However, most of the depositing material is confined to areas close to the well sites, due to deposition from the top-hole portion of the drilled wells (ie top-hole cuttings) that is ejected at the seafloor. This is coupled with the fact that the bulk of the discharges are medium sand-sized or larger rock chippings, as these have a high sedimentation velocity and therefore deposit close to the point of discharge.

As described in *Chapter 4*, up to 120 production wells may be drilled within the Offshore Study Area, namely within the Golfinho, Prosperidade and Mamba gas fields. Based on the dispersion modelling results from the Atum 1 and Golfinho O wells, the cumulative area deposition footprints for the total number of wells planned in each of the gas fields is projected to be (1) :

- Prosperidade and Mamba Gas Fields:
    - total footprint (>0.01mm) = 226km^2;
    - deposition to >1mm = 95km^2; and
    - deposition to >10mm = <1km^2.

- Golfinho Gas Field (2):
    - total footprint (>0.01mm) = 126km^2.
    - deposition to >1mm = 17km^2; and
    - deposition to >10mm = <1km^2.

The combined deposition footprints for the three gas fields at full production are:

- total footprint (>0.01mm) = 352km^2;
- deposition to >1mm = 112km^2; and
- deposition to >10mm = 1km^2.

Benthos living in and/or on unconsolidated sediments within the zone of deposition may be inundated by treated discharged cuttings and/or residual drilling muds, leading to smothering effects due to the clogging of respiratory and feeding apparatus by fine sediments (residual drilling mud fraction). This may result in benthos mortality and possibly altered benthos communities, with implications for higher levels in the marine food chain such as demersal fish and their predators. In addition, the settlement of organic-rich treated synthetic-based muds (SBM) cuttings on the seabed may result in a localised increase of nutrients in the footprint area. This may encourage microbial growth and organic decay, affecting oxygen levels, and may have the potential to impact benthos production. However, given the water depths in the gas fields and the predicted depths of the drill cuttings (including muds) and extent of the footprint area, potential impacts related to oxygen depletion on benthos are not likely to occur from a localised increase of nutrients.

Currently, there are no available quantitative regional data showing whether there are unique biological communities on the seabed. Remotely Operated Vehicle (ROV) surveys around current meter deployment sites in the offshore gas fields show varying degrees of bioturbation in the form of sediment mounds, but few megafauna (animals >10mm) on the sediment (see *Chapter*

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(1) These calculations are based on the assumption of 60 wells in Prosperidade and Mamba Gas Fields, and 60 wells in Golfinho Gas Field. However the exact total per gasfield is yet to be confirmed.

(2) Based on the mean of May and November 2011 predictions.

7). However, given that most marine invertebrates reproduce through broadcasting eggs and sperm and there is usually a pelagic larval stage in the life history before settlement into benthic habitats, it can be assumed that there is at least a regional distribution of the fauna. This is supported by large-scale species richness gradients across multiple degrees of latitude for benthic fauna, reported by Macpherson (2002).

In near shore environments, the major classes of benthos living in and on the sediments (Mollusca, Crustacea and Annelida) can withstand instantaneous burial by up to 30cm of sediment, due to their abilities to migrate upwards through the sediment pile (Maurer et al., 1980; 1981; 1982). Therefore, any deposition of sediment of less than 30cm is unlikely to generate mortalities due to inundation. Near shore sediments are subject to redistribution by wave action and strong tidal flows, etc. However, this does not apply below the storm wave base in deeper waters (70 to 200m for extreme waves) (Sherwood et al., 1994), as mechanisms are not available there to redistribute the sediments.

Smit et al. (2008) analysed benthos species sensitivity to burial by drill cuttings and muds in a continental shelf environment from a database consisting of 39 effect values for 32 benthos species, which included molluscs, crustaceans and polychaetes. The derived minimum (EC_5 (1)) and median (EC_{50} (2)) effect concentrations for instantaneous burial depths were 6.3mm (95 percent confidence intervals 3.1-10.6mm) and 54mm (95 percent confidence intervals 37-89mm) respectively. However, the nature of drilling and drill cuttings disposal precludes instantaneous burial effects of benthos in the offshore area as the cuttings are discharged over the full period of production drilling, at an anticipated frequency of one well every 70 - 75 days. This gradual deposition allows the fauna to migrate upwards through the sediment pile as it deposits. Therefore, the Smit et al. (2008) EC_5 value is considered extremely conservative for drilling applications, and the EC_{20} (3) is taken to be a more realistic threshold. From the data presented in Smit et al. (2008), this equates to a burial depth of approximately 10mm.

Recovery from disturbance is reported to be variable and is also linked to the degree of bioturbation and associated redistribution of fine sediments. Gates and Jones (2012) report the presence of burrowing crabs (*Geryon*) within 5m of an exploration well (drilled with water-based drilling mud) three years after drilling. This implies that at least macrobenthos (>1mm fauna) may recover from the effects of drill cuttings and mud discharges within a three to five-year period in zones of high deposition (>10cm) (Gates & Jones, 2012). Within the high deposition zones, effects on benthos distribution may be regarded as long term due to the degree of sediment property transformation.

(1) The concentration of material that is estimated to be effective in producing some chronic response in 5 percent of the test organisms.

(2) The concentration of material that is estimated to be effective in producing some chronic response in 50 percent of the test organisms.

(3) ie 20 percent of the benthos community may be affected if the deposition was instantaneous.

The sessile fauna present on reef structures that occur in the deepwater areas for which modelling was conducted, and for the seabed in the wider area of the gas fields in general (see *Chapter 7*), are considered to be widely distributed. For example, the deep (cold) water coral *Lophelia* has been recorded throughout the Atlantic Ocean and deepwater Gorgonia spp. have similarly wide distributions (WoRMS, 2012). However, these fauna are known to have slow to very slow growth rates (Roark et al., 2009; CORIS, 2012) and thus any damage that may be caused to them may have long-lasting effects, extending decades or longer. Similar types of fauna appear to occur on both high and low-relief reef structures in the Offshore Study Area. The low-relief structures appear to be more barren of macrofauna than the higher-relief areas (CSA, 2012). Low-relief reef structures are also apparently more ubiquitous than the high-relief reef structures, but this may be a result of the very restricted data set available (10 sites with restricted spatial coverage ROV video records, see *Chapter 7*). However, for the purposes of this assessment, high-relief reef structures are accorded a higher importance rating than reef structures with low relief.

There is little information available on the sensitivity of deepwater sponges, hard corals, soft corals, sea fans (Gorgonacea, Pennatulacea spp.), Crinoidea and other communities to sedimentation. CSA (2012) noted a thin sediment veneer on some of the deepwater reefs on which these fauna were observed in Area 1, implying that they will survive some level of sediment inundation although lethal and sub-lethal effect thresholds are not known. The sediment burial depth threshold reported for deepwater corals in Norway is 6.5mm (Larson & Purser, 2011). Observations on the deepwater coral *Lophelia pertusa* showed that although acute effects at this burial level were restricted (<1 percent mortality), chronic effects were observed in 42 percent of the experimental exposures (Larson & Purser, 2011). This was expressed as a reduction in the tissue covering of the coral skeletal material, likely a result of oxygen depletion of the tissues due to the degradation of organic material in the fine fraction [<63µm equivalent spherical diameter (ESD)] of drill cuttings. The generation of such effects of coral in the offshore gas fields may potentially lead to the proliferation of biofouling organisms on some corals – although, as mentioned above, there is a lack of information available of such effects on deepwater corals.

Effects to benthic and reef organisms such as those described above may be limited to burial by very fine sediments. In practice, this is probably unlikely to reach significant levels (up to millimetres), as very fine sediments are most easily dispersed by ambient currents. Inundation by the larger sediment sizes in drill cuttings discharges are considered to be a lower risk, due to the relatively low risk of oxygen depletion resulting from organic matter remineralisation (Larson and Purser, 2011). However, these may still have effects on benthic and reef organisms. The cumulative effects of repeated sediment inundation on *L. pertusa* were tested in experimental exposures and the species was shown to be resilient, although this may not be the case for other key stages of the life cycle (eg planktonic larvae).

Taking the above into consideration, the adopted thresholds for this assessment of effects on reef organisms are burial depths of 1mm for chronic non-lethal effects and 10mm for acute or lethal effects; ie an acute/chronic ratio of 10, and a no-effect threshold of <1mm. These are the same as those considered for sediment epifauna and infauna. Due to generally slow growth rates reported for deepwater reef organisms (Roark et al., 2009; CORIS, 2012), any effects are expected to endure for 10 to 100-year periods, or longer in the case of damage to some black coral (Antipatharian) species.

Benthos

Benthos within the deposition footprint of the discharged drill cuttings and drilling fluids will be exposed to the effects of burial (ie deposition >10mm) in a seafloor area approximating 0.008km^2 for each well. Here the EC_{20} threshold is interpreted as an acute (ie lethal) effect level, and therefore the effect is classed as being of high intensity and is likely to occur. The affected seabed area would be approximately 0.96km^2 (1). The impacted area remains within the defined onsite scale (see *Section 11.3*). Impact magnitude will be low and impact significance will be MINOR.

Reef Organisms

Reef structures and their associated biological communities in the Golfinho and Prosperidade gas fields, and in the Mamba Gas Field - if present - will be placed at risk of enduring acute effects of inundation from discharged drill cuttings and drilling fluids. The reefs at risk would be those within the >1mm deposition layer, as it is considered in a worst case, that any sub-lethal effects on corals may have indirect consequences. For example, the development of biofouling communities on affected corals may eventually cause the smothering and death of corals. Simulation modelling indicates that the respective risk area is approximately 0.93km^2 at each well location. However, from observations it is clear that reef structures in the Golfinho and Prosperidade gas fields are small, isolated structures (and this is likely to be similar of those in Mamba Gas Field if present), so the actual affected areas are predicted to be much smaller than the predicted deposition footprint.

The recovery of reef communities that may be affected would take appreciable time, due to generally slow growth rates. Therefore, acute impacts would extend to the long term. Given the extent of the full suite of production wells to be drilled in the offshore gas fields is 120, the spatial extent of this impact is predicted to be 112km^2. Actual reef structures at risk are estimated to be 10 percent of the total areas of the respective deposition footprints, ie 11km^2 (derived from CSA, 2012 and current meter site surveys in Area 1) and thus, the extent of the impact is local. It should be noted that both the high and low-relief structures largely comprise scattered rock and sediment, and do not

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(1) 0.008 km^2 per well and a total of 120 wells.

apparently support high densities of fauna (as detailed in *Chapter 7*). Therefore, the extent of the impact to reef organisms is largely reduced. The intensity of the impact could be high. The magnitude of the impact is considered to be medium and, given that the impact is likely to occur, the significance of the impact will be MODERATE.

The level of confidence in the predictions about the effects of physical inundation on marine organisms in the offshore gas fields is low to medium, as information about the biological communities on the seabed at these depths is currently inadequate, as is information about the recovery rates of these organisms from such disturbances.

11.4.2 Mitigation Measures

Benthos

The objective of the mitigation measure outlined below is to reduce as far as practically possible the extent of the deposition footprint on the seafloor of the discharged treated cuttings and residual muds to >1mm.

- Employ a subsurface discharge chute extending to approximately 10 to 15m depth for the overside disposal of treated drill cuttings and residual muds (1). This will reduce the size of the deposition footprint that is 1mm threshold is reduced.

Reef Organisms

The objective of the mitigation measures outlined below is to minimise the risk of generating acute effects on reef communities by avoiding discharging cuttings and drilling fluids in close proximity to high-relief reefs, and thereby to reduce the intensity of any impacts.

- Residual discharges of treated drill cuttings and residual muds should be restricted to distances of >500m from deepwater high-relief reefs as determined by ROV video surveys.

11.4.3 Residual Impacts

Benthos

The use of a subsurface discharge chute will promote the integrity of the initial density flow of the discharged cuttings, allowing deeper penetration before the onset of the lateral advection phase at the level of neutral buoyancy and helping to reduce the footprint of the impact, although it will still remain as onsite. The impact significance will remain as MINOR.

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(1) This will promote the integrity of the initial density flow of the discharged cuttings, allowing deeper penetration before the onset of the lateral advection phase at the level of neutral buoyancy.

Table 11.2 Impact of Physical Inundation by Treated Drill Cuttings and Residual Muds on Offshore Benthos and Deepwater Reef Organisms

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Long term	Long term
Extent	Onsite	Onsite
Intensity	High	High
Magnitude	**Low**	**Low**
Likelihood	**Likely**	**Likely**
Significance	**MINOR**	**MINOR**
	Operational Phase: N/A	

Reef Organisms

The discharge of cuttings and drilling fluids away from high-relief reef structures will reduce impact intensity and magnitude to medium and low respectively. The significance of the impact of physical inundation by drilling cuttings and residual muds on reef structures and associated organisms will be reduced to MINOR significance.

The level of confidence in the impacts to benthos and reef organisms is low to medium, as information about the biological communities on the seabed at these depths is currently inadequate, as is information about the recovery rates of these organisms from such disturbances.

Table 11.3 Impact of Physical Inundation by Treated Drill Cuttings and Residual Muds on Offshore Reef Organisms

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Long term	Long term
Extent	Local	Local
Intensity	High	Medium
Magnitude	**Medium**	**Low**
Likelihood	**Likely**	**Likely**
Significance	**MODERATE**	**MINOR**
	Operational Phase: N/A	

11.5 WATER QUALITY IMPACTS ON OFFSHORE MARINE ECOLOGY FROM DISCHARGED TREATED DRILL CUTTINGS AND RESIDUAL MUDS

11.5.1 Impact Assessment

Toxicity effects on benthos and organisms in the water column and potential contamination effects of high food value organisms eg shellfish and fish, through flesh tainting may be caused by the chemicals associated with discharged drilling cuttings containing residual muds. Three categories of drilling muds/fluids are to be used for drilling activities in the Golfinho, Prosperidade and Mamba gas fields: water-based muds (WBMs), used to drill the upper portions of a well; and SBMs or low toxicity oil-based muds (LTOBMs) to drill deeper portions.

Water-based Muds

WBMs are generally considered to be the least toxic of the drilling muds (Patin, 1999), although they do contain heavy metals in the barite component. Low-metal WBMs have been tested for solubility of the metals in sea water and the pore water of marine sediments by Crecelius et al. (2007, cited in Impacto Lda, 2008). Their laboratory tests indicated that mercury and other heavy metals are not released in significant quantities into sea water or pore water, and concluded that it is not likely that low-metal barite will cause environmental effects to organisms living in the water column. Further, experimental and field studies have shown that acute toxic effects of WBMs can be manifested only at high concentrations, and are only found within a few metres of the discharge point (Patin, 1999, cited in Impacto, 2008).

Due to the absence of a riser system during the drilling of the uppermost portions of a well, drill cuttings and the WBMs will be discharged directly to the seabed. This is standard industry practice and is largely accepted by environmental protection authorities globally, providing the concentrations of mercury and cadmium in the barite do not exceed 1mg/l and 3mg/l respectively. It is assumed that the barite used for drilling will comply with this specification; eg as per those of the United States Environmental Protection Agency (USEPA). Based on this, toxicity effects on marine organisms from discharged WBMs would be of a low intensity, restricted to the duration of the discharge during the initial approximately 15 percent of the period of well drilling (Impacto, 2008), and localised to the well site. Owing to the density of the mixture, any effect of increased turbidity on the water column above is unlikely.

Synthetic-based Muds

SBMs comprise synthetic components such as esters, paraffins and olefins, which are generally less toxic than oil-based muds (OBMs) due to reduced concentrations of aromatic compounds. Tests on SBMs have shown them to be practically non-toxic to marine organisms (Patin, 1999). SBM impacts on the water column when discharged with cuttings are generally considered to be negligible, due to their low solubility in sea water and the intermittent and transient discharge patterns adopted (OGP, 2003, cited in Impacto, 2008).

The SBMs expected to be used for production drilling are characterised by a polyaromatic hydrocarbon (PAH) content of less than 0.001 percent and a total aromatic content of less than 0.5 percent (OGP, 2003), as required by the USEPA, for example. The cuttings and muds abstracted are returned to the drilling rig where they are separated by shale shakers. The SBMs are recycled while the cuttings are discharged to sea after treatment to meet good international industry practice. A residual volume of SBM remains on the cuttings.

Due to low solubility, linked low toxicity effects, intermittent discharge and low residence time in the water column, it is likely that encounter rates with filter feeding pelagic fish will be low and therefore assimilation of tainting compounds, eg hydrocarbons, into fish flesh should be correspondingly low, if it occurs to any measurable extent at all.

Low Toxicity Oil-based Muds

LTOBMs are used for drilling activities in some parts of the world, such as the OSPAR Convention's maritime area; they are only in formulations designed for zero-discharge where all the used mud is either recycled (usually onshore) or re-injected with cuttings into the rocks below the seabed. It is assumed that any LTOBMs used for drilling in the offshore gas fields of Area 1, or the Mamba Gas Field of Area 4, will comply with Good International Industry Practise (GIIP) such as the UK Revised Offshore Chemical Notification Scheme in terms of OSPAR (see http://www.cefas.co.uk/ocns).

Accordingly, it is anticipated that the mud components will be of inherently low toxicity to marine organisms, and it is therefore highly unlikely that significant negative impacts will occur as a direct result of routine drilling activities by the Project.

Any impacts on marine organisms from the discharge of drill cuttings with residual fluids/muds adhered to these, are predicted to be of a low intensity, because of the low toxicities of the quantities and types of muds used/or input to the offshore environment. Any effects to benthos will be short term, as benthos recovery rates are within this time scale (ie months to years) (eg Newell et al., 1998) and recovery from effects in the water column will be faster (days for phytoplankton to months for zooplankton) (Parsons et al., 1977). Similar to hydrocarbons that may be discharged with synthetic based muds (described above), discharges of residual LTOBMs will be intermittent and as the hydrocarbon components are particle reactive (eg OGP, 2005) they should transit the water column rapidly with the sinking drill cuttings. Accordingly, although possibly of higher fish impact potential, the probability of generating tainting effects on filter feeding fish populations in the water column is low. Flesh tainting in the benthic environment should be limited to organisms foraging in the area of the drill cuttings deposition. These would be deposit feeders, eg some species of polychaete worms, molluscan nudibranchs etc., as opposed to fish that may form part of any fishery. Thus although tainting may possibly occur effects on fish flesh quality for human consumption are considered to be negligible.

Impacts from discharges are judged to be of low magnitude, and as impacts effects to benthos are likely to occur, impact significance will be MINOR.

The degree of confidence in the predictions about the impacts on marine organisms from toxic effects is medium, because information about biological communities on the seabed at these depths is limited.

11.5.2 *Mitigation Measures*

The objective of the mitigation measures outlined below is to reduce the intensity of effects on benthos by reducing levels of toxicity in the discharges.

- The drill rigs will be designed in accordance with GIIP to have an efficient solids control and mud recirculation system, including shakers, mud cleaners, dryers and centrifuges for the treatment of drill cuttings.
- WBMs and low toxicity additives should be used whenever possible (eg concentrations of mercury and cadmium in the barite should not exceed 1mg/l and 3mg/l respectively).
- SBMs and LTOBMs that are low in toxicity, biodegradable and do not bioaccumulate will be used (eg PAH content of less than 0.001 percent and a total aromatic content of less than 0. 5 percent).
- All chemicals used should conform with the revised Cefas Offshore Chemical Notification Scheme (1) and OSPAR's PLONOR (pose little of no risk) list of substances (2).
- Treated cuttings discharged into the sea will have a maximum oil concentration in accordance with GIIP.

11.5.3 *Residual Impact*

The use of low toxicity drilling fluid components and the adequate treatment of cuttings before discharge will reduce hydrocarbon concentrations and the intensity of any effects, as toxicity risks will be minimal. Impacts are evaluated to be of negligible magnitude and NEGLIGIBLE significance to marine organisms.

Table 11.4 Impact of Toxicity Effects on Water Column, Seabed and Offshore Marine Ecology from Discharged Treated Drill Cuttings and Residual Muds

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Short term	Short term
Extent	Onsite	Onsite
Intensity	Low	Negligible
Magnitude	**Low**	**Negligible**
Likelihood	**Likely**	**Unlikely**
Significance	**MINOR**	**NEGLIGIBLE**
	Operational Phase: N/A	

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(1) http://www.cefas.defra.gov.uk/industry-information/offshore-chemical-notification-scheme.aspx

(2) http://www.ospar.org

11.6 IMPACTS OF DISCHARGE OF HYDROTEST WATER ON OFFSHORE WATER QUALITY AND MARINE ECOLOGY

11.6.1 *Impact Assessment*

Prior to commissioning, the structural integrity of the subsea system is determined using a hydrostatic pressure test, in which all pipelines are filled with water, pressurised above the intended operating pressure and monitored for leaks or pressure loss over a specified time period. Additives such as oxygen scavengers and biocides are often added (1) to the water as a preventative measure to control the risk of potential corrosion and micro–organism growth in the pipes.

After a pressure test is completed, the pressure is released and the pipelines dewatered by pushing a 'pig' through the line, using pressurised air or gas. The hydrostatic test process, including filling, testing and depressurising, can range from a few days to a few weeks, depending on pipe sizes and lengths. The discharged water typically contains the contaminants and particulate matter present in the pipelines and the additives. Additives are customarily used at concentrations of 1,000ppm. The Project proposes to release the hydrotest water into the sea at the major gathering manifolds distributed around the natural gas fields. The estimated volume to be discharged over the testing cycle is 120,700m^3, which will be released at approximately 9,500 litres/minute through the 22-inch diameter pipes and at approximately 4,900 litres/minute from the 16-inch diameter pipes. This equates to a discharge velocity of approximately 0.65m/s and an overall discharge period of 11-12 days if discharged continuously. It is more likely, however, that discharges will be discontinuous as segments of the infrastructure are tested.

The main factors that determine the composition of discharged hydrotest water are the characteristics of the source water, anti-corrosion additives, any residues not removed during flushing, and reactions occurring within the pipe during testing, such as corrosion. Constituents in the hydrotest water are mainly due to mill scale breakdown (eg iron oxides and traces of manganese and copper) and unreacted additives and their reaction products (eg inorganic salts such as ammonium bisulphite) when oxygen scavengers are used. Previous studies have shown that constituent levels in the used hydrotest water are generally not toxic, but that treatment is often required specifically to lower turbidity (which can attain 4,000 Nephelometric Turbidity Units or NTUs) and to raise dissolved oxygen levels (can be reduced to <1mg/l) (CSIRO, 2005).

The hydrotest water discharged at the major gathering manifolds distributed in the offshore gas fields at depths of approximately 1,000 – 2,300m is estimated at 120,700m^3. It may contain inorganic sulphite salts, residual biocides, dyes and may be turbid. This will compromise bottom water quality

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(1) Trade products to be used include Pipetreat 2001, Aquahesive 5836 and Hydrosure Biocide Stick.

in the natural gas fields during commissioning ie the construction phase. It is predicted to occur as a number of events, ie short-term just before gas extraction starts. It will impact water quality at the onsite scale, but will have negligible or undetectable effects (negligible intensity) on marine ecology and/or marine ecological processes because of natural dilution processes (eg CSIRO, 2005). The magnitude of the impact to marine organisms is predicted to be negligible and, similarly, the impact significance is NEGLIGIBLE.

The degree of confidence in this assessment is medium, as there are no measurement data for the behaviour of discharged hydrotest water at the planned release depths – and such data would be extremely difficult to acquire. The final lengths of pipelines to be installed, and the constituents and quantities of additives to be used, are not yet known. The planned discharges would be a small fraction of the Desalination Plant discharges.

11.6.2 Mitigation Measures

The Project will consider the pollution prevention and control measures set out in the IFC EHS Guidelines for Offshore Oil and Gas Developments for the management of hydrotest waters. In accordance with these GIIP guidelines, the Project will prepare of a hydrotest disposal procedure that considers point of discharge, rate of discharge, chemical use and dispersion with the objective to maximise the dilution of the hydrotest water in the water column.

Hydrotest water shall be re-used/recycled in the process (ie to hydrotest the onshore facilities).

11.6.3 Residual Impact

A phased approach to the discharge of hydrotest water, with increased discharge pressure will ensure that the water quality effects of the discharges are restricted to close proximity of the release points in the offshore natural gas fields. The impact significance to marine organisms will remain as NEGLIGIBLE.

Table 11.5 Impact of Discharge of Hydrotest Water on Offshore Water Quality and Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Short term	Short term
Extent	Onsite	Onsite
Intensity	Negligible	Negligible
Magnitude	**Negligible**	**Negligible**
Likelihood	**Unlikely**	**Unlikely**
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**
	Operational Phase: N/A	

11.7 IMPACTS OF INCREASED NOISE, LIGHTING AND VESSEL MOVEMENTS ON OFFSHORE MARINE ECOLOGY

11.7.1 *Impact Assessment*

The additional vessels and helicopters employed either to establish the offshore systems (drilling, engineering work, security and services, etc) or to visit the LNG Facility or associated infrastructure during operations will, among other things, result in:

- increased quantities of ships' operational waste discharges to sea; and
- increased noise, lighting and vessel movements (the latter with the risk, however unlikely, of collisions with whales).

The direct or indirect discharge or disposal to sea of solid waste, liquids, gases and particulates is regulated through national and international law. Specifically applicable is the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), to which Mozambique is a signatory. Accordingly, it is assumed that all Project vessels will be MARPOL 73/78 compliant and that the law will be obeyed. Equipment will be used to ensure that no thresholds are exceeded to ensure no impacts of significance occur. Consequently, this aspect is not assessed further.

The potential impacts of vessel and helicopter noise, lighting and movement are not regulated to the same extent, and are assessed below.

Offshore vessels will be operational 24 hours per day during construction (for approximately 18 months). During operations, shipping levels offshore in the gas fields will be much lower. The noise emitted by vessels may affect the movements and behaviour of marine fauna. Noise from helicopters travelling between the LNG Facility and the offshore vessels may also disturb turtles, marine mammals and seabirds. In addition, lighting from the vessels may attract and disorient certain species, in particular migrating birds and some fish species, which may then be more easily preyed upon by other fish and by seabirds. There is an abundant whale fauna in the Offshore Project Area in the vicinity of the gas fields, and fast-moving vessels may collide with individual whales, causing serious injury and usually mortality.

The area of potential impacts on any marine fauna is localised to the vicinity of the vessels and is limited to the short-term duration of construction and commissioning. Excluding injuries to whales, even in severe cases of disturbance, only a chronic effect on a minute proportion of fish, squid, turtle and/or bird populations concerned may occur. The potential impact is therefore evaluated to be of NEGLIGIBLE significance. The effects of vessel collisions with or disturbance to whales may be more severe, due to their conservation importance. Accordingly, the extent of the impact of vessel collisions with whales can be considered international. The intensity and magnitude could be high at both individual whale and whale population level. However, as impacts are unlikely to occur, the associated impact is predicted to be of MODERATE significance.

The degree of confidence in this assessment is medium, because the behaviour of vessel crew members cannot be predicted.

11.7.2 Mitigation Measures

The objective of the mitigation measures outlined below is to reduce harmful interactions with marine organisms by reducing noise, lighting and vessel speed.

- Develop a Marine Mammal Observation Procedure (MMOP) that addresses, at least, the need for trained marine mammal observers (MMO's), record keeping, vessel movement, light, noise, avoidance strategies and helicopter traffic. Specific measures to be included are outlined below.
    - Reduce travelling speeds if whales, dolphins or turtles are encountered, to afford the animals the opportunity to move out of the way.
    - Trained MMOs will be present during drilling and construction works in the area of the subsea infrastructure to keep a watch for the presence of marine mammals and turtles. They will record sightings to assist research and to plan additional avoidance strategies.
    - If any species of marine mammals, particularly whales, are sighted near the path of a vessel, the vessel will gradually divert to avoid the marine mammal or slow down to idling speed, if this can be done safely.
    - Instruct helicopters to maintain a minimum height of 500m over bird foraging areas, surfacing cetaceans or groups of turtles, and prohibit circling or hovering over marine mammals (eg for casual viewing) unless essential for safety or emergency purposes.
    - Minimise non-essential lighting on vessels, and shield and/or reduce the number of lights shining directly onto the water as far as possible.
- Keep any disoriented but otherwise unharmed seabirds found on vessels at night in dark containers and release them during daylight. Any ringed/banded birds found on vessels should be reported to the appropriate ringing/banding scheme.
- Prohibit all crew members from killing or causing injury to marine fauna (any crew members found to have deliberately killed or caused injury to marine fauna shall be dismissed immediately and removed to shore).

- Undertake environmental awareness training of all crew members, which includes training on the conservation status of cetaceans and turtles.

11.7.3 *Residual Impact*

The mitigation measures will help to reduce the effects on individual organisms and could reduce the probability of any impact occurring. The impact significance is of NEGLIGIBLE significance for fish, squid and/or bird populations. The specific whale mitigation measures outlined above will ensure that vessel collisions with whales are avoided, and thus impact significance is reduced to NEGLIGIBLE.

Table 11.6 Impact of Noise, Lighting and Vessel Movements on Offshore Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Short term (whales long term)	Short term
Extent	Onsite	Onsite
Intensity	Low (whales high)	Low
Magnitude	**Negligible (whales high)**	**Negligible**
Likelihood	**Likely (whales unlikely)**	**Unlikely**
Significance	**NEGLIGIBLE (whales MODERATE)**	**NEGLIGIBLE**
	Operational Phase	
Duration	Short term (whales long term)	Short term
Extent	Onsite	Onsite
Intensity	Low (whales high)	Low
Magnitude	**Negligible (whales high)**	**Negligible**
Likelihood	**Likely (whales unlikely)**	**Unlikely**
Significance	**NEGLIGIBLE (whales MODERATE)**	**NEGLIGIBLE**

11.8 *IMPACTS OF STRUCTURES MODIFYING HABITATS ON THE OFFSHORE SEABED*

11.8.1 *Impact Assessment*

The impact assessed in this section is of the changes to the character of the seabed by adding hard substrate (subsea infrastructure), which will result in changes to benthos community structure, ie it may crush some organisms and provide an altered habitat for colonisation by others.

The Subsea Production System of Pipeline End Termination Structures (PLETs), trees, manifolds, pipelines, umbilicals and carbon steel mudmat supports will be installed over an area of 350km^2 on the seabed. Items will be lowered through more than a kilometre of water onto the seabed by DP vessels on the sea surface, with the assistance of ROVs. Final locations and layout will be defined as reservoir engineering work continues. The subsea system will be operated via electro-hydraulic controls from onshore within the LNG Facility.

Cementing of the casing in the upper sections of the wells may result in a release of excess cement from the top of the wells into the marine environment. Such spilled cement would settle on the seafloor and may smother benthic marine life in the vicinity of the wells, although volumes are likely to be very small.

The placement of the approximately 1,100,000m^2 (1.1km^2) of hard metallic structures and interconnecting pipelines on the seabed and deposition of top-hole cuttings from approximately 120 wells (120 x 0.0003142km^2/well = 0.4km^2) will permanently modify the seabed environment. The extent of the impact would be onsite and at a low intensity, because disturbances would be relatively isolated and located in an extensive undisturbed area of more than 1,000km^2 within Area 1 and Area 4. However, a minor proportion of this area may host deepwater reef structures with corals, tunicates and other sessile fauna. As most of the area appears to be homogeneous sand/muddy sand/mud, these low to high-relief reef structures will probably be vital habitats, particularly for deepwater fish. Damage to these features could have important effects on the natural biodiversity of the region. Any impacts to reef structures would be of a similar scale and duration to those identified above. However, the impacts will be of high intensity and magnitude, and there will be definite changes to the benthos community, and the associated impact is predicted to be of MODERATE significance.

The degree of confidence in this assessment is high, based on previous experience of introducing new infrastructure into the marine environment.

11.8.2 Mitigation Measures

The objective of the mitigation measures outlined below is to reduce the intensity of effects and to cause as little disruption as possible to sea life and shipping.

- Survey all candidate pipeline corridors by ROV and realign corridors if they intercept deepwater reef structures during construction.
- Survey all locations for subsurface infrastructure by ROV and avoid to the extent practical areas of high and low-relief deepwater reef structures.
- No mitigation measures are deemed necessary for the balance of the operations, although sound operational procedures would reduce the risk of unnecessary disturbance by the placement and movement of infrastructure on the seabed, or by dropped objects or accidental cement spills.

11.8.3 Residual Impact

During the construction phase, the residual impact would be confined to the addition of hard structures to the apparently vast area of unconsolidated sediments in the offshore gas fields. Impacts will be exerted at the onsite scale, and be permanent but of low intensity. Both the impact magnitude and the significance rating would be NEGLIGIBLE during the construction phase.

Table 11.7 Impact of Structures Modifying Habitats on the Offshore Seabed

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Permanent	Permanent
Extent	Onsite	Onsite
Intensity	High	Low
Magnitude	**High**	**Negligible**
Likelihood	**Definite**	**Definite**
Significance	**MODERATE**	**NEGLIGIBLE**
	Operational Phase: N/A	

11.9 IMPACTS OF DREDGING-INDUCED TURBIDITY ON NEAR SHORE MARINE ENVIRONMENT (SEAGRASS, CORAL REEF AND ASSOCIATED BIOLOGICAL COMMUNITIES)

11.9.1 Impact Assessment

Capital dredging (1) will occur as part of the construction of the Pioneer Dock, the MPD, LNG Export Jetty, Dolphins and ship-turning circles, and gas import pipeline corridor. The estimated dredge volume associated with capital dredging is up to 11.9Mm^3. It is envisioned that up to two Cutter Suction (CS) Dredgers will be utilised, and may operate concurrently in the gas import pipeline corridor and the berth and shipping channel development areas. During the operational phase, there may be a requirement for maintenance dredging (2). Predicted maintenance dredge volumes will be small, because of the low sediment transport rates in Palma Bay (Moffatt & Nichol, 2011).

Dredge material from capital dredging is to be discharged to an onshore reclaim for the development of the MPD (up to approximately 7.0 Mm^3), with the balance (up to approximately 4.1 Mm^3) being disposed to sea (see *Chapter 4*). Dredge material from maintenance dredging will be disposed to sea. The identified area for offshore disposal is at the head of the Afungi Canyon. In both cases, the dredge material is to be pumped as a slurry from the dredgers to the placement area through pipelines. The on-land reclaim will dewater via a discharge to sea at the seaward end of the MPD. The reclaim will be designed such that suspended sediment concentrations in the discharge will be limited to approximately 100mg/l. The marine discharge will be through a pipeline lying on the seabed aligned down the canyon. The discharge depths will be between 50m and 70m. *Figure 11.7* shows a schematic view of the respective dredging and dredge material placement operations in Palma Bay.

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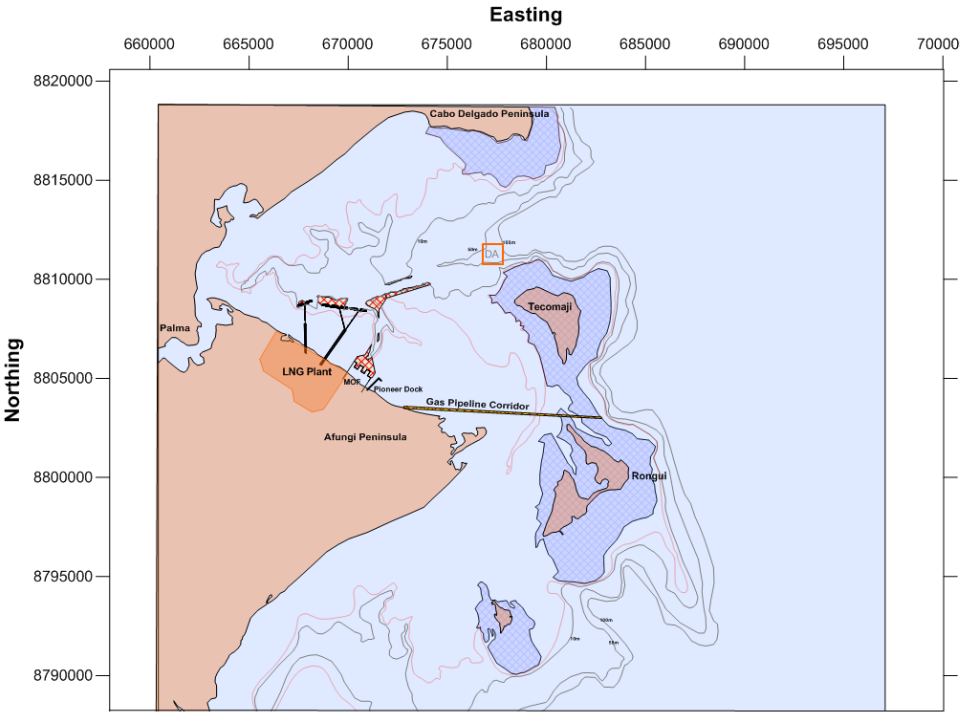
(1) Capital dredging is the initial dredging to create a deeper harbour basin and a deeper navigation channel, and facilitate the construction of near shore infrastructure.

(2) Maintenance dredging involves the removal of generally naturally occurring siltation from channel beds to maintain the design depth of navigation channels and ports.

Figure 11.7 ***Proposed Dredge Areas for the Berths, Shipping Channels and Gas Import Pipeline Corridor and Dredge Spoil Disposal Site***



Source: Lwandle, 2012.

Key: Red hatching: shipping channels and gas import pipeline corridor. Red square: dredge spoil disposal site.

Dredging can result in increased turbidity in the following ways:

- by the action of the CS Dredger head in the dredge areas;
- at the dewatering point from the onshore reclaim; and
- at the offshore dredge placement area.

The latter is expected to be minimal and constrained to water depths >50m, as the discharged slurry will be denser than sea water and will tend to flow down the Afungi Canyon into deeper water.

Elevated turbidity affects underwater light distributions and increases particulate loads in the water column. A decrease in underwater light can affect primary producers including phytoplankton, macrophytic algae (seaweeds), seagrass and Zooxanthellae symbionts in corals through reducing light energy available for photosynthesis. Increased particulate loads in the water column typically interfere with filter-feeding organisms, bivalve molluscs such as clams and barnacles (crustacea), corals, some fish species, and fish in general through clogging of their gills. Near shore fish species are, however, resilient to relatively high suspended sediment concentrations – fish eggs can survive exposures to 100mg/l total suspended sediment (TSS), fish larvae 500mg/l and even sensitive species of adult fish 1,000mg/l over 24-hour periods (EMBECOM, 2004).

Important biotopes within Palma Bay are seagrass meadows and coral communities, as these comprise the majority of the biodiversity within the system and support artisanal fishing to a large extent. Seagrass beds extend to water depths of 6 to 8m, while corals extend to water depths of at least 35m. Underwater light level thresholds for seagrass and corals are broadly similar and lie in the range of 3 to 30 percent of surface irradiance (SI) for seagrass (Erftemeijer & Lewis, 2006) and 1 to 35 percent for corals (PIANC, 2010) (1).

A threshold of 25 percent SI is considered protective of both seagrass species present in Palma Bay, including *Halophila, Syringodium* and *Thalassia* (Erftemeijer & Lewis, 2006), and corals, especially massive, branched and plate species (PIANC, 2010). Findings from underwater light field monitoring and modelling in Australia has allowed the formulation of the percent SI/TSS relationships shown in *Figure 11.8*, and indicates that the equivalent TSS threshold concentration for 25 percent SI underwater light thresholds is 10mg/l, within the depth range of seagrass and most corals (Environmetrics Australia, 2007).

In terms of particulate loads, TSS concentration thresholds protective of most benthic organisms where no effects are observed are <20mg/l, exposures of 20-80mg/l for 72-hour periods may generate sub-lethal (chronic) effects, and exposures >80mg/l may generate lethal (acute) effects (EMBECOM, 2004). In contrast, effect concentrations given in PIANC (2010) indicate that corals may be sensitive to TSS concentrations below the no-effect level shown above. Therefore, the 10mg/l threshold derived for light attenuation is applied here, specifically for the highly diverse fringing coral reef around the Palma Bay islands.

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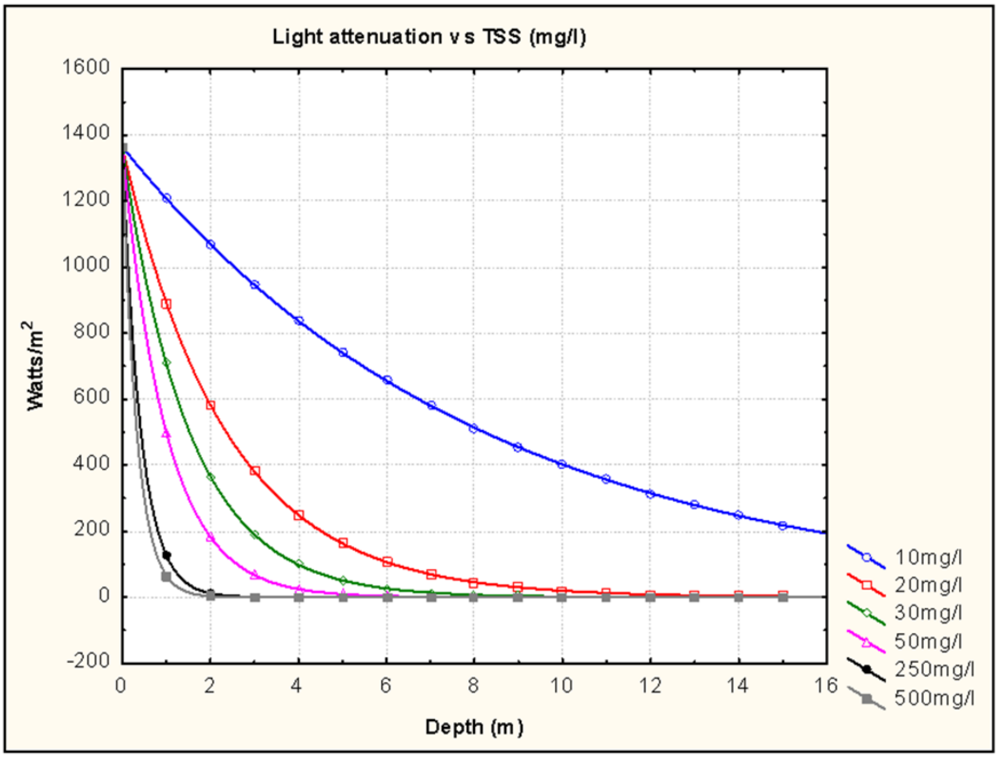
(1) With the exception of branching corals which is 60 percent.

Figure 11.8 Light Attenuation versus TSS

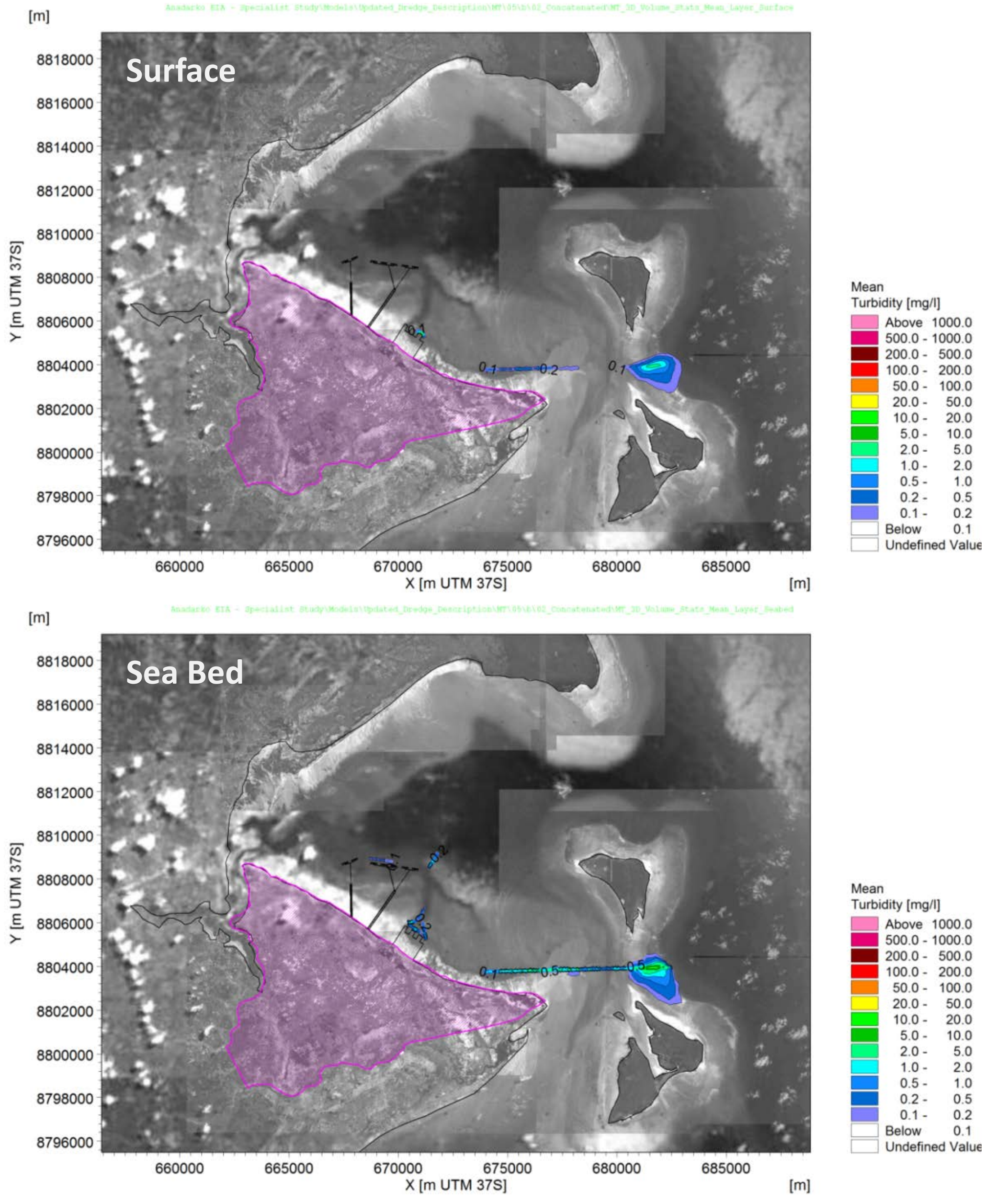


Source: Lwandle, 2012 compiled from data in Environmetrics, Australia (2007).

Turbidity plume distributions for the various turbidity sources (dredging of the offshore pipeline channel, deepening of the access channel for the MPD and Pioneer Jetty, dredging of the MPD turning basin and dewatering of filling operations for the LNG Export Jetty) were modelled for a 12-month period by PRDW (2012). A total of eight dredging scenarios were modelled, ranging from a single CS Dredger working either the pipeline corridor or the berth and shipping channel areas, to two dredgers working in tandem. The worst-case scenario presented by PRDW (2012) is that of two dredgers working in tandem, with concurrent material discharges to the land reclaim and the offshore placement areas. The statistical mean distribution and the predicted maximum concentrations in the modelled surface and bottom layers for this worst-case scenario are illustrated in *Figure 11.9* and *Figure 11.10*.

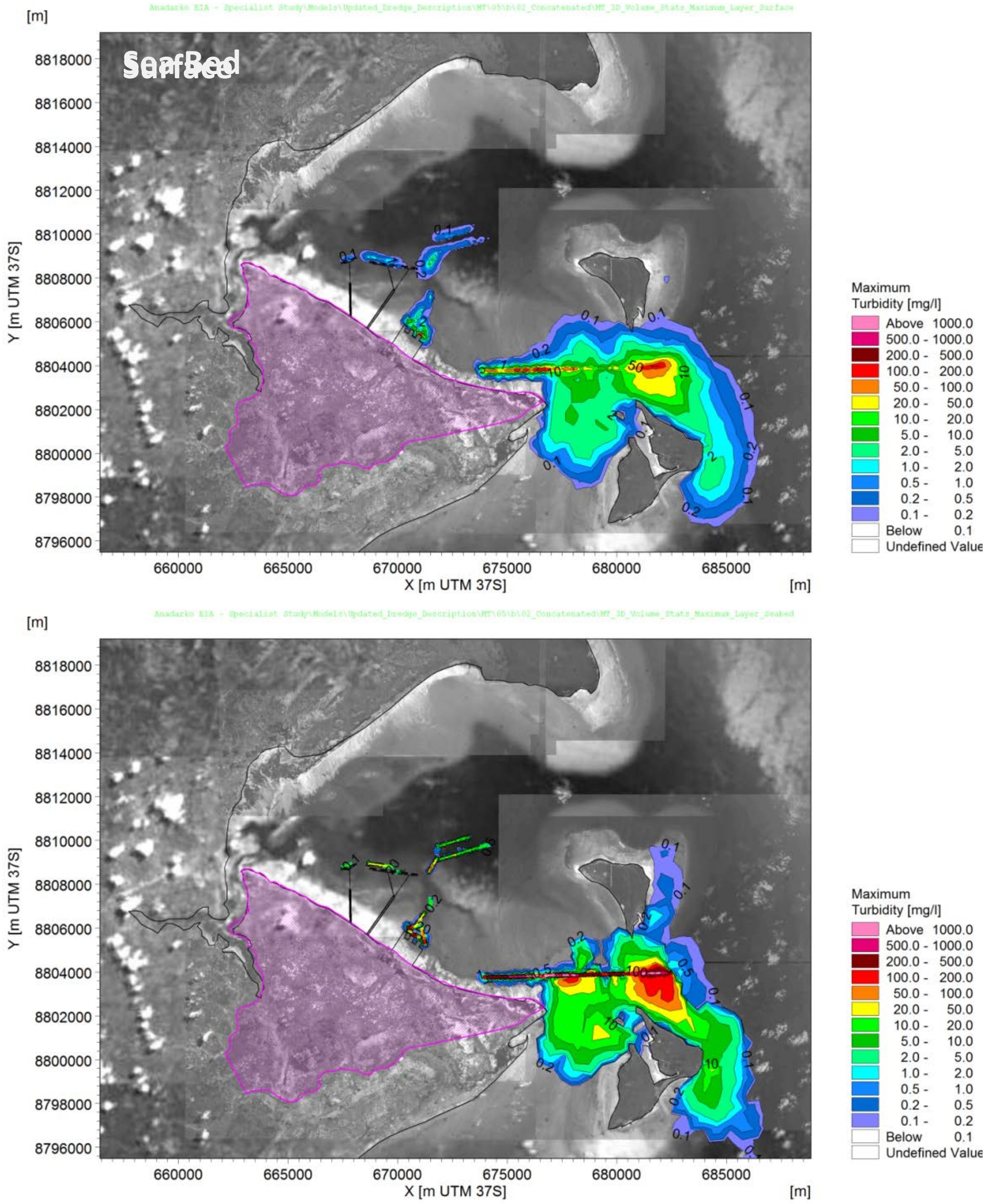
It is apparent that, in terms of maximum levels, turbidity at the seafloor is widely disbursed and attains very high levels adjacent to the dredged pipeline corridor. Turbidity flows from the reclaim, and those associated with dredging in the berths and shipping channel areas, although reaching similar intensities, are far more spatially constrained. As expected, the turbidity signal is considerably reduced at the sea surface, while the predicted mean TSS distributions are limited to the areas of direct disturbance (ie the dredge footprint).

Figure 11.9 Predicted Distributions of the Mean Concentrations of TSS for Surface (Top) and Seabed (Bottom) over a One-year Dredging Period



Source: PRDW, 2012.

Figure 11.10 Predicted Distributions of the Maximum Concentrations of TSS for Surface (Top) and Seabed (Bottom) over a One-year Dredging Period



Source: PRDW, 2012.

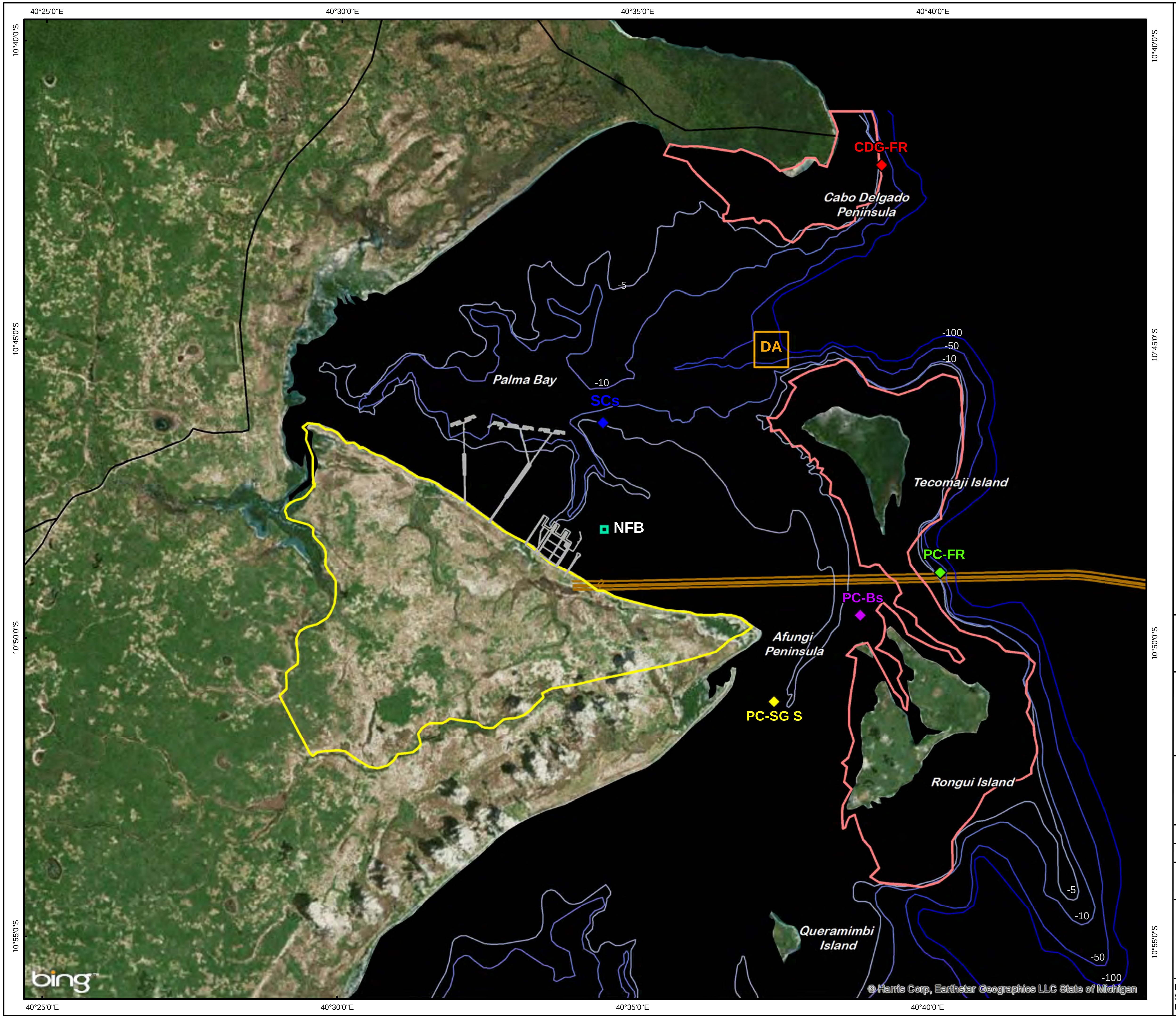
The modelled mean distributions show relatively low effects of turbidity at the sea surface and the seabed across all of the dredging areas and at the land reclaim discharge site. Suspended sediment concentrations in the surface layer do not exceed 10mg/l at any location, while at the seabed there is a minor exceedance at the offshore extent of the pipeline corridor (see *Figure 11.9*). In contrast, the modelled maximum concentrations (see *Figure 11.10*) show a larger area, where the suspended sediment concentrations exceed 10mg/l. At the surface, this occurs in the immediate vicinity of the land reclaim discharge and along much of the pipeline corridor. At the seabed, 10mg/l is exceeded in all of the dredge areas. However, at the berth and navigation channel locations, this is largely restricted to the dredging footprint (1). Along the pipeline corridor high concentrations occur more extensively, with extremely high suspended sediment concentrations (>1,000mg/l) predicted for the corridor itself and large areas adjacent to the corridor where concentrations may exceed 10mg/l.

Therefore, according to the predicted maximum suspended sediment concentrations distribution, appreciable proportions of the Palma Bay seagrass meadows and coral areas in the vicinity of the pipeline corridor may be at risk from elevated turbidity. Deleterious effects on these communities are exerted by the absolute concentrations and durations of exposure to elevated levels. Specifically to gain insight into the latter, aspect time series estimates of total suspended sediment concentrations over the modelling period were extracted from the model output for five sites in Palma Bay (*Figure 11.11*).

Comparison of their respective locations with the predicted suspended sediment concentrations in *Figure 11.11* and *Figure 11.12* show that only three of the sites (Palma Bay seagrass, pipeline corridor seagrass and pipeline corridor coral bommies) would be exposed to appreciable suspended sediment concentrations.

Figure 11.12 shows the temporal exposure patterns for these sites. The time series plots indicate that sites in the berth and shipping channel area may be exposed to elevated turbidity levels for periods extending to six months or more. However, the predicted mean and maximum turbidity levels in this location are low (mean values) and, even though the maximum values are high, elevated turbidities are spatially restricted (*Figure 11.9* and *Figure 11.10*). In the pipeline corridor, periods of high turbidity levels are predicted to be short in duration (*Figure 11.12*) so even though the spatial extent of the maximum turbidity levels is large, actual exposures within this are predicted to be episodic and of short duration (days).

(1) The dredging footprint is the area of the seafloor impacted directly by the action of the dredging operation.



TITLE:
Figure 11.11:
Locations for which Time Series of TSS Concentrations were extracted from the Turbidity Modelling

CLIENT:

Anadarko Moçambique Área 1, Lda

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DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000

DRAWING: Turbidity Modelling.mxd	REV: A

ERM
Great Westerford Building
240 Main Road
Rondebosch, 7725
Cape Town, SOUTH AFRICA
Tel: +27 21 681 5400
Fax +27 21 686 073

Impacto
Projectos e Estudos Ambientais
ERM

Projection: UTM Zone 37 S Datum: WGS84 Source: Bing Maps ©2010 Microsoft Corporation. Lwandle Technologies, 2012. Inset Map: Esri Data & Maps	SIZE: A3

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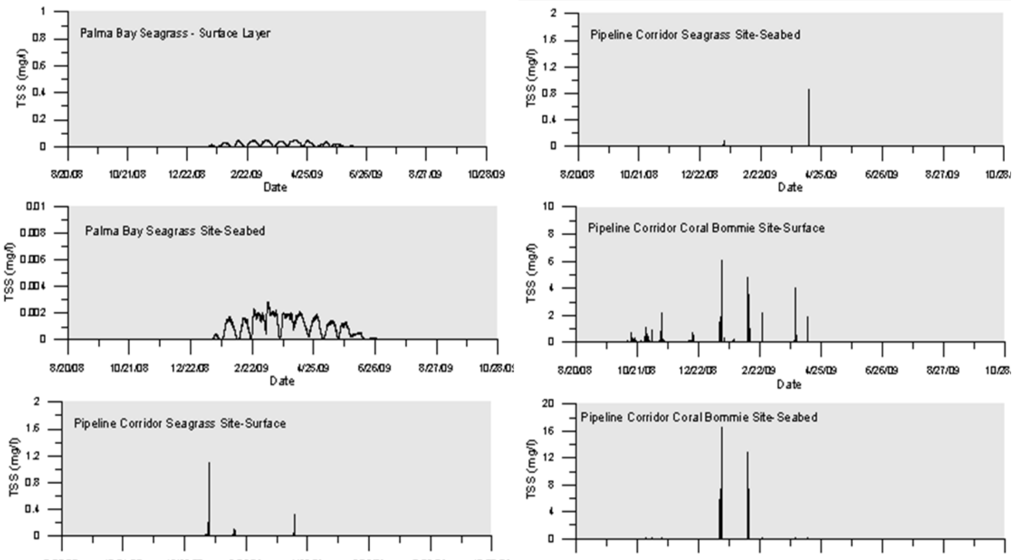
Figure 11.12 Modelled Time Series Distributions of TSS Concentrations in the Surface and Seabed Layers over One-year Dredging Period at Selected Sites in Palma Bay



Source: PRDW, 2012 and Lwandle, 2012.

Turbidity increases in Palma Bay due to capital dredging and, to a far lesser extent, maintenance dredging for the marine facilities may potentially reduce seagrass growth, deleteriously affect coral and coral reefs and compromise associated biological communities. Turbidity generated while dredging the pipeline corridor will likely be of high intensity, as suspended sediment concentrations are predicted to exceed the defined response threshold of 10mg/l and may affect the high biodiversity fringing coral reefs and coral bommies around Tecomaji and Rongui islands and seagrass beds in the area.

Seagrass recovery periods are predicted to be relatively rapid (months to years, according to Erftemeijer & Lewis, 2006). However, coral communities may take longer (years), particularly if massive corals are severely affected. Recovery time scales of decades may apply for lethal effects (Richmond, 2002).

These effects of increased turbidity on corals, seagrasses and associated communities within Palma Bay from capital dredging during the construction phase are predicted to extend to the local scale, and may be long term in duration for corals but short term for seagrasses. Impacts are likely to occur, and the impact intensity is expected to be medium. Impact magnitude during the construction phase is expected to be medium, and therefore effects on marine ecology are likely to be of MODERATE significance.

During the operational phase, maintenance dredging impacts will be restricted to onsite and will be of much lower intensity and magnitude (medium and low respectively). TSS is still likely to exceed the given thresholds, and therefore affect marine ecology, over the long term. Impact significance is thus predicted to be of MINOR significance.

The degree of confidence in this assessment is medium, as the predictions are based on simulation modelling and limited field data for dredge plume behaviour in these environments.

11.9.2 Mitigation Measures

The objective of the mitigation proposed below is to reduce the intensity and extent of the impacts from the initial capital and maintenance dredging effect in Palma Bay (ie the TSS concentrations within turbidity plumes and the areas affected).

Mitigation measures should be focused on the control of turbidity outside of the dredging footprint which is defined as the zone of high impact (ZHI), in which acute (lethal) levels of disturbance will occur, but within the boundary of the zone of moderate impact (ZOMI) (in accordance with the dredging guidelines for Western Australia (WA EPA, 2011)). Within the ZOMI, chronic (sub-lethal) effects may occur but eventual recovery of the affected communities is expected. The bounds of the ZOMI are set at 500m distance from the outer boundaries the dredge areas (ie the ZHI). An example is shown in *Figure 11.8* below where the marine facilities construction area has been considered as an amalgamated whole, ie the dredge areas are not treated individually with separate ZOMIs.

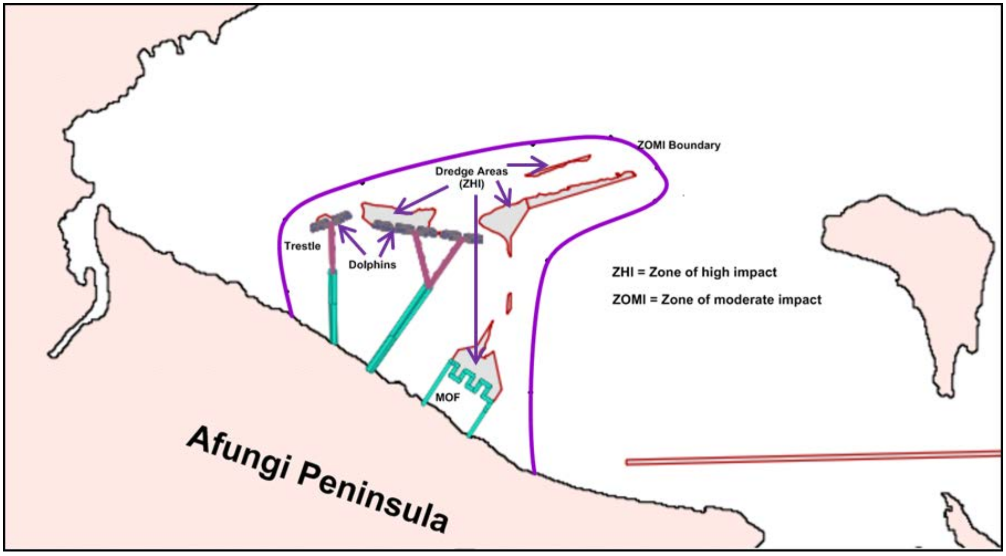
Within the ZOMI turbidity levels should not exceed 100mg/l TSS. In addition, turbidity levels in the ZMOI can exceed 10mg/l depending on the time durations during which exceedances occur. The 100mg/l and 10mg/l TSS values are broadly representative of the 1% and 25% surface light intensity (see *Figure 11.8*). Outside of the ZOMI, turbidity should be less than 10 mg/l and no more than 5mg/l above ambient levels. In this zone of influence turbidity plumes may occur, but should be transient and not generate adverse effects on coral or seagrass communities. Within the ZOMI the critical subsurface light thresholds at 5m depths are set at 25%, 10% and 1% of the surface light intensity, or their approximate TSS equivalents of 10mg/l, 30mg/l and 100mg/l.

During dredging, including reclaim management where applicable, as part of an adaptive management approach dredge plume intensity monitoring should be conducted on a near real time basis at locations within the outer boundary of the ZOMI. In a layout such as the example in *Box 11.1* suitable monitoring locations would be near to the outer eastern, northern and western boundaries where water depths exceed 5m. Note that a reference station will also be needed nearby but outside of the ZOMI to track ambient turbidity levels during dredging.

An example of the required responses to exceedances of the specified thresholds is outlined below:

- Turbidity levels are >10mg/l TSS equivalent – No action as this is expected for the ZOMI;
- turbidity levels approach 30mg/l TSS equivalent – If the threshold is exceeded for 40 days in a rolling 60 day period then determine causes and moderate dredging rate or move dredging activity to reduce turbidity levels. If the threshold is exceeded 50 days in a rolling 60 day period (ie 10 exceedances where exceedance 1 = 40 day period, 2 = 41 days, 3 = 42 days etc) stop dredging until dredging is shown not to be the cause at an acceptable level of certainty. In this case resume dredging. If dredging is the cause then modify dredging practice to reduce turbidity generation; and
- turbidity levels are >100mg/l TSS equivalent – If this threshold is exceeded for 40 days in a rolling 60 day period modify dredging practice to allow turbidity levels to dissipate. Monitor turbidity levels created during dredging activities to ensure turbidity levels of 10mg/l are not exceeded more than 500m from the dredging sites.

Box 11.1 ***Schematic Representation of the Marine Facilities Construction and Dredge areas in Palma Bay with a Demarcated Zone of Moderate Impact Outer Boundary (purple)***



Source: Lwandle, 2013. Approximately to scale.

11.9.3 Residual Impact

During the construction phase, impacts from capital dredging are restricted to within the ZOMI. Nested within this zone is the ZHI where the duration of effects will be permanent and of high intensity as the affected areas will be physically modified by the excavations associated with dredging. The limitation of lethal effects is restricted to within this zone and an expected medium term (<7 years) recovery of coral and seagrass communities within the larger zone of moderate impact will reduce the impact significance rating to MINOR.

Increased turbidity associated with maintenance dredging during the operational phase will be constrained in terms of discharge TSS concentrations and underwater light levels. The residual impact from this activity will be of a low intensity with a low magnitude. The effect of increased turbidity in the water quality on corals, seagrasses and associated biological communities is rated to be of MINOR significance.

The degree of confidence in this assessment is medium, as the predictions are based on simulation modelling and limited field data for dredge plume behaviour in these environments.

Table 11.8 *Impacts of Dredging-induced Turbidity on Near Shore Marine Environment (Palma Bay Seagrass, Coral Reef and Associated Biological Communities)*

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase (Capital Dredging)	
Duration	Long term	Long term
Extent	Local	Onsite
Intensity	Medium	Medium
Magnitude	Medium	**Low**
Likelihood	**Likely**	**Likely**
Significance	**MODERATE**	**MINOR**
	Operational Phase(Maintenance Dredging)	
Duration	Long term	Long term
Extent	Onsite	Onsite
Intensity	Medium	Low
Magnitude	**Low**	**Low**
Likelihood	**Likely**	**Likely**
Significance	**MINOR**	**MINOR**

11.10 IMPACTS OF TURBIDITY GENERATED FROM THE CUTTING OF A TRENCH THROUGH CORAL REEF AND ROCK ON NEAR SHORE MARINE ECOLOGY

11.10.1 *Impact Assessment*

The offshore sections of the gas import pipeline corridor pass over coral basement rock and associated reef. Different options to bring the pipelines into the bay are being considered and the final configuration and method will be finalised during the FEED. However, as described in *Chapters 4* and *5,* the cutting of a trench through the coral reef and rock is proposed as part of the Project's base case. The trench to house the pipelines is created with a CS Dredger with the cutter head physically grinding through the reef structure. There is uncertainty on how the coral rock in the gas import pipeline dredging will respond to this. Some international experience, for example PIANC (2010), indicates that this process may generate very fine particles and a large and persistent turbidity plume, as shown in *Figure 11.13*. Local (Saldanha Bay, South Africa) experience with CS dredging in areas with calcrete shows that the turbidity plumes may become highly concentrated and dense, and cover extensive areas of the seabed.

Figure 11.13 Example of a Turbidity Plume Generated by a Cutter Suction Dredger Dredging Coral Structures

Source: PIANC, 2010.

In a coral reef environment, these dense plumes may be trapped in gullies and crevices and exert deleterious effects on reef structure and associated organisms. If this occurs, the effects will be at a local scale, although long term to permanent and of high intensity. The magnitude of the impact would be high and, as effects on marine ecology will be likely, the impact significance will be MAJOR.

The level of confidence in this assessment is low, as data on rock properties or CS dredging in northern Mozambique near shore environments are not available.

11.10.2 Mitigation Measures

The objective of the mitigation proposed is to avoid creating the intense turbidity plumes that have been observed to be generated by CS Dredgers operating in coral environments.

Prior to the commencement of dredging coral reef and coral basement formations between Tecomaji and Rongui islands, undertake a pilot test of the selected dredge technique to check whether the action of the chosen dredging technique, eg CS Dredger head, on the coral basement and corals in the pipeline corridor is likely to generate plumes of very fine material.

- If such plumes occur dredging contractor is to implement measures to constrain the dispersion of such fines from the dredge area during the dredging operations. This can be done by controlling dredging rate or modifying the dredging schedules or other techniques that the dredging contractor may have at his disposal.

- If pilot test shows plumes of material occur, monitor turbidity levels created during dredging activities as per the procedures described in *Section 11.9.2.*

These measures will be included in separate plans developed for construction and maintenance dredging that will be developed by the Project.

11.10.3 Residual Impact

Impacts are restricted to the onsite scale where the duration of effects will be permanent and of high intensity due to physical modifications associated with dredging. Lethal effects will be limited to the ZHI within the onsite scale. Because medium term (<7 years) recovery of coral and seagrass communities is expected within the larger ZOMI, a residual impact significance rating of MINOR is anticipated for the ZOMI.

Table 11.9 Impacts of Turbidity Generated from the Cutting of a Trench through Coral Reef and Rock on Near Shore Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Long term to permanent	Long term
Extent	Local	Onsite
Intensity	High	Medium
Magnitude	**High**	**Low**
Likelihood	**Likely**	**Likely**
Significance	**MAJOR**	**MINOR**

11.11 IMPACT OF INUNDATION OF SEABED AND BENTHOS BY DEPOSITING FINE SEDIMENTS FROM DREDGING ACTIVITIES ON NEAR SHORE MARINE ECOLOGY

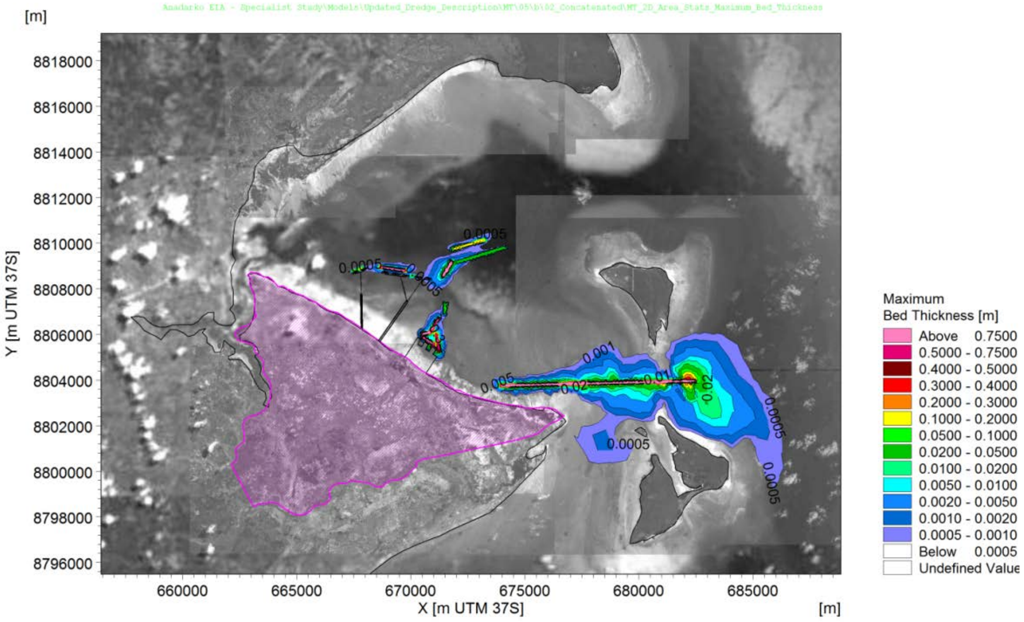
11.11.1 Impact Assessment

The sediments suspended by dredging in Palma Bay and those reintroduced to the marine environments by dewatering outflows from reclaims will sink out of the water column and deposit on the seafloor. The location of the deposition depends on the balance between bottom shear stress and resuspension requirements in terms of turbulence of the suspended sediments. Depositing sediments can inundate seagrass beds and bury corals or cover them with a veneer of sediment. This can cause coral mortality, especially in small-sized colonies, susceptible species and size classes, while the latter can generate sub-lethal effects such as reduced photosynthetic efficiency, changes in polyp activity and mucus production to remove sediment (PIANC, 2010). Effects on seagrass can include reduced photosynthesis due to the covering of leaf chloroplasts. The sub-lethal and lethal effects of burial vary with the period of burial.

Sedimentation thresholds for coral range from 10 to 300mg/cm²/day (PIANC, 2010). Following Doorn-Groen (2007), a conservative threshold of absolute burial depth of 7mm is used in this assessment. Data in Erftemeijer and Lewis (2006) indicate that *Thallasia*, *Thalassodendron*, *Halophila*, *Syringodium* and *Enhalus* (all genera recorded in Palma Bay) can withstand burial depths of 4cm, which is accepted as the conservative threshold for seagrasses in Palma Bay.

The distribution of sedimentation associated with the dredging activities required for the marine facilities and gas import pipeline corridor has been modelled by PRDW (2012). Predicted maximum deposition thicknesses for the 12-month modelled period (2008/2009) are shown in *Figure 11.14***.** It is estimated that the respective thresholds will be exceeded in the dredging locations along the pipeline corridor; however, the exceeding of thresholds will be limited to these areas. Seagrass and coral adjacent to the corridor may be affected by increased levels of sedimentation.

Figure 11.14 Predicted Maximum Inundation Depth Distributions from Dredging in Palma Bay over a 12-month Period



Source: PRDW, 2012.

The deposition of fine sediments generated by capital dredging in Palma Bay causes a high intensity impact (sub-lethal and lethal effects) at the local scale in seagrass beds and coral reefs, with linked negative effects on associated organisms. The duration of the impact will be medium term as seagrass recovery periods are predicted to be relatively rapid – months for fast-growing small species such as *Halophila* and *Halodule,* to years for slower-growing larger forms such as *Thalassia* (Erftemeijer & Lewis, 2006). Coral communities may require years to decades (ie long term) to recover from lethal effects, particularly if massive corals are severely affected. The magnitude of the impact to both seagrass and coral is high during construction and low during operations. As the impact is likely to occur during the construction phase, impact significance will be MAJOR.

Similarly, during the operational phase, the deposition of fine sediments generated by maintenance dredging will affect seagrass beds and coral reefs, but at the onsite scale and at a medium intensity. The impact significance is rated as MINOR.

The level of confidence in this assessment is medium, as the predictions are based on simulation modelling. However, there are no local available data on the effects of such impacts.

11.11.2 Mitigation Measures

The objective of mitigation is to reduce the intensity and extent of the effect, ie the amount of sediment depositing in the affected area. However, the resuspension of sediment at the CS Dredger head is an unavoidable effect. Selection of dredging equipment by the contractor will be appropriate to the depths and material types to be dredged and to minimise the creation of plumes. Dredging induced inundation and the biological responses to this specifically in corals must be determined.

11.11.3 Residual Impact

In the absence of practical mitigation measures, the significance of residual impacts will remain unchanged from those identified for the pre-mitigation scenario, both during construction and operations. To minimise the residual impact where possible, the Project is currently investigating the optimal solution during FEED.

Table 11.10 Impacts of Inundation of Seabed and Benthos by Depositing Fine Sediments from Dredging Activities on Near Shore Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase (Capital Dredging)	
Duration	Medium term (seagrass) to long term (coral)	Medium term (seagrass) to long term (coral)
Extent	Local	Local
Intensity	High	High
Magnitude	**High**	**High**
Likelihood	**Likely**	**Likely**
Significance	**MAJOR**	**MAJOR**
	Operational Phase (Maintenance Dredging)	
Duration	Medium term	Medium term
Extent	Onsite	Onsite
Intensity	Medium	Medium
Magnitude	**Low**	**Low**
Likelihood	**Likely**	**Likely**
Significance	**MINOR**	**MINOR**

11.12 IMPACT OF DREDGING REMOBILISED CONTAMINANTS ON NEAR SHORE MARINE ECOLOGY

11.12.1 *Impact Assessment*

Heavy metals and synthetic organic compounds held in the dredge area sediments may be remobilised to the water column through the agitation and turbulent mixing that dredging brings. The origins of such contaminants are, by definition, linked to human activity, mainly industries, agriculture and human settlements. None of these are developed to the extent where they may significantly influence water and sediment quality in the catchments of Palma Bay. This is evident by the sediment quality data listed in *Chapter 7* (eg Al, As, Ba, Be, etc) and the generally low dissolved inorganic nutrient concentrations measured in the bay and adjoining estuaries on Afungi Peninsula. The measured trace metal concentrations are well within the environmental quality targets listed for the West Indian Ocean Land Based (WIOLAB) region (UNEP & CSIR, 2009), and are also compliant with the sediment quality thresholds for the sea disposal of dredged sediments set by the 1996 Protocol to the London (Dumping) Convention (1). Accordingly, risks of pollution effects from remobilised contaminants due to dredging activities in Palma Bay are considered to be low.

Potential impacts to marine organisms will be short term during the construction phase and long term during the operational phase, as maintenance dredging will continue for the life of the Project. Due to the low concentrations of heavy metals and synthetic organic compounds within the target dredge area sediments of Palma Bay, the likelihood of harmful impacts to marine organisms is considered to be unlikely during capital and maintenance dredging (construction and operational phases respectively). The impact intensity is predicted to be negligible during both phases and, consequently, the significance of the impact is rated as NEGLIGIBLE.

The degree of confidence in the assessment is high, due to the current lack of development around Palma Bay and its catchment and the current sediment heavy metal concentrations for Palma Bay sediments.

11.12.2 *Mitigation Measures*

Given the apparent absence or very low presence of heavy metals and synthetic organic compounds within the native dredge area sediments, the significance of the potential impact is considered to be NEGLIGIBLE and mitigation is considered unnecessary.

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(1) http://www.imo.org/ourwork/environment/pollutionprevention/pages/1996-protocol-to-the-convention-on-the-prevention-of-marine-pollution-by-dumping-of-wastes-and-other-matter,-1972.aspx

Table 11.11 Impact of Dredging Remobilised Contaminants on Near Shore Marine Ecology

	Without Mitigation	Residual Impact (with Mitigation)
	Construction Phase	
Duration	Short term	Short term
Extent	Local	Local
Intensity	Negligible	Negligible
Magnitude	**Negligible**	**Negligible**
Likelihood	**Unlikely**	**Unlikely**
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**
	Operational Phase (Maintenance Dredging)	
Duration	Long term	Long term
Extent	Onsite	Onsite
Intensity	Negligible	Negligible
Magnitude	**Negligible**	**Negligible**
Likelihood	**Unlikely**	**Unlikely**
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**

11.12.3 *Residual Impact*

The impact significance to marine organisms from remobilised heavy metals and synthetic organic compounds into the water column as a result of dredging will remain NEGLIGIBLE during the construction and operational phases.

11.13 *IMPACT OF DREDGING-INDUCED SEABED MODIFICATION ON NEAR SHORE MARINE ECOLOGY*

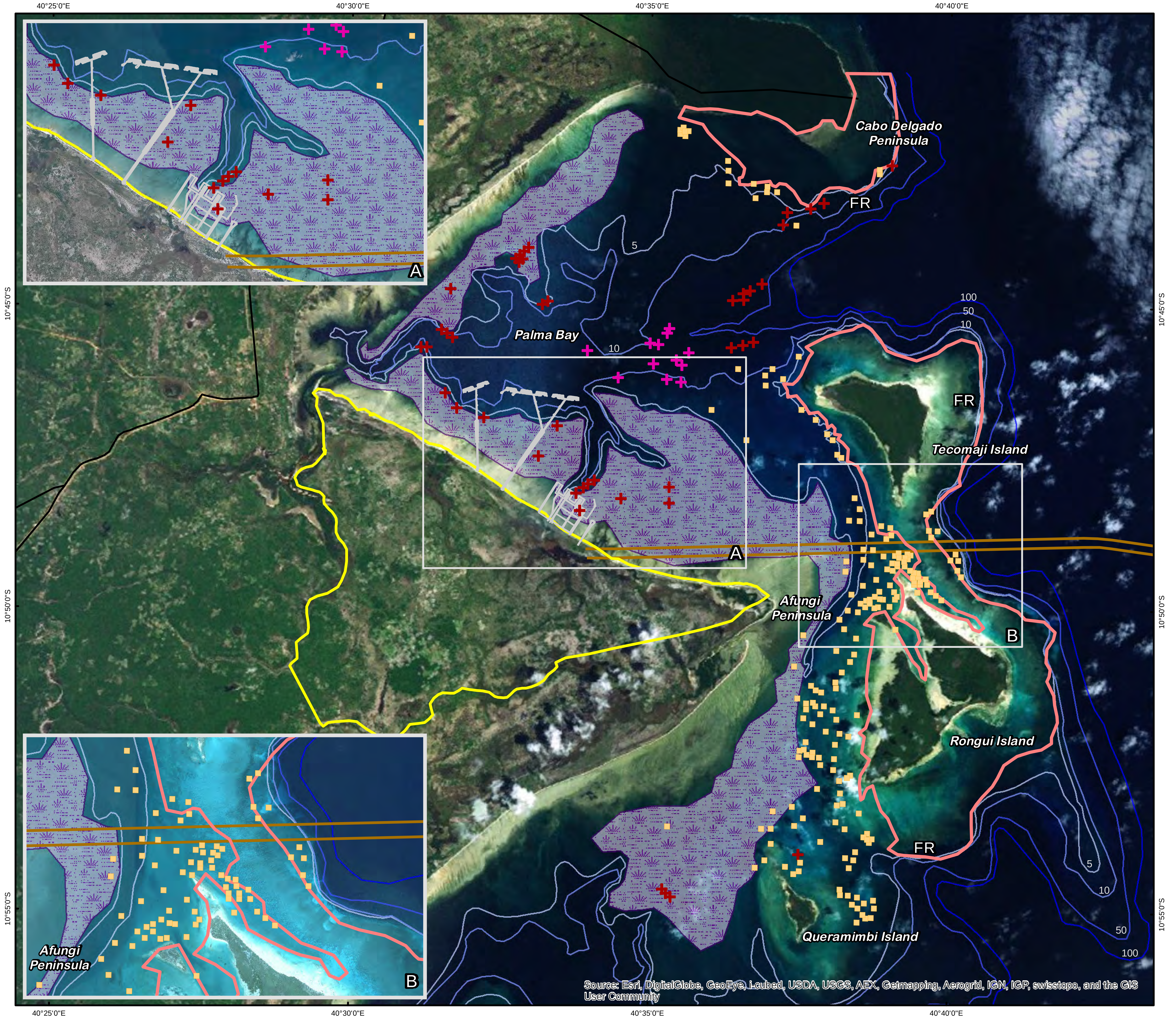
11.13.1 *Impact Assessment*

Dredging for the approach channel to the Near Shore infrastructure and/or turning circles will remove or damage coral bommies on the western side of the channel (see *Figure 11.15*), affect approximately 16ha of seagrass meadows on the edge of the existing channels into the bay (see *Figure 11.15*), and alter the bathymetry of the southern portion of Palma Bay. In addition, dredging of the pipeline corridor will traverse approximately 7.6km of seagrass meadows, the coral bommie field west of Tecomaji and Rongui islands, the fringing coral reef between these islands and the deeper offshore soft coral community (see *Figure 11.15*). These modifications will have important consequences, including the loss of an estimated 152ha of seagrass area and habitats for coral biotopes. They will also directly and indirectly affect associated fish and invertebrate communities.

Impacts to the seagrass meadows and coral bommie field west of Tecomaji and Rongui islands will be permanent, as dredging of the approach channel and turning circle will continue during operations (ie maintenance dredging). Impacts to the fringing coral reef between these islands will be long term, as the corals are expected to begin recolonisation after the pipelines are laid.

Due to seabed modification by capital dredging activities in Palma Bay, seagrass and coral biotopes within the proposed dredge locations will definitely be damaged or destroyed (see *Figure 11.15*). The impact will be exerted at the local scale, and will have high intensity effects. The magnitude of the impact will be high, given the high biodiversity value of the damaged biotopes. Impact significance is expected to be MAJOR.

The degree of confidence in the assessment is high as damage will occur, habitats will be modified and recovery is uncertain.



TITLE:

Figure 11.15: Location of Pipeline Corridor, Dredging Areas and Sensitive Marine Biotopes

CLIENT:

Anadarko Moçambique Área 1, Lda

eni

DATE: Oct 2013	CHECKED: IE	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 110 000

DRAWING:
Location of Pipeline Corridor, Dredging Areas.mxd

REV:
A

ERM
Great Westerford Building
240 Main Road
Rondebosch, 7725
Cape Town, SOUTH AFRICA
Tel: +27 21 681 5400
Fax +27 21 686 073

Impacto Projectos e Estudos Ambientais

ERM

Projection: UTM Zone 37 S Datum: WGS84
Source: Bing Maps ©2010 Microsoft Corporation.
Lwandle Technologies, 2012. Inset Map: Esri Data

SIZE:
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11.13.2 *Mitigation Measures*

Seabed modification for the navigation channels and turning circles cannot be mitigated without compromising navigation safety for Project vessels using the Near Shore infrastructure. There is, however, some scope for mitigating impacts in the pipeline corridor. The objective of the mitigation measures outlined below is to reduce the extent of the effect of dredging-induced seabed modifications on marine biotopes and organisms, and to enhance at least partial recovery of some of the affected biological communities.

Mitigation measures to minimise impacts in the pipeline corridor include the following.

- Align the pipeline trench as far south as possible in the proposed corridor between Tecomaji and Rongui islands, within the constraints of engineering and construction feasibility. This will significantly limit the damage to the fringing reef between the islands of Tecomaji and Rongui, where the extent of fringing reef is much reduced in the area closer to the northern tip of Rongui Island.

- Reduce the width of the pipeline corridor to as low as practically possible, targeting approximately 100m, and employ a trenching procedure that avoids the requirement for a CS dredge (see *Section 11.9.2*).

- Enhance the recolonisation and regrowth of seagrass by providing suitable substrate such as shell grit for the attachment of germinating seagrass, or similar procedures where practical.

- Align the pipeline to avoid as much impact to the coral bommies to the extent practical. It is assumed that any coral bommies impacted would die or be seriously disturbed by the pipeline trenching process. Where bommies are impacted place either concrete blocks or quarried stone in 'clumps' in the disturbed area. The blocks or rocks will provide substrates for colonisation by corals and allow some level of recovery of the associated communities (*Figure 11.16*) (1).

- Follow a similar approach as described above adjacent to the trenched area that goes through the fringing reef – and allow natural recolonisation to proceed (2) .

- Involve a coral taxonomist in detailed surveys along the gas import pipeline corridor prior to construction to determine the presence of *Acropora aspera* (3) and other coral species classified as endangered or rare in the IUCN Red List. Note that this is precautionary as, due to its role in

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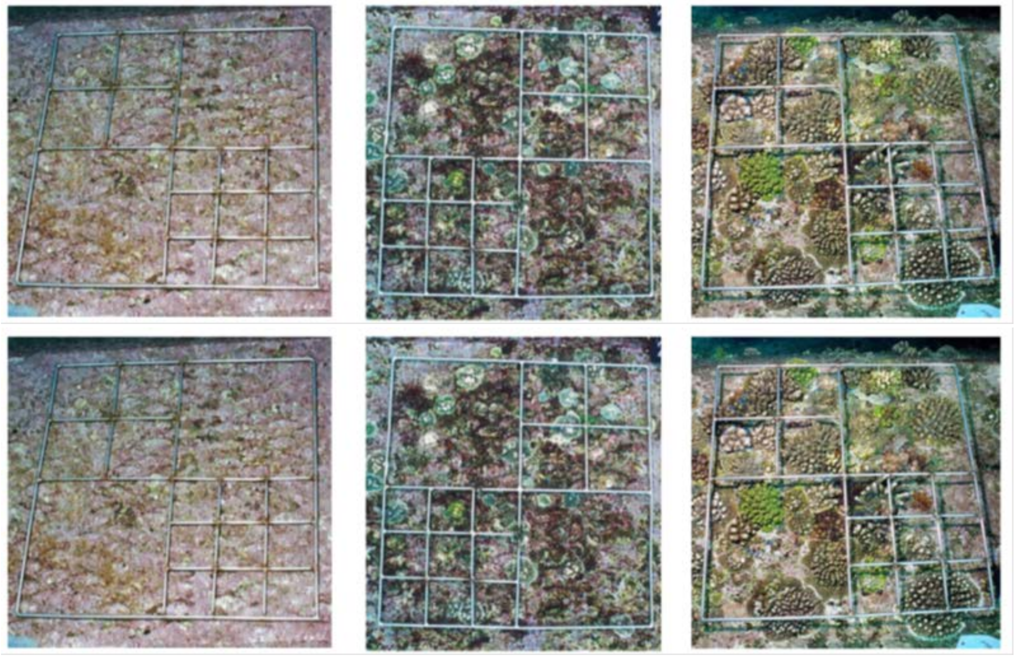
(1) This may be augmented by transplanting bommies but it is considered to be impractical to achieve this with a large number and size of the bommies that will be at risk.

(2) As opposed to attempting transplanting due to anticipated stronger wave and current forces.

(3) Categorised as 'Vulnerable' according to the IUCN Red List.

coral dispersal through the Western Indian Ocean, endemism within the East African Coral Coast ecoregion is low (Obura, 2012) and coral species are likely to be distributed throughout the ecoregion (Spalding *et al.*, 2007). As far is practical a representative collection of individual coral colonies present in the pipeline corridor, including IUCN Red List species, will be translocated away from area directly affected by construction.

Figure 11.16 Example of Coral Recolonisation of Concrete Eco-blocks at 2m Depth



Left: At installation. Centre: + two years. Right: + four years.

Source: PIANC, 2010.

11.13.3 Residual Impact

Seagrass and coral biotopes will be damaged or destroyed due to seabed modification by dredging in Palma Bay, but by implementing the above mitigation measures, the area of seagrass damaged will decrease from approximately 152ha to 46ha and the recolonisation rates will be enhanced, reducing the duration of the negative effect. The effects on coral bommies will be reduced by the narrower pipeline trench, and recolonisation enhanced by providing settlement substrate for coral larvae. The realignment of the pipeline trench closer to Rongui Island will significantly reduce the effects on the fringing reef between Tecomaji and Rongui islands.

Taking into consideration the above mitigation, impact duration is likely to be medium as the impact will extend beyond the construction phase (up to seven years). Impacts are likely to be local, and of medium intensity and low magnitude. As some seagrass and coral biotopes will be damaged or lost, the impact is definite. This, coupled with a low magnitude, will result in an impact of MINOR significance during the construction phase.

The degree of confidence for the assessment of the residual impact is medium, as there is no direct experience indicating that seagrass recolonisation will be successful in Palma Bay. Similarly, there are no monitoring data for East African coral recolonisation processes or recovery rates, so success rates are uncertain.

Table 11.12 Impact of Dredging Induced Seabed Modification on Near Shore Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Long term (fringing reef) to permanent	Medium term
Extent	Local	Local
Intensity	High	Medium
Magnitude	**High**	**Low**
Likelihood	**Definite**	**Definite**
Significance	**MAJOR**	**MINOR**
	Operational Phase: N/A	

11.14 IMPACT OF DISPOSAL OF DREDGE MATERIAL AT THE HEAD OF CANYON ON NEAR SHORE MARINE ECOLOGY

11.14.1 Impact Assessment

Dredge material will be pumped as a slurry to the head of the Afungi Canyon, where it will be discharged at the seafloor. The discharge pipe will be regularly relocated in the dredge material placement area to avoid accumulations of sediment, which may slump and generate possibly erosive turbidity flows down the continental slope located close offshore of the placement area. The designated material placement area is approximately 1km^2 in extent and is shown in *Figure 11.11*. The discharged sediment will smother and possibly result in the death of benthos within the placement area. The estimated 4.1Mm^3 of sediment from capital dredging and potential volumes of maintenance (to be determined during FEED) dredge material to be discharged will not be instantaneously dumped within the site, but will be progressively added over time.

The impact will be generated at the local scale, is likely to occur, and will be of high intensity in the dredge material placement area. Sediment texture in the dredge material and dredge material placement areas are dominated by sand, with low proportions of gravel-sized sediments (mostly coral and shell debris) and mud, similar to the material to be dredged. The dredge material will therefore be suitable for recolonisation, which will be both from in-migration and larval settlement. Recovery periods are predicted to be one to three years (Newell et al., 1998) and the duration of impact is therefore predicted to be short term. The impact intensity is expected to be high and the impact magnitude is considered to be medium. The impact significance rating is MODERATE.

The level of confidence in this assessment is medium, as although there are abundant surveys showing the limited effects of dredge material disposal in open coast dynamic environments, there are no local data to support this.

11.14.2 Mitigation Measures

The objective of the mitigation measures outlined below is to limit the impact to within the boundaries of the dredge material placement area and to ensure that biological communities adjacent to the designated dredge placement area are not exposed to smothering effects.

- Monitor benthos communities adjacent to the placement area pre- and post-dredging including taxonomic, abundance and biomass distributions.

- Record the locations of dredge material disposal and avoid dredge material disposal beyond the designated dredge placement area. To be developed as part of the maintenance dredging plan.

11.14.3 Residual Impacts

Benthos within the dredge placement area are likely to suffer lethal effects from dredge material but will recover within one to three years after the cessation of dredging. Through the implementation of the above mitigation, these effects will be limited to the dredge placement area itself and the intensity and magnitude of the impact are reduced to medium and low respectively. The impact significance will reduce to MINOR.

Table 11.13 Impact of Disposal of Dredge Material at the Head of Canyon on Near Shore Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Short term	Short term
Extent	Local	Local
Intensity	High	Medium
Magnitude	**Medium**	**Low**
Likelihood	**Likely**	**Likely**
Significance	**MODERATE**	**MINOR**
	Operational Phase: N/A	

11.15 IMPACT OF MODIFICATION TO SAND BEACHES GENERATED BY THE PRESENCE OF NEAR SHORE PROJECT INFRASTRUCTURE ON MARINE COMMUNITIES

11.15.1 Impact Assessment

The Near Shore Project infrastructure marine facilities required for the proposed Project comprise a temporary Pioneer Dock, a MPD for heavy and/or large items, berths for loading LNG Carriers with product and LNG Export Jetties and trestles/causeways connecting these to land. Navigation marker buoys and possibly leading lights will also need to be established. The creation and actual presence of these facilities will generate impacts on the physical coastal processes, the biological communities and marine ecological processes.

The extensive intertidal sand beaches on the northern shore of Afungi Peninsula are varied and biologically productive, as they support seagrass meadows and an array of benthic organisms (see *Chapter 7*). These beaches provide resources to artisanal fishers and forage for coastal birds, eg crab plovers, plovers, sandpipers, egrets, herons, hamerkop, etc. Autotrophs on the beaches include blue-green algae, algal mats, benthic diatoms and seagrass. The beaches receive particulate organic matter (POM) from the offshore seagrass beds, as indicated by seagrass wrack on the tide lines, and small estuaries that drain Afungi Peninsula. The overall POM supply sustains filter feeders such as bloodworm and mussels, and the predator community, including whelks, birds, etc.

The installation of the causeways and port structures will interrupt and cut off the longshore transport of sediment, resulting in changes in sedimentation patterns as well as longshore exchanges of POM across the intertidal area. It is expected that a change in sedimentation patterns will include increased accretion on the up-drift side of the infrastructure and the erosion of beaches on the down-drift side (PRDW, 2012). It will change the beach structure through the creation of pocket beaches, possibly affecting biogeochemical attributes and the intertidal and shallow subtidal biological community, in particular a loss of species dependent on high POM exchange. This effect may extend higher up the food chain to foraging birds using the intertidal area.

The installation of causeways and port structures across the intertidal beaches and extending into the shallow subtidal zone will permanently modify the beach structure and dependent ecological processes at a high intensity through the interruption of longshore sea water and POM exchanges. Impacts will begin during the construction phase and extend throughout the lifetime of the Project. This effect will be generated at an onsite scale, and impacts will be of a medium magnitude. The likelihood of the impact occurring is definite. The significance of the impact is predicted to be MODERATE for both construction and operational phases.

The degree of confidence for the assessment is medium, as although the broad properties and characteristics of the affected beaches are known, the dependencies on sea water and POM fluxes are not fully understood. The presence of H_2S in lower intertidal sediments implies surplus organic matter supply; therefore, the intertidal beach macrofauna, at least, may not be heavily influenced by these changes.

11.15.2 Mitigation Measures

The objective of the mitigation measures below is to ensure that some longshore sediment and water exchange is maintained to prevent the isolation of the pocket beaches and facilitate POM supply, reducing the intensity of the impact. Mitigation measures include:

- placement of bridging/culverts within the causeways to ensure some water/particulate matter exchanges; and

- development of an active shoreline management and monitoring programme that includes:

    - a beach monitoring programme; and
    - use of land-based construction equipment to move sand from the areas of accretion to areas where erosion is evident.

11.15.3 Residual Impact

Longshore exchanges of sediment, sea water and POM are partially reduced by the change in design to the causeway structures, allowing a modified intertidal and shallow subtidal beach biological community to exist and sustain the dependent ecological processes. This will reduce the intensity of the impact to medium during both the construction and operational phases. Impact magnitude of the residual effect will be low and, given that the changes to the beach structure will definitely occur, the impact significance is expected to be MINOR. In addition, the suggested mitigation measures will help to reduce the erosion of beaches on the down-drift side of the Near Shore Project infrastructure.

Table 11.14 Impact of Modification to Afungi Peninsula Sand Beaches by Installation of Causeways and Port Structures on Marine Communities

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Permanent	Permanent
Extent	Onsite	Onsite
Intensity	High	Medium
Magnitude	**Medium**	**Low**
Likelihood	**Definite**	**Definite**
Significance	**MODERATE**	**MINOR**
	Operational Phase	
Duration	Permanent	Permanent
Extent	Onsite	Onsite
Intensity	High	Medium
Magnitude	**Medium**	**Low**
Likelihood	**Definite**	**Definite**
Significance	**MODERATE**	**MINOR**

11.16 IMPACT OF CONSTRUCTION OF ARTIFICIAL HARD STRUCTURES ON NEAR SHORE MARINE ECOLOGY

11.16.1 *Impact Assessment*

The LNG Export Jetties and various port structures will introduce hard structures into what is predominantly a sediment environment. The presence of this infrastructure will result in a loss of parts of the productive sand beach and subtidal zones along the northern coast of Afungi Peninsula. The presence of the introduced infrastructure will allow the establishment of hard substrate communities, macroalgae, mussels, oysters, barnacles, crabs, etc in the lower intertidal zone, and corals, sponges and associated organisms in the subtidal zone. The colonised structures will add to the habitat and associated biodiversity in the region but will potentially diminish some of its productivity, as areas of seagrass meadow will be reduced.

The introduction of new structures to the region may also facilitate colonisation by alien and potentially invasive species released into Palma Bay, by increasing the abundance of 'virgin' hard substrate material not native to the area (the impact of potential aliens or invasives is assessed in *Section 11.18*).

The impacts to the marine biotopes and associated communities within the Palma Bay will be similar for the construction and operational phases. The establishment of hard structures will potentially diminish productivity and change the biological communities in the bay at an onsite scale. The impact intensity will be medium, in that the altered environment will continue to function, but in a modified way. The impact is definite and will be long term to permanent. Impacts for both the construction and operational phases are considered to be of MODERATE significance.

The degree of confidence in this assessment is medium, as there are no monitoring data for East African coral colonisation processes or recovery rates, so success rates are uncertain.

11.16.2 *Mitigation Measures*

The objective of the mitigation measures outlined below are to (i) enhance biodiversity in at least the subtidal areas affected ; and (ii) to manage potential water quality impacts from corroding hard structures.

- Ensure that the protection employed for the footwall is suitable for colonisation by corals, sponges and associated organisms. This can be concrete, so-called eco-blocks (*Figure 11.16*), or large quarried stone, for example.

- Monitor and hard structures regularly for signs of excessive corrosion, undertake maintenance where required.

11.16.3 *Residual Impact*

The extent of seagrass areas lost will remain the same. However, with the introduced mitigation measures outlined above, the intensity is reduced to low to medium during both the construction and operational phases. Biodiversity in the affected areas is likely to increase and the resultant magnitude of the impact is reduced to low. Consequently, the residual impact significance is expected to be MINOR.

Table 11.15 Impact of Construction of Artificial Hard Structures on Near Shore Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Permanent	Permanent
Extent	Onsite	Onsite
Intensity	Medium	Low to Medium
Magnitude	**Medium**	**Low**
Likelihood	**Definite**	**Definite**
Significance	**MODERATE**	**MINOR**
	Operational Phase	
Duration	Permanent	Permanent
Extent	Onsite	Onsite
Intensity	Medium	Low to Medium
Magnitude	**Medium**	**Low**
Likelihood	**Definite**	**Definite**
Significance	**MODERATE**	**MINOR**

11.17 IMPACT OF PROJECT-GENERATED NOISE ON MARINE ORGANISMS IN THE NEAR SHORE

11.17.1 *Impact Assessment*

The major sources of noise in Palma Bay created by the Project are expected to be construction pile-driving and noise associated with shipping operations and dredging. Ship movements in the bay will introduce low-level noise pollution in the intensity range of 50-90dB re 1µPa @1m (1) (2). These noise levels approximate known thresholds of effects on marine organisms [53-85dB re 1µPa @1m (LGL, 2010)] and are therefore not assessed any further, as minimal effects can be predicted.

CS Dredgers produce broadband noise between 70Hz and 1kHz continuously at sound source levels of 160-180dB re 1 µPa @ 1m. Dredging occurs in shallow water, and reflection and absorption of sound energy occurs. Further, irregular seafloor features such as coral outcrops create sound shadows that

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(1) Available at http://www.dosits.org/science/soundsinthesea/commonsounds/

(2) The source level of a specific sound source is often quoted as the (theoretical) sound level that would be measured at a distance of 1m from the source. It is standard to give source levels for underwater sound sources in units of dB re1µPa @1m.

complicate the calculation of safety radii as may be attempted from sound attenuation rates in deeper water. Predictions of safety radii for fish from sound distribution measurements in a North Sea application indicate that the Permanent Threshold Shift (PTS) would be limited to within 13m of a dredger, whereas Temporary Threshold Shift (TTS) could occur within 260m. If the sound thresholds for fish injury advocated by Popper et al. (2006) are applied, no effects are predicted, as the peak sound source level is less than the injury threshold. The effects of noise associated with dredging activities are thus not further assessed.

Percussion pile-driving will generate noise underwater with peak energy distributed in the 125 to 2,500Hz frequency (Elmer, 2007). Depending on pile diameters, the corresponding broadband sound peak to peak exposure levels range from 185 -198dB re 1µPa @1m at 750m distance (Matushek and Betke, 2009).

The organisms at risk from pile-driving noise levels in Palma Bay are marine mammals (whales and dolphins) and fish. Invertebrates do not have air bladders and so are considered to be relatively impervious to underwater sound at these levels. The threshold peak impulse sound pressure for direct physical trauma in marine mammals and fish is generally considered to be 200dB (McCauley, 1994; Richardson et al., 1995) with the United States of America Marine Fisheries Service setting a conservative limit of 180dB re 1µPa rms (US NMFS, 2000) for cetaceans.

Underwater sound produced by piling operations can cause hearing impairment in whales and dolphins, and/or alter their behaviours. Hearing impairment can be either temporary or permanent, depending on the intensity and duration of exposure (IWC, 2004). Temporary impairment can be caused by exposure to narrowband sound for relatively short (hours) periods of time at received levels of 134-173 dB re 1 µPascal rms (1) when this is 80 to 90dB above the species-specific threshold. As stated, these thresholds vary between species, but a conservative estimate that should include most baleen whales (eg humpback) and dolphins is an increase of 40-80dB (IWC, 2004). Behavioural modification may be generated at 120dB and above (Southall et al., 2007). However, there is some evidence for habituation if a sound source is semi-continuous (eg pile-driving), with humpback, minke, gray and fin whales showing this behavioural trait (NRC, 2003).

Fish mortality appears to require very high sound intensity levels. Hastings (1990, in Turnpenny & Nedwell, 1994) found that lethal thresholds for fish began at 229dB re 1 µPa rms and transient stunning was reported at 192 to 198 dB received, but that captive fish usually recovered after 30 minutes. Turnpenny and Nedwell (1994) noted that such transient stunning

(1) Broadband sound intensity data (dB re 1 µPa @ 1 m) are generally reported as peak to peak (p-p), zero to peak (0-p), root mean squared (rms) and/or sound exposure level (SEL). Safety radii are currently specified in rms units (US NMFS, 2000). The following approximate conversions apply for the same sound measured at the same location: 160 dB re 1 µPa @ 1 mrms = 170-1720-p, 176-178p-p and 145-150 dB re 1 Pa2.sSEL (from LGL, 2010).

could be lethal in the wild due to an increase in predation – but this, of course, requires that the predator is not similarly affected. Conversely, Santulli et al. (1999) reported no mortalities or overt pathological injury to caged European sea bass when exposed to received sound intensity levels above 200dB re 1 µPa rms.

Received impulsive sound can also cause sub-lethal pathological effects, including damage to hair cells in the hearing maculae, at received sound intensity levels of 150-193dB re 1µPa rms with no observed recovery (McCauley et al., 2003), and short-term biochemical responses but with unknown physiological effects at >200dB re 1µPa rms (Santulli et al., 1999). The most commonly observed responses to impulsive sound are behavioural. This can be restricted to startle and alarm responses at 150-160dB re 1µPa rms (Pearson et al., 1992) and subtle changes in distribution after exposure to 12 days at a source sound intensity level of 222.6dB re 1µPap-p (Slotte et al., 2004).

Critical underwater sound levels for whales and dolphins, therefore, are considered to be 180 dB re 1 µPascal rms for pathological injury and 120 dB re 1 µPa rms for temporary hearing impairment and behaviour, while that for fish is 150 dB re 1 µPascal rms for pathological injury and behaviour modification (1). Effect levels on turtles are not well defined, but it is assumed that these are similar to whales and dolphins (based on CSA, 2008).

The red line in *Figure 11.17* shows the sound attenuation curve for percussion piling with source sound levels back-calculated from the Matushek and Betke (2009) measurements. This indicates that whales/dolphins within 100m of the sound source (ie percussion piling) may suffer pathological injury and those within 80km may modify their behaviour, while fish within 600m may suffer permanent hearing impairment from percussion piling.

The sound energy attenuation plots in *Figure 11.17* are in agreement with sound attenuation patterns derived from acoustic modelling for seismic surveys in water depth of 25m south of Rongui Island (*Figure 11.18*). These show similar ranges to those calculated in *Figure 11.17*, although the distributions are elliptical as opposed to uniformly circular.

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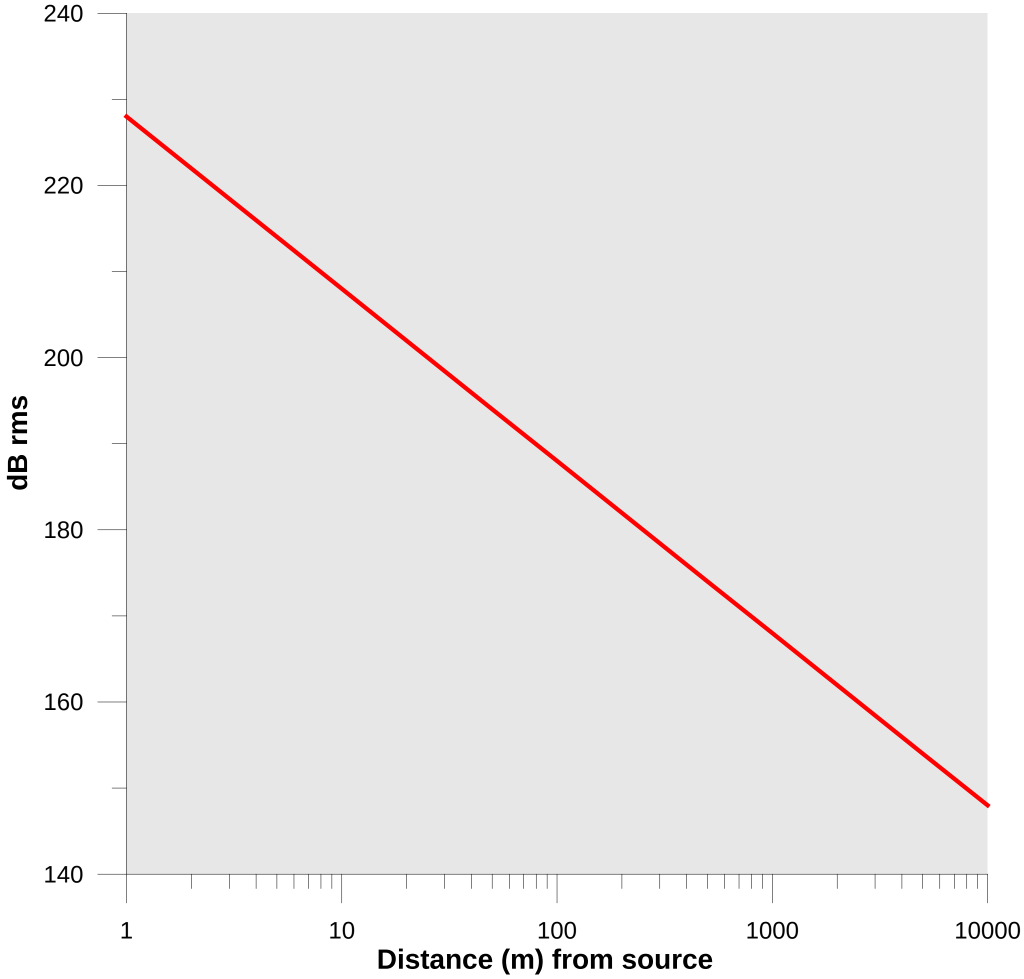
(1) This is quite conservative, as Popper et al. (2006) argues that levels of 190dB re 1 µPascal2.sec SEL are more appropriate for pile-driving generated sounds.

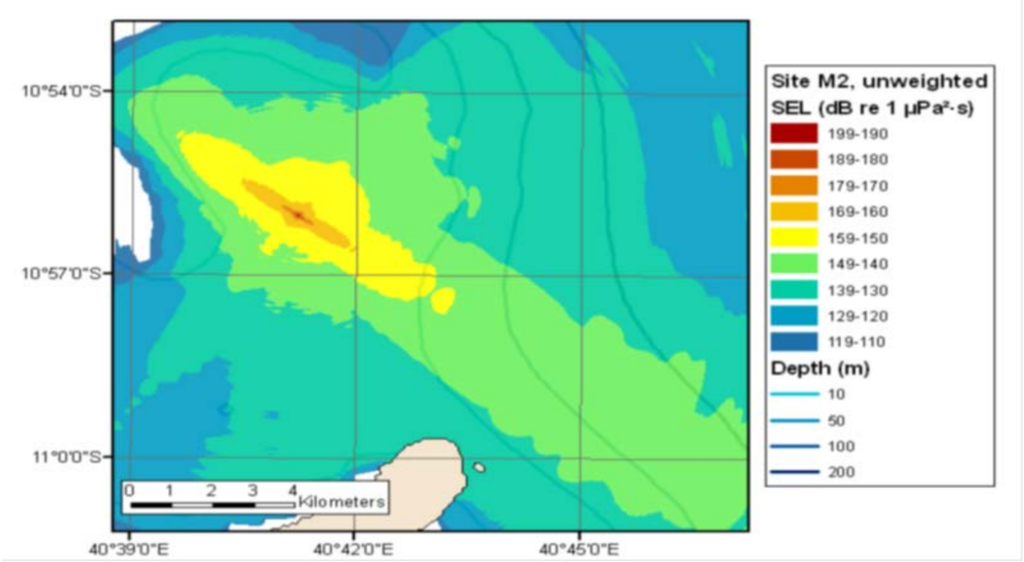
Figure 11.17 Sound Attenuation for Percussion Pile-driving with Distance Estimated, from Madsen et al. (2006)



Key:
The red line represents attenuation for percussion.

Source: Lwandle, 2012 based on Madsen et al., 2006.

Figure 11.18 Modelled Sound Field Map for Seismic Surveys in 25m Depth South of Rongui Island



Source: CSA, 2008.

It is apparent from *Figure 11.17* that the TTS effects on whales, dolphins and turtles will be only exceeded very close to the sound source, ie at the onsite extent within Palma Bay. Behavioural modifications could extend to the regional scale. Fish may experience some behavioural disturbance and non-lethal injury within 600m of the sound source, or at the onsite extent. This will endure for the short term during the construction phase only, and is rated to be of medium intensity and magnitude. Impacts to fish present are likely to occur during pile-driving. Dolphins, whales and turtles are expected to move away from unhealthy noise levels, and impact significance is predicted to be MODERATE.

The degree of confidence in the assessment is medium, specifically for the possible effects on whales, dolphins and turtles –they have to be within a close range of the generated sound to experience behavioural responses.

11.17.2 Mitigation Measures

The objective of the mitigation measure outlined below is to avoid the undue disturbance of megafauna (whales, dolphins and turtles) in particular, when in close proximity (<600m) of the piling site within Palma Bay.

- Where feasible, the MMOP should allow for a 'soft start' procedure when megafauna are present in the bay, for approximately 20 minutes prior to operating at the full cycle rate for percussion piling.

This will provide the opportunity for megafauna in particular to move out of the range of disturbance. As pointed out above, it is assumed that whales, dolphins and turtles will generally vacate areas where sound levels are uncomfortably high.

11.17.3 *Residual Impact*

The behavioural disturbance of and/or injury to whales, dolphins and turtles may be exerted at the local scale, but with a low likelihood of occurrence. The intensity and effective magnitude ratings will be reduced to low and the significance rating to NEGLIGIBLE should a 'soft start' procedure be implemented prior to percussion piling when megafauna are present in the bay.

Table 11.16 Impact of Noise on Marine Organisms in the Near Shore

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Short term	Short term
Extent	Regional (behaviour)/onsite (injury)	Local
Intensity	Medium	Low
Magnitude	**Medium**	**Low**
Likelihood	**Likely**	**Unlikely**
Significance	**MODERATE**	**NEGLIGIBLE**
	Operational Phase: N/A	

11.18 *IMPACT OF BALLAST WATER DISCHARGES FROM LNG CARRIERS AND THE INTRODUCTION OF ALIEN SPECIES ON NEAR SHORE MARINE ECOLOGY*

11.18.1 *Impact Assessment*

During the operational phase, LNG Carriers will enter Palma Bay under ballast and will then discharge this while being loaded with LNG at the export berths. Ballast water discharges bring the risk of releasing organisms (including non-indigenous) entrained in source ports into the receiving port environment ie Palma Bay. In addition, the introduction or spreading of non-indigenous species through hull fouling of (typically slow-moving) vessels such as dredgers or Project equipment can occur, when fragments of organisms that reproduce vegetatively are transported to a receiving port and become established.

Carlton and Geller (1993) recorded >350 taxa in Japanese ballast water samples taken from vessels in Oregon, USA. Most of these taxa were holo- and meroplanktonic forms, but all of the major marine taxa were represented. This case shows that it is possible to transport entire plankton species assemblages across oceans. Further, Hutchings (1992) has provided evidence that, when ballast water is drawn from heavily populated areas with inadequate waste water treatment systems, viral pathogens such as cholera (*Vibrio cholerae*) (1) and contaminants can also be translocated through ballast water exchanges.

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(1) http://www.imo.org/Conventions.

Once released into ports, alien species can become invasive through the establishment of populations, and can disrupt ecological processes. Carlton and Geller (1993) record 45 'invasions' attributable to ballast water discharges in various coastal states around the world. The invasives include planktonic dinoflagellates and copepoda, nektonic Scyphozoa, Ctenophora, Mysidacea and fish, and benthos such as Annelid oligochaeta and polychaeta, Crustacean brachyura and Molluscan bivalves. The establishment of benthic species in particular is aided by the presence of uncolonised surfaces such as those associated with new berth developments.

Species introduced from ballast water discharges can also impact seagrass stands. In the northern Mediterranean, the introduced *Caulerpa racemosa* replaced the host seagrass species *Posidonia oceanica* over large areas (>100 km^2), completely altering the seagrass biotope and having implications on fisheries (Williams, 2007). Similarly, coral reefs can be affected through the introduction of marine organisms via ballast waters in a number of ways, including the alteration of reef structures by introduced coral species. For example, the Indo-Pacific *Tubastarea coccinea* introduced to the Caribbean Sea is affecting local coral reef species (Goldberg & Wilkinson, 2004).

In view of the globally recorded negative effects of alien species transfers, the International Maritime Organisation (IMO) considers these introductions to new environments via ships' ballast water or other vectors as one of the four greatest current threats to the world's oceans (Awad et al., 2004). To reduce these risks, the IMO has instituted ballast water management regulations (1), including requirements for open ocean ballast water exchanges and associated ballast water management record books. The implementation of open ocean ballast water exchanges has been shown to reduce plankton concentrations within ballast water holding tanks on container vessels by 90 percent (Ruiz & Smith, 2005). The process can be abetted by long transit voyages between loading ballast water at the LNG offloading ports (probably in the Far East) and ballast water discharge in Palma Bay, which reduces the viability of organisms held in entrained ballast water.

All LNG Carriers loading LNG in Palma Bay will comply with the IMO requirements for open ocean ballast water exchange and/or the IMO standard of not discharging ballast water into Palma Bay if it holds <10 organisms larger than 50µm per cubic metre volume (2). The discharge of ballast water that is treated to IMO standards could include low concentrations of eggs, larvae or adults of alien species that may become invasive and alter local and regional biological communities. If invasive alien species are transferred into the bay, the effects on biodiversity and marine ecology (including seagrasses and corals) may be severe and affect communities permanently, and potentially at a regional scale. Impacts will be of high intensity and magnitude, as the effects can reverberate throughout the food chain and

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(1) See http://www.imo.org/ Conventions.

(2) See http://www.imo.org/ Conventions.

would be long term. The probability of this occurring is considered to be unlikely. The impact significance is rated as MODERATE.

Compliance with IMO guidelines on ballast water treatment has shown a large reduction in the viability of any organisms that may be discharged with ballast water, and therefore the degree of confidence in the assessment is high.

11.18.2 Mitigation Measures

The objective of the mitigation measures outlined below is to further reduce the probability of releasing alien species into Palma Bay via ballast water discharges with time. These should be considered in a Ballast Water Management Plan.

- All ships entering Palma Bay that are linked in any way to the Project are to comply with current IMO regulations concerning ballast water discharge and treatment and be early adopters of IMO sanctioned techniques and processes to further reduce the viability of organisms entrained in ballast water.
- All slow-moving craft such as barges, entering the area from non-East African ports, are to have hull inspections for 'hitch-hiking' sessile alien species, eg barnacles, mussels, sponges, etc. If these are found, then controls are to be instituted to reduce the associated risks of them escaping to the Palma Bay marine environment. This should include requirements for hull inspection certificates prior to barge departures from their loading ports.

11.18.3 Residual Impact

The progressive adoption of developing ballast water control measures and processing techniques, as and when sanctioned by the IMO, will further reduce the likelihood of the release of non-indigenous organisms over time. However, due to the high magnitude of the effects that may arise should invasive species become established in northern Mozambique, the significance rating would remain as MODERATE, although the impact is unlikely to occur given the proposed mitigation during the construction and operational phases.

Compliance with the current IMO guidelines on ballast water treatment has shown a large reduction in the viability of any organisms that may be discharged with ballast water, and it is expected that new treatment methods accepted by that body will be more effective. The confidence in the mitigated scenario assessment is high.

Table 11.17 Impact of Ballast Water Discharges from LNG Carriers and the Introduction of Alien Species on Near Shore Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Long term	Long term
Extent	Regional	Regional
Intensity	High	High
Magnitude	**High**	**High**
Likelihood	**Unlikely**	**Unlikely**
Significance	**MODERATE**	**MODERATE**
	Operational Phase	
Duration	Long term	Long term
Extent	Regional	Regional
Intensity	High	High
Magnitude	**High**	**High**
Likelihood	**Unlikely**	**Unlikely**
Significance	**MODERATE**	**MODERATE**

11.19 IMPACT OF DISCHARGES FROM DESALINATION AND SEWAGE TREATMENT PLANTS ON NEAR SHORE WATER QUALITY AND MARINE ECOLOGY

11.19.1 Impact Assessment

The LNG Facility and its workforce will require potable water during the construction and operational phases. This will be acquired or supplemented by a reverse osmosis (RO) Desalination Plant. The planned workforce will also generate domestic sewage. The discharges from the Desalination and Sewage Treatment Plants will be combined and discharged into Palma Bay via the co-discharge outfall (1), and could pose environmental risks through the modification of sea water quality.

Desalination Plant effluents comprise brine and low concentrations of various chemicals used to prevent biofouling (typically sodium hypochlorite and biocides) and adjust pH (generally hydrochloric acid and sodium hydroxide). Additional chemicals typically used include sodium meta-bisulphite (a dechlorination agent), anti-scalants (generally organic acids) and coagulants (such as ferric chloride) (2). Brine at usually 60 to 70 PSU is continuously discharged, while water and system treatment chemicals may be discharged in batch mode to coincide with RO filter backwashing.

The main impacts on the receiving environment of desalination plants are from the brine itself, minor reductions in pH and possibly heavy metals scavenged from metal surfaces in the RO plant, such as nickel, chromium, molybdenum and iron (older plants may also have copper and lead in their effluents). This is to be processed to meet national and international

(1) The outfall for co-discharges will facilitate the discharge of treated sewage effluent, treated stormwater run-off from process areas, desalination plant brine and LNG Facility waste water. The impacts associated with stormwater and waste water on marine ecology are assessed in *Section 11.21*.

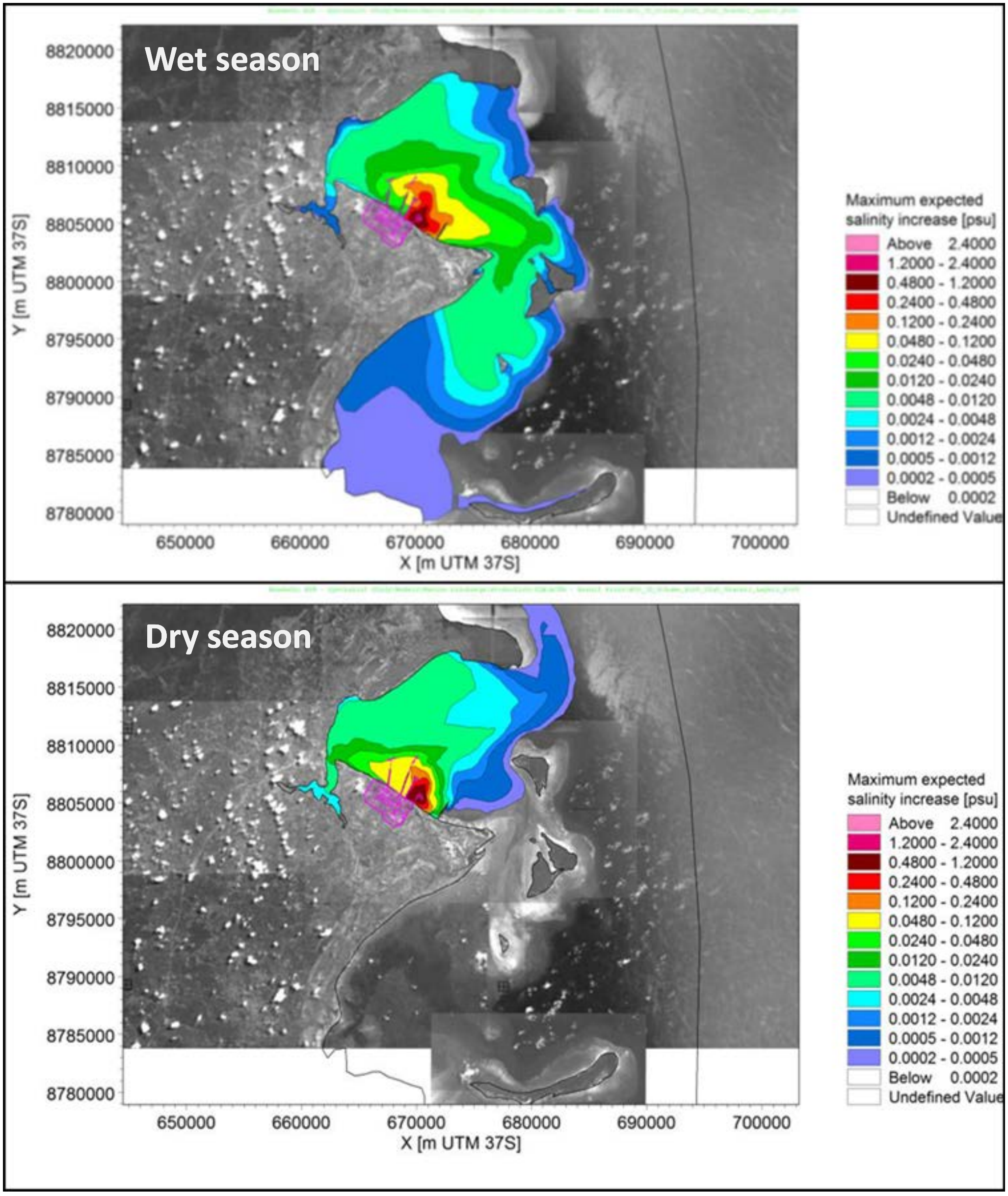
(2) http://www.pacinst.org/reports/desalination/desalination_report.pdf.

standards. The environmental risks represented by the brine are primarily the creation of a density interface between the brine and overlying water body, which limit oxygen and particulates exchanges between the seabed and water body, and salinity elevations that affect osmotic balances between marine organisms and their environment. Thresholds for the latter in terms of corals and seagrasses are 40 PSU (RPS, 2009). It is assumed that the brine water discharge configuration can optimise mixing with the receiving water body and therefore prevent density layering. Thresholds for co-discharges, considered to be primarily heavy metals, are those set as environmental quality targets (EQTs) for the WIOLAB region (UNEP & CSIR, 2009).

The discharge of treated domestic sewage is to comply with all the applicable standards, regulations (national and international) and/or approval or authorization . The highest risk to the marine environment is from eutrophication, especially due to increased levels of inorganic nitrogen. Eutrophication can promote phytoplankton growth, which affects light distribution, thereby compromising seagrasses and corals. In extreme cases, it can also affect oxygen distributions, impacting fish and other organisms. Threshold concentrations of inorganic nitrogen are 0.015 (corals) to 0.500mg/l (seagrasses). This implies that dilution factors of 20 to 670 need to be achieved at discharge to avoid compromising the EQTs. However, during the wet season, ambient dissolved nitrogen concentrations are 0.027mg/l *(Chapter 7),* implying that an upper dilution factor of 370 will be sufficient to avoid risks of any nutrient concentration increases above ambient levels in Palma Bay.

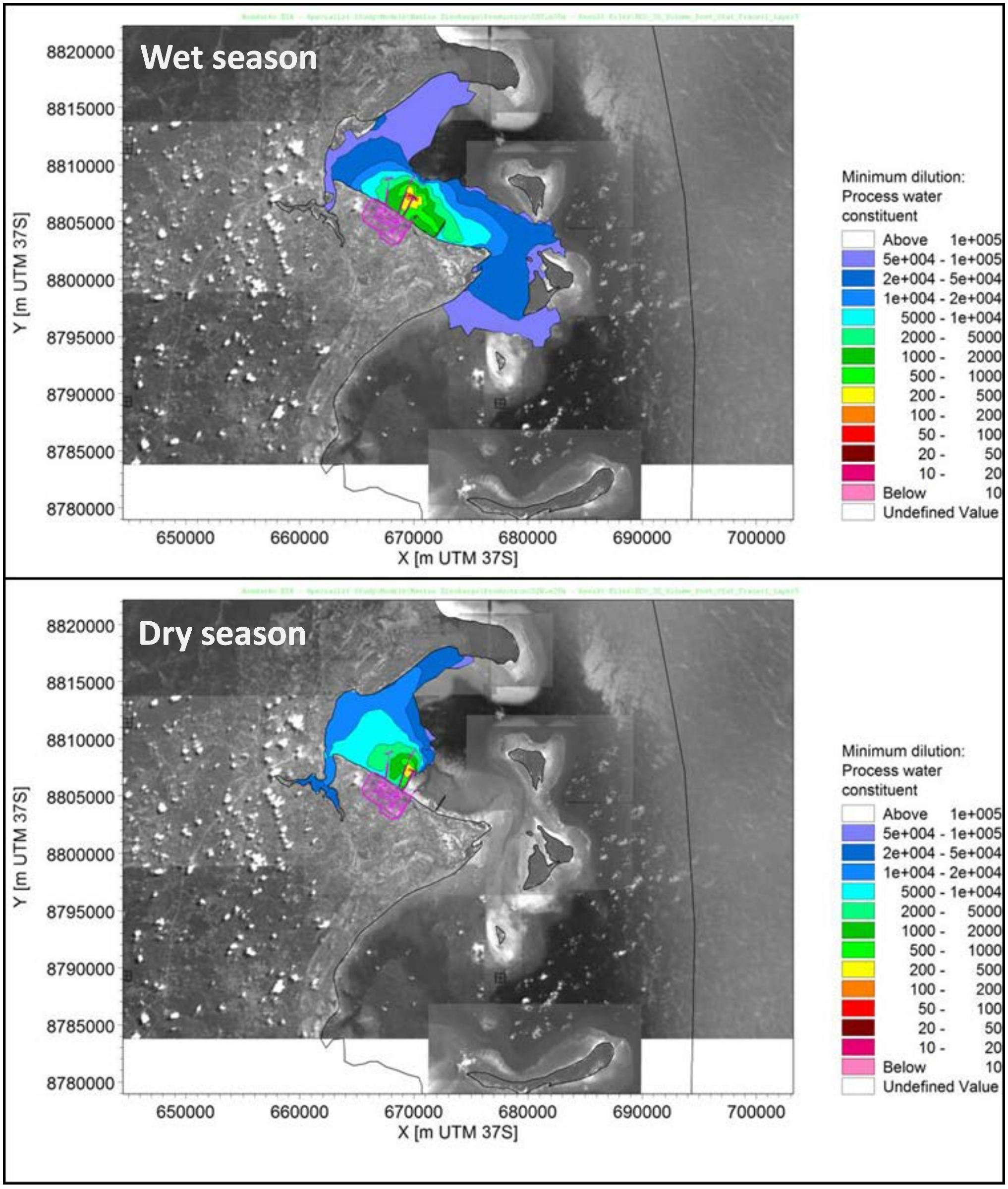
The behaviour of discharges from the proposed desalination plant and sewage treatment plants were modelled by PRDW (2012). *Figure 11.19* shows the predicted distribution for brine, and *Figure 11.20* depicts the predicted distribution for domestic effluent (as a conservative tracer, ie subject to dilution processes only and not being chemically or biologically transformed).

Figure 11.19 Maximum Increase in Salinity near the Seabed for the Brine Discharge during the Wet Season (Top) and Dry Season (Bottom)



Source: PRDW, 2012.

Figure 11.20 *Minimum Dilutions in the Surface Layer for Treated Sewage Effluent (Process Water) during the Wet Season (Top) and Dry Season (Bottom)*



Source: PRDW, 2012.

The predicted distributions indicate that the discharged brine will not exceed the specified receiving water quality threshold for coral and seagrass of 40 PSU (above), as the ambient salinities are approximately 35 PSU across most of Palma Bay (*Chapter 7*) and the maximum increase modelled is +2.4 PSU. Dilutions of sewage effluent are predicted to be high, and it is apparent that the set receiving water quality threshold will be exceeded in the immediate area of the discharge point only (200 to 500 dilution band in *Figure 11.20*).

Operational water discharges from the Desalination and domestic sewage treatment plants could compromise water quality in Palma Bay at the onsite scale over the life of the Project, but with negligible or undetectable short-term effects on marine ecology and/or marine ecological processes. The impact magnitude is rated as negligible and, given that effects will be unlikely, impact significance is expected to be NEGLIGIBLE.

The degree of confidence in the assessment is high. The planned discharges have low discharge rates, and the PRDW (2012) model results are consistent with measurements and other modelling investigations for desalination and treated sewage treatment plant discharges.

11.19.2 Mitigation Measures

The objective of the mitigation measure outlined below is to restrict the intensity and extent of related impacts.

- Ensure that the Project's process water (eg brine and treated sewage effluent) for operational discharges into Palma Bay operate at optimum efficiency in line with the Projects Water Resources and Wastewater Management Plan, through auditable maintenance schedules, and meet all water quality-related effluent parameters.

- Treated sewage will comply with all the applicable standards, regulations (national and international) and/or approval or authorization.

Through the course of FEED, the optimal solution for treatment and disposal of effluents will be investigated.

11.19.3 Residual Impact

With the implementation of the mitigation outlined above, water quality effects of the discharges will be restricted to the immediate proximity of the release points, resulting in a reduced risk to corals and seagrasses within Palma Bay. Impact significance will remain NEGLIGIBLE.

Table 11.18 Impact of Desalination and Treated Sewage Discharges on Near Shore Water Quality and Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Short term	Short term
Extent	Onsite	Onsite
Intensity	Negligible	Negligible
Magnitude	**Negligible**	**Negligible**
Likelihood	**Unlikely**	**Unlikely**
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**
	Operational Phase	
Duration	Long term	Long term
Extent	Onsite	Onsite
Intensity	Negligible	Negligible
Magnitude	**Negligible**	**Negligible**
Likelihood	**Unlikely**	**Unlikely**
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**

11.20 IMPACT OF THE DISCHARGE OF TREATED PRODUCED WATER INTO THE NEAR SHORE ON MARINE ECOLOGY

11.20.1 *Impact Assessment*

Produced water is water that was trapped along with the natural gas being extracted, within the sedimentary rock formations. Produced water is extracted from the wells along with the natural gas. The produced water will be treated to meet applicable standards (see below) and discharged into Palma Bay. Alternative discharge measures in the industry include discharge at the sea surface within the natural gas field or injecting the produced water and transmitting it back into the reservoirs from which it was drawn. However, these options are not available to the Project as there will be no surface platforms at the natural gas well sites.

Produced water has the potential to contain dispersed oil, hydrocarbons, polycyclic aromatic hydrocarbons, phenols, ketones and alcohols, along with zinc, lead, manganese, iron and barium and naturally occurring radioactive materials (NORM) (Veil et al., 2004). The volumes of produced water extracted depend on the rock strata hosting the natural gas as well as the characteristics of the well itself (horizontally vs vertically drilled) and the type of well completion, etc (Veil et al., 2004). The risks associated with produced water discharges include, toxicity effects on organisms in or passing through the discharge plume and tainting effects on shellfish and fish that are harvested for human consumption.

The estimated volumes of produced water that will be delivered to the LNG Facility are 1,600bbl/Train/day, which will subsequently be treated and discharged. When two Trains are operational, this will generate 3,200bbl/day, which is equivalent to 509m^3/day. At full production it is estimated that six Trains will run, and the corresponding produced water volume will be 9,600bbl/day or 1,526m^3/day. The available information about the natural gas field formation water quality is summarised in *Table 11.19*.

The mean salinity of the produced water is approximately 12ppt, although this varies considerably across the samples analysed, and ammonia and strontium concentrations are high. Comparisons with WIOLAB's EQTs (UNEP & CSIR, 2009), however, indicate that the produced water concentrations are compatible with these guidelines.

Table 11.19 Project's Produced Water Quality – from Samples Drawn from an Average Depth of 2,750m below the Seabed Compared to WIOLAB Environmental Quality Targets (EQTs)

Variable	**Units**	**Means**	**Standard Deviation**	**Sample Size**	**WIOLAB EQT**
pH		7.35	0.35	23	7-9
Salinity	ppt	12.45	26.85	26	15-36
Li	µg/l	1.99	0.97	23	
Na	µg/l	4077.54	1193.71	26	
NH_4	µg/l	33.71	8.00	20	600

Variable	Units	Means	Standard Deviation	Sample Size	WIOLAB EQT
K	µg/l	71.16	39.30	26	
Mg	µg/l	11.07	7.16	26	
Ca	µg/l	771.17	677.10	26	
Al	µg/l	0.07	0.05	14	
B	µg/l	118.54	55.53	26	
Ba	µg/l	5.02	2.91	26	
Cu	µg/l	0.05	0.04	9	1.3
Fe	µg/l	4.08	7.91	14	
Mn	µg/l	0.47	0.54	26	
P	µg/l	0.19	0.10	11	50
S	µg/l	35.63	31.86	26	
Si	µg/l	58.00	25.10	26	
Sr	µg/l	24.71	18.78	26	
Zn	µg/l	1.14	0.63	26	15

Source: Anadarko, 2012. WIOLAB EQTs from UNEP & CSIR, 2009.

Although heavy metal concentrations within produced water are typically low, hydrocarbons and phenols may be more variable. Such compounds have the potential to taint fish flesh (UNEP & CSIR, 2009). The organisms that may be affected are primarily those in the footprint of the discharge plume where dilutions are predicted to be relatively low (eg > than 500x as shown in *Figure 11.20*). Important taxa potentially affected include bivalve molluscs and fish, such as Siganidae, that forage on epiphytes on seagrass; both groups form part of the artisanal fishery in the region.

Flesh tainting can occur at low in water concentrations, eg 1 mg/l for phenol and 0.25 mg/l for benzene, toluene, ethylbenzene, and xylenes (BTEX) compounds (UNEP & CSIR, 2009). Despite the presence of such compounds in produced waters, OGP (2005) reports that detection of tainting effects in both wild and caged organisms exposed to produced water discharges is uncommon. Given that fishing activities within the area of effluent discharge are likely to be limited due to exclusion zones that will be imposed in the bay (see *Chapter 4*) and given that discharge plume dilution rates are predicted to be high (as detailed above), it is considered unlikely that tainting effects on organisms landed by the artisanal fishery or aquaculture industry will be measureable.

Treated produced water will be discharged into Palma Bay during the operational phase, adding to the potential load being delivered by process water and/or stormwater discharges. This could compromise water quality in Palma Bay at the onsite scale for the life of the Project (ie long term), but it is expected that this will have undetectable effects or negligible intensity on marine ecology and/or marine ecological processes. Impact magnitude is likely to be negligible and, thus, impact significance is predicted to be NEGLIGIBLE. It should be noted, however, that the optimum methods to address all Project discharges will be further investigated during FEED.

The degree of confidence in this assessment is medium, due to the limited water quality baseline available for formation water.

11.20.2 *Mitigation Measures*

Although not deemed necessary according to the significance rating allocated, it is suggested that the treated formation water be discharged along with the brine from the Desalination Plant at the LNG Export Jetty. The flow rate from the Desalination Plant discharge will be approximately 120l/sec. The estimated discharge rate for the formation water is approximately 18l/sec for six Trains, ie 15 percent of the Desalination Plant discharges. This will add a marginal benefit in brine dilution, due to the generally low salinity levels expected in the formation water (*Table 11.19*).

The objective of the mitigation measure outlined below is to achieve an environmentally safe discharge of treated formation water.

- In line with the Project's Water Resources and Wastewater Management Plan, combine the flow of the treated produced water with the co-discharge described in *Section 11.19*.

11.20.3 *Residual Impact*

The impact significance rating will remain NEGLIGIBLE.

Table 11.20 Impact of the Discharge of Treated Produced Water into the Near Shore on Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase: N/A	
	Operational Phase	
Duration	Long term	Long term
Extent	Onsite	Onsite
Intensity	Negligible	Negligible
Magnitude	**Negligible**	**Negligible**
Likelihood	**Likely**	**Likely**
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**

11.21 THE IMPACT OF EPISODIC STORMWATER DISCHARGES FROM THE LNG FACILITY ON NEAR SHORE MARINE ECOLOGY

11.21.1 *Impact Assessment*

Run off from the LNG processing areas will be directed to one or more internal collection systems. This potentially contaminated stormwater will be drained to the stormwater retention basin and inspected. If deemed acceptable, the water will be discharged directly into Palma Bay. If deemed unacceptable for discharge, the stormwater will be treated onsite prior to discharge into Palma Bay. Therefore, contaminant loads in stormwater discharged through the outfall into Palma Bay will be low.

The stormwater retention basin allows for the removal (via settling out) of any suspended solids. It will be sized to a capacity sufficient to catch the 'first flush' of stormwater. This generally contains the highest contaminant loads.

Episodic stormwater discharges from the LNG Facility area during construction or operations could compromise water quality over the short term, at an onsite scale, within Palma Bay. Effects on marine ecology and/or marine ecological processes are likely to occur, but are predicted to be of negligible intensity and of low magnitude. This impact is likely to occur and, thus, the impact significance is MINOR during the construction and operational phases.

The degree of confidence in this assessment is high. The stormwater management system will be adequate for its purposes and is designed to accommodate a 100-year storm event. LNG facilities are not known to generate high contaminant loads, and the PRDW (2012) model results are consistent with measurements and other modelling investigations for stormwater discharge from process areas.

11.21.2 Mitigation Measures

The objective of the mitigation measure outlined below is to prevent contaminated stormwater from being discharged to Palma Bay.

- Establish a Water Resources and Wastewater Management Plan to GIIP for stormwater management.

- Establish a stormwater management system with stormwater retention dam(s) sufficient to capture the first flush of stormwater. Treat any stormwater that may be impacted (particularly by hydrocarbons) prior to disposal or discharge.

11.21.3 Residual Impact

The water quality effects of any stormwater discharges managed through the Project's stormwater system are unlikely. If they occur, however, effects would be restricted to modifications of the Near Shore surface salinity fields, with NEGLIGIBLE significant implications for the marine ecology of Palma Bay.

Table 11.21 Impact of Episodic Stormwater Discharges from the LNG Plant on Near Shore Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Short term	Short term
Extent	Onsite	Onsite
Intensity	Negligible	Negligible
Magnitude	**Low**	**Low**
Likelihood	**Likely**	**Unlikely**

	Without Mitigation	Residual Impact (with Mitigation)
Significance	**MINOR**	**NEGLIGIBLE**
	Operational Phase	
Duration	Short term	Short term
Extent	Onsite	Onsite
Intensity	Negligible	Negligible
Magnitude	**Low**	**Negligible**
Likelihood	**Likely**	**Unlikely**
Significance	**MINOR**	**NEGLIGIBLE**

11.22 *IMPACT OF INFILLING AN ESTUARY ON NEAR SHORE MARINE ECOLOGY*

11.22.1 *Impact Assessment*

The onshore LNG Facility footprint covers a small estuary with mangrove stands towards its eastern boundary (*Figure 11.21*). This estuary will be filled in, probably with sediment reclaimed during the dredging campaigns. The flows from the estuary catchment will be rerouted towards the east and drain into Palma Bay through an artificial mouth. The existing mangrove stand will be removed during this process.

The mangrove community in this estuary includes Avicennia, Sonneratia and Rhizophora spp. (*Figure 11.21*) in the estuary mouth area. This is similar to the estuary at Palma and the larger mangrove stands around the estuary on the eastern tip of Afungi Peninsula. It is assumed that the backshore flora is also similar to these larger systems, which will then include Bruguiera, Ceriops and Xylocarpus spp. Thus, although diverse in terms of mangroves, the stands that will be filled in are not unique in Palma Bay or the larger region (Richmond, 2002).

Figure 11.21 Avicennia (Foreground) and Rhizophora spp. (Background) Mangroves in the Estuary on the Eastern Boundary of the Proposed LNG Facility

Source: Lwandle, 2012.

Mangroves in estuaries are known to be highly productive and complement other biotopes, including seagrasses and coral reefs, in ecological function and biodiversity. The impacts on marine ecology resulting from the loss of the estuary and associated mangrove stand during the construction phase will be permanent, of medium intensity and at a local scale (Palma Bay). Owing to the smaller size of the mangrove stand compared with the others in the bay and wider area of the northern Cabo Delgado coastline, the magnitude is rated as medium. As this impact will definitely occur under the proposed Onshore Project Footprint, the significance is MODERATE.

The degree of confidence in this assessment is high. Even though the impacted mangrove stand is relatively small compared with others that exist in Palma Bay and beyond, the loss of the mangrove system is considered to be a medium biodiversity loss.

11.22.2 Mitigation Measures

The Onshore Project layout has been revised to avoid and minimise impacts to sensitive areas across the Afungi Project Site. However, the preservation of this particular mangrove stand is incompatible with the establishment of the LNG Facility on the designated site. The objective of the mitigation measures outlined below is to obtain some benefit from the area to be filled in by harvesting its resources.

- Infill from the top of the remaining estuary to the bay to allow motile organisms, such as fish and crabs, to escape to the downstream Palma Bay water body and shoreline.

11.22.3 Residual Impact

Resources such as wood should be harvested/extracted and optimal use made of the mangrove system prior to the infilling of the estuary. The impact ratings remain the same post-mitigation, including significance, which is rated as MODERATE, as the establishment of the LNG Facility will result in the loss of a multispecies mangrove stand on the LNG Processing Area's eastern boundary.

Table 11.22 Impact of Infilling and Estuary on Near Shore Marine Ecology

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Permanent	Permanent
Extent	Onsite and local	Onsite and local
Intensity	High (onsite)/Medium (local)	High (onsite)/Medium (local)
Magnitude	**Medium**	**Medium**
Likelihood	**Definite**	**Definite**
Significance	**MODERATE**	**MODERATE**
	Operational Phase: N/A	

11.23 IMPACT OF SECURITY/EXCLUSION ZONES ON FISH DISTRIBUTIONS IN THE NEAR SHORE

11.23.1 Impact Assessment

The establishment of permanent and semi-permanent security or exclusion zones in the intertidal, shallow subtidal and deeper areas around the LNG Facility and the Near Shore infrastructure (Pioneer Dock, MPD and LNG Export Jetties) during the construction and operational phase will displace artisanal fishing effort in Palma Bay. It is noted that fishing and/or marine resource and/or estuary resource exploitation is likely to increase in the bay, due to the influx of people into the area. The displacement is predicted to increase fishing pressure outside of the security zones. Some measure of protection will be provided to the fish community within the zones. These comprise a minor proportion of the Palma Bay water surface area and will therefore not be significant. Intertidal beach areas within the security zones may become biologically richer, with possible benefits to foraging coastal seabirds. This, too, is uncertain, as the beaches themselves will have been modified to a large degree by the marine facilities.

The establishment of security zones around the LNG Facility and the Near Shore Project infrastructure will displace artisanal fishing efforts and locally increase exploitation pressure on the fish community outside of the zones over the long term. The intensity of the effects is likely to be medium at the local scale. Impact magnitude is expected to be low magnitude in the wider context. Informal observations during field surveys indicate that fishing pressure is already high in Palma Bay and surrounds, with even fish classed as marine ornamentals (eg butterfly fish, banner fish, moorish idols, etc) being caught by trap and harpoon and presented for sale in the local fish market. The likelihood of the impact occurring is likely and, thus, impact significance is rated as MINOR.

The degree of confidence in this assessment is low, as the increased extent of fishing pressure is not known given that the fishing pressure is already high in Palma Bay.

11.23.2 *Mitigation Measures*

No mitigation measures are identified.

11.23.3 *Residual Impact*

The impact significance remains unchanged, as no mitigation measures have been identified.

Table 11.23 Impact of Security Zones on Fish Distribution in the Near Shore

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Long term	Long term
Extent	Local	Local
Intensity	Medium	Medium
Magnitude	**Low**	**Low**
Likelihood	**Likely**	**Likely**
Significance	**MINOR**	**MINOR**
	Operational Phase	
Duration	Long term	Long term
Extent	Local	Local
Intensity	Medium	Medium
Magnitude	**Low**	**Low**
Likelihood	**Likely**	**Likely**
Significance	**MINOR**	**MINOR**

11.24 IMPACT OF SHIP OPERATIONAL DISCHARGES ON NEAR SHORE MARINE FAUNA AND SEABIRDS

11.24.1 *Impact Assessment*

This impact considers the effects on water quality and the health of marine fauna and seabirds within the bay of discharging sewage, deck drainage, bilge water and machinery space drainage, emissions to the atmosphere and galley and garbage waste originating from shipping operations into Palma Bay. The impacts could potentially arise from contractors operating support and other vessels that are not compliant with the provisions of MARPOL 73/78 or other relevant international and domestic instruments. Since LNG Carriers operate under strict international standards, it can be assumed that they will adhere to IMO requirements, but the effectiveness of controls on other vessels is uncertain.

Directly or indirectly discharged solid and liquid wastes from marine vessels during any phase of the development could potentially result in a proliferation of litter and compromised water quality, which could harm marine organisms, seabirds and biodiversity in Palma Bay. If the maritime laws are obeyed, the potential pollution impacts of routine operational emissions, discharges and waste disposal at sea will typically be localised, of medium intensity, and short term in duration. Impacts to marine ecology are likely to occur should the discharges take place and would be of medium magnitude, thus resulting in impacts of MODERATE significance.

The degree of confidence in this assessment is medium, as the extent of control over and inspection of vessels to be undertaken by the Project and contractor vessels was not specified at the time of report compilation.

11.24.2 Mitigation Measures

The objective of the mitigation measures outlined below is to eliminate discharges into Palma Bay and provide adequate waste reception and disposal facilities.

- Prior to the establishment of the Port Reception Facilities in Palma Bay (ie during the construction phase) vessels associated with the EPC Contractor will comply with MARPOL 73/78 and utilise MARPOL compliant waste facilities elsewhere for offloading wastes.

- All Project vessels will comply with MARPOL 73/78. This will, among other things, necessitate the provision of Port Reception Facilities for vessels based at the facility (ie support vessels and tugs), as well as effective waste disposal.

11.24.3 Residual Impact

If the maritime laws are successfully enforced and adequately managed, and Port Reception and associated recycling or disposal facilities are provided, the potential pollution impacts of routine operational emissions and discharges will remain at a local scale, at a low intensity. Impacts will be short term in duration ie they may occur but would be of low magnitude. Impact significance is deemed to be NEGLIGIBLE through all phases of the Project.

Strict compliance with the requirements of MARPOL 73/78 would ensure that the degree of confidence in the mitigated scenario assessment is high.

Table 11.24 Impact of Ships Operational Discharges on Near Shore Marine Fauna and Seabirds

	Without Mitigation	**Residual Impact (with Mitigation)**
	Construction Phase	
Duration	Short term	Short term
Extent	Local	Local
Intensity	Medium	Low
Magnitude	**Medium**	**Low**
Likelihood	**Likely**	**Unlikely**
Significance	**MODERATE**	**NEGLIGIBLE**
	Operational Phase	
Duration	Long term	Long term
Extent	Local	Local
Intensity	Medium	Low
Magnitude	**Medium**	**Low**
Likelihood	**Likely**	**Unlikely**
Significance	**MODERATE**	**NEGLIGIBLE**