

Chapter 4

Project Description

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4 PROJECT DESCRIPTION

4.1 INTRODUCTION

The purpose of this chapter is to describe the components of the Project from construction to operation and eventual decommissioning. This chapter explains the Project in terms of the following main sections:

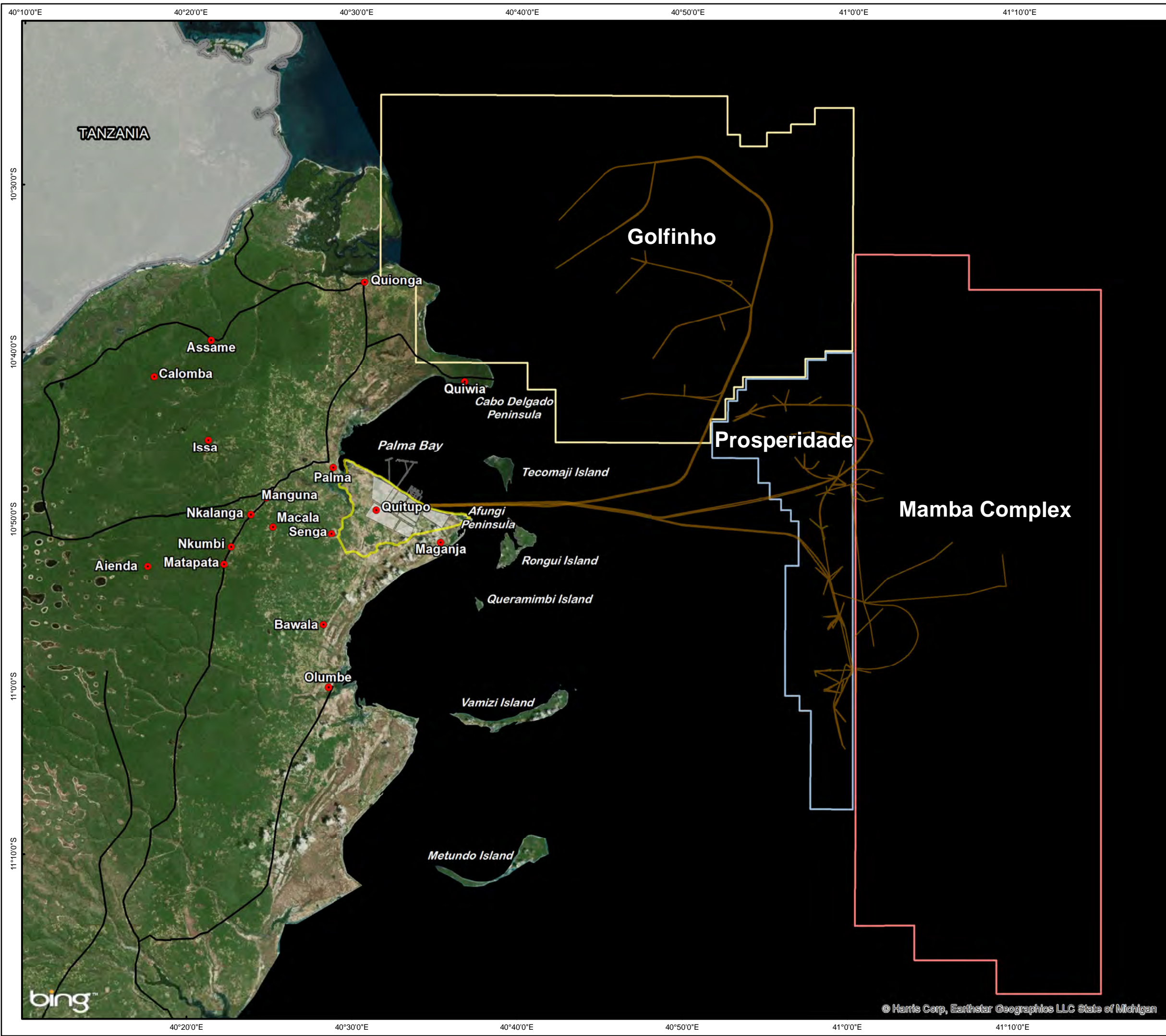
- *Section 4.2: Overview of the Project;*
- *Section 4.3: Offshore Project component description;*
- *Section 4.4: Onshore Project component description;*
- *Section 4.5: Near Shore Project component description;*
- *Section 4.6: Management of Emissions, Discharges and Solid Wastes; and*
- *Section 4.7: Decommissioning and Closure.*

The Project design is currently being refined during a Front End Engineering and Design (FEED) process. Where specific information is currently unavailable or has not yet been defined, conservative assumptions and estimates have been inserted into this project description, which has been used as the base case for this EIA.

4.2 OVERVIEW OF THE PROJECT

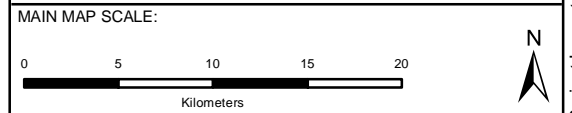
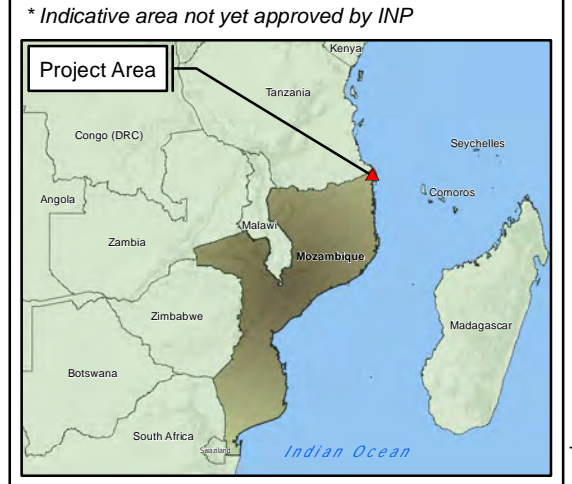
The Project is designed to collect, transport, process and export (in liquefied form) natural gas in northern Mozambique. This process begins offshore, where natural gas will be extracted from gas reservoirs below the seafloor via subsea wells. The gas will be collected and transported to the onshore LNG Facility by pipelines. Once onshore, the gas will be processed, converted to liquid (through cooling the gas) and stored in storage tanks. The liquefied gas will then be transported through insulated pipelines to one of two export jetties ⁽¹⁾, where it will be loaded into LNG vessels to be transported to international markets. These specially designed ships maintain the LNG in a liquid state for sea voyages of several thousand kilometres. The indicative Project layout is illustrated in *Figure 4.1*.

(1) Hereafter the two jetties are referred to as the 'LNG Export Jetty'.



Legend

- Villages / Settlements
- Regional Roads
- Proposed Pipeline Corridor Route
- Jetty
- Onshore Layout
- Afungi Project Site
- Prosperidade Gas Field
- Golfinho Gas Field *
- Mamba Complex Gas Fields



TITLE:
Figure 4.1:
Indicative Project Layout

CLIENT:

Anadarko
 Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: KG	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 400 000
DRAWING: Indicative Project Layout.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

Projection: UTM Zone 37 S. Datum: WGS84
 Source: Bing Maps ©2010 Microsoft Corporation.
 AMA1, 2012. Inset Map: Esri Data & Maps

SIZE:
A3

4.2.1 *Primary Project Components*

The main components of the Project are grouped together and discussed as offshore, onshore and near shore components of the overall Project. These are defined below, and a detailed discussion of these Project components is provided in *Sections 4.3 to 4.6*:

- The Offshore Project components will consist of the Area 1 and Area 4 offshore production wells and the infrastructure necessary to develop the gas reserves. This also includes the offshore pipeline system, which will convey natural gas from the offshore production fields to the onshore facilities.
- The Onshore Project components will comprise the LNG facilities and supporting infrastructure (eg worker accommodation facilities, construction areas, access roads and airport).
- The Near Shore Project components will consist of the marine infrastructure within Palma Bay necessary for construction, operation and maintenance of the Project. This includes logistic, support and export facilities (eg shipping channels, Pioneer Dock, Multi-Purpose Dock and LNG Export Jetty).

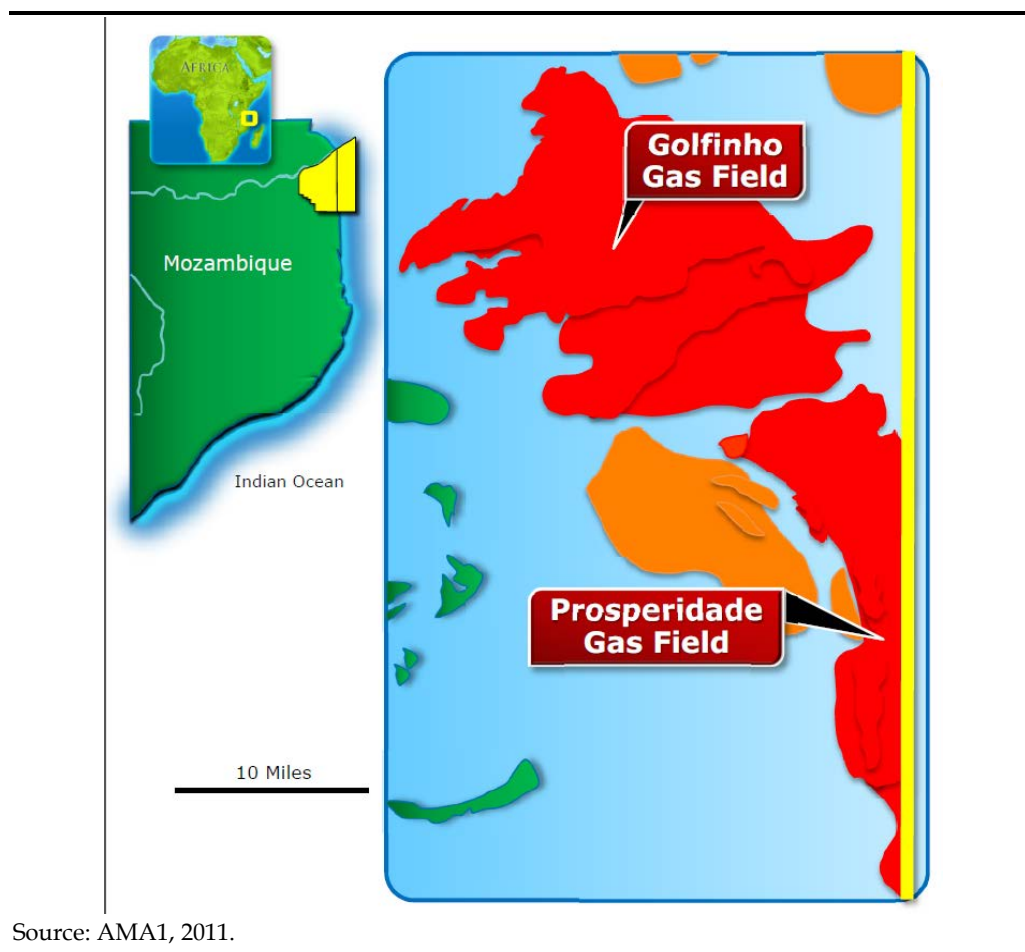
4.2.2 *Project Location and Footprint*

Offshore Project Location

AMA1 was granted exclusive rights to explore and exploit commercial quantities of hydrocarbons in Offshore Area 1 of the Rovuma Block, in the Rovuma Basin, offshore northern Mozambique, on 20 December 2006. To date, the AMA1 development consists of Golfinho Gas Field ⁽¹⁾, in the northern portion of Area 1, and the Prosperidade Gas Field, located to the south (*Figure 4.2*) gas fields are predominately located in the northern and eastern part of Area 1, approximately 50km offshore and in water depths of approximately 1,500m. They include the Windjammer, Barquentine, Lagosta, Camarão, Golfinho and Atum gas discoveries, where in excess of 65 trillion (10¹²) cubic feet (TCF) of recoverable natural gas has been identified to date. These subsea gas fields cover an area of approximately 350km². Future exploration and production activities conducted by AMA1 will also be located within Area 1.

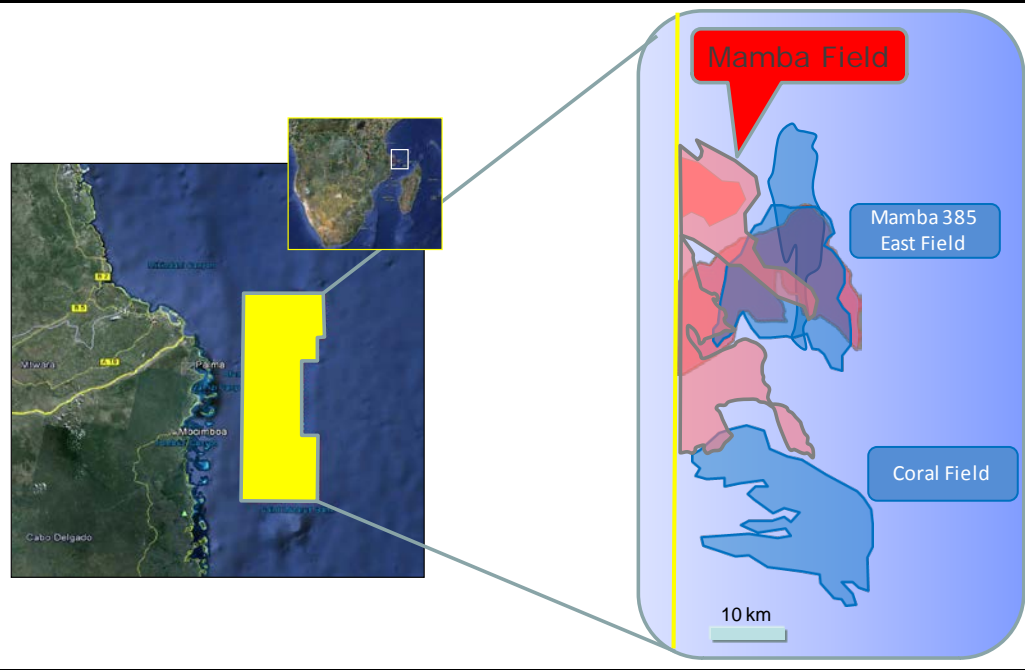
(1) Note: As of the date of this publishing, the extents of the Golfinho Gas Field have not been formally approved by INP.

Figure 4.2 Area 1 Gas Fields

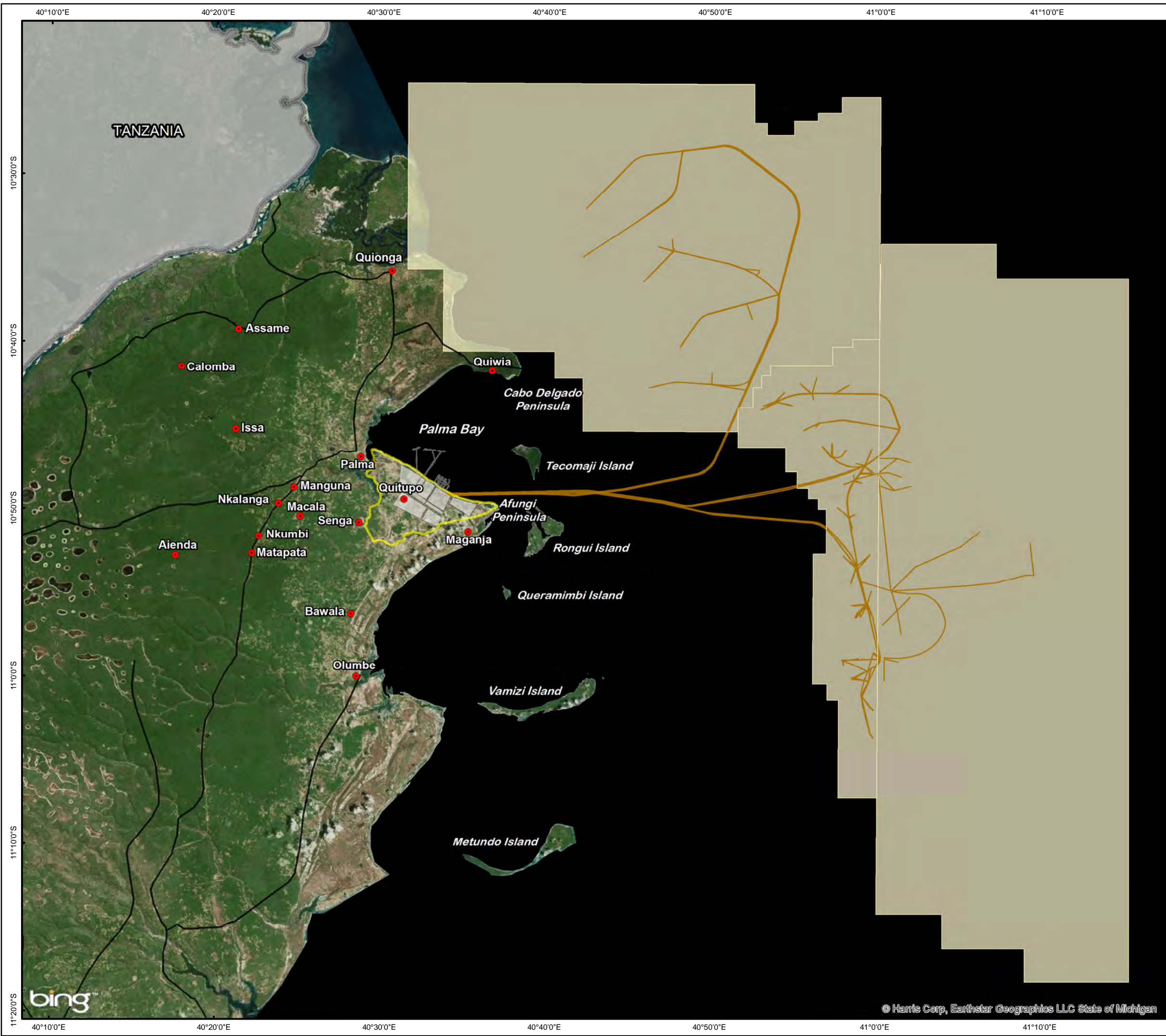


Eni East Africa S.p.A. (“eni”) was granted exclusive rights to explore and exploit commercial quantities of hydrocarbons in offshore Area 4 of the Rovuma Block, in the Rovuma Basin, offshore Northern Mozambique, 20 December 2006. To date eni development consists of Mamba Gas Fields, in the western and eastern portion of Area 4 and Coral Gas Field located in the south (Figure 4.3). These fields are predominately located in the western part of Area 4, approximately 55km offshore and in water depths ranging between 1,500m and 2,300m. They include the Mamba South, Mamba North, Mamba North East and Coral gas discoveries where approximately 80 TCF of natural gas in place has been identified to date. These subsea gas fields cover an area of approximately 1,100km². Future exploration and production activities conducted by eni will also be located within Area 4.

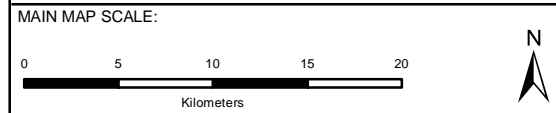
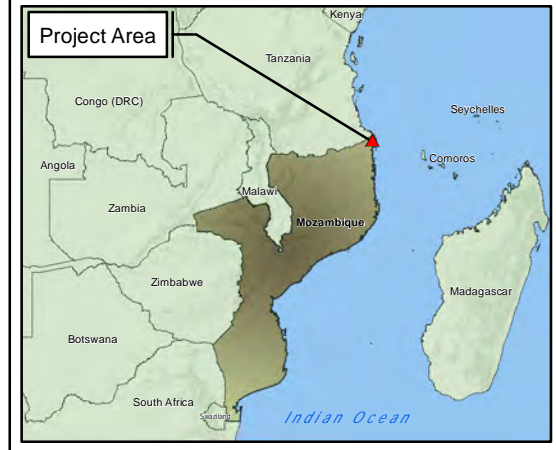
Figure 4.3 Area 4 Gas Fields



Natural gas produced from these subsea reservoirs will be transferred to the onshore LNG Facility via an approximately 45km subsea pipeline corridor, as indicated in *Figure 4.4* below. The current route of this pipeline will cross between the islands of Rongui and Tecomaji and make landfall on the north-eastern coastline of the Afungi Peninsula.



- ### Legend
- Villages / Settlements
 - Regional Roads
 - Jetty
 - ▭ Onshore Layout
 - ▭ Afungi Project Site
 - Proposed Pipeline Corridor Route
 - ▭ Gas Fields



TITLE:
Figure 4.4:
Gas Fields and Pipeline Corridor

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DRAWING: Gas Fields and pipeline corridor.mxd		REV: A

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Projection: UTM Zone 37 S, Datum: WGS84
 Source: Bing Maps ©2010 Microsoft Corporation.
 AMA1, 2011. Inset Map: Esri Data

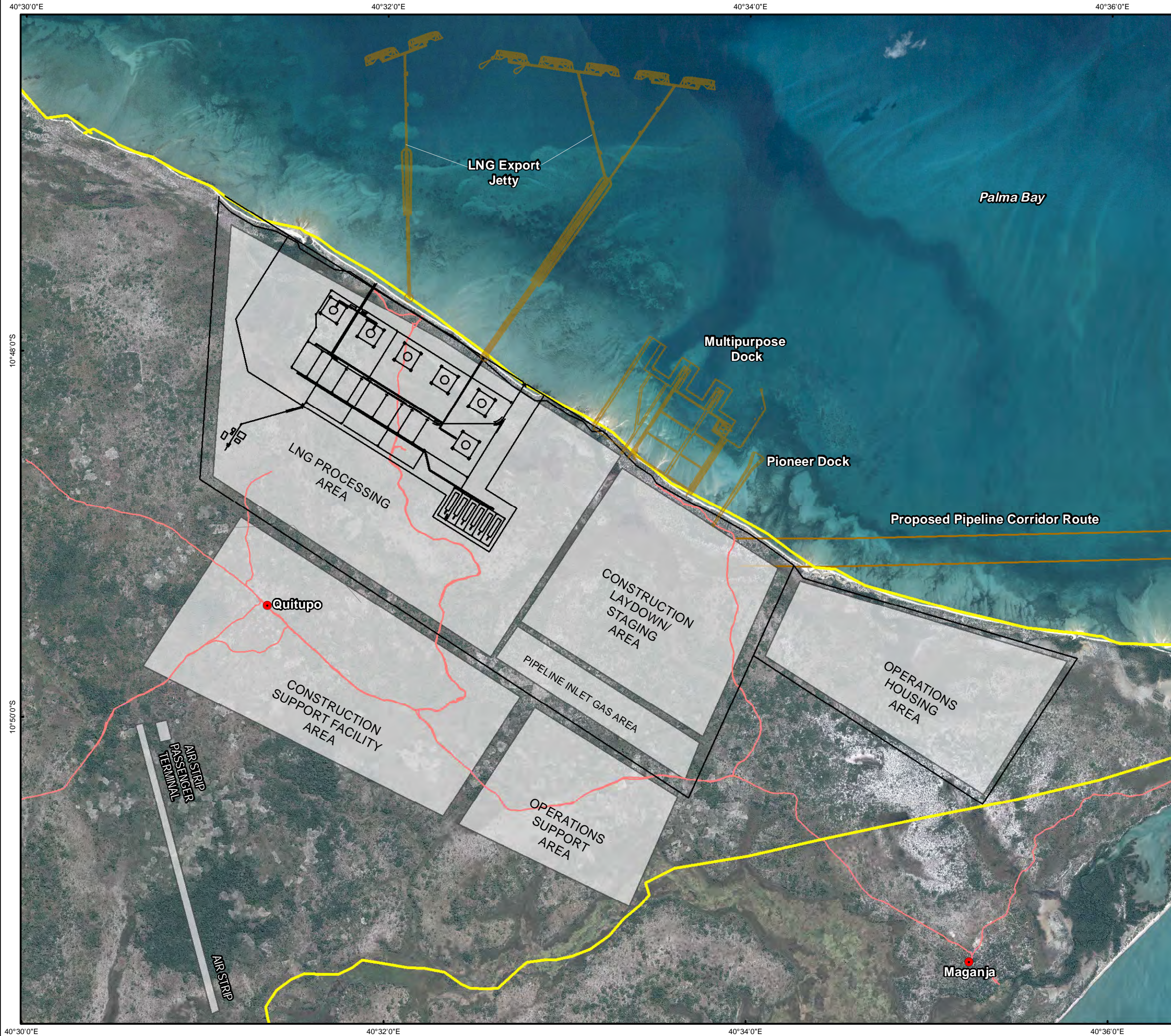
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Onshore Project Location

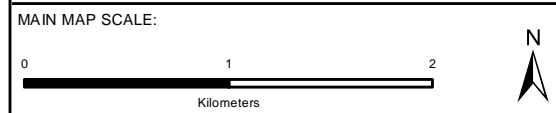
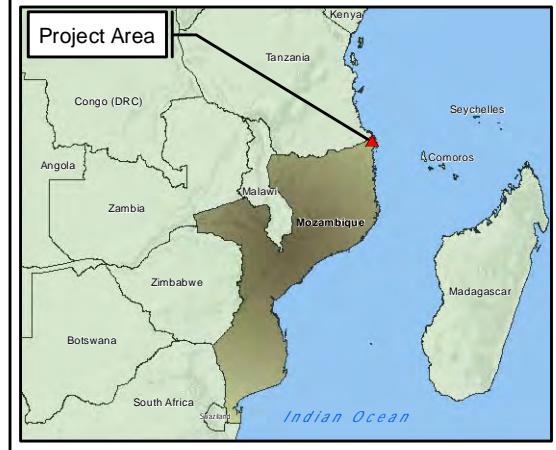
The land area obtained for the onshore component of the Project is approximately 7,000ha. Rovuma Basin LNG Land, Lda. ('RBL') incorporated by AMA1 and Empresa Nacional de Hidrocarbonetos, E.P (ENH), is the holder of the Right to Use and Enjoy Land (known as a 'DUAT') for the above mentioned land area. AMA1 currently possesses exclusive rights to the land within the DUAT for the development of the Project, but other operators may be granted rights to use the referred land and under such understanding eni will enter in the capital of RBL and will be granted equal rights as AMA1. This 7,000ha area is referred to Afungi Project Site. The onshore component of the Project includes the LNG Facility, storage tanks, temporary and permanent worker housing, construction and maintenance areas, supplemental construction laydown areas, airstrip, power generation facilities (gas turbines), waste disposal facilities, water and wastewater treatment facilities and buffer zones. The footprint of the onshore infrastructure, including the airstrips, is approximately 3,600ha of the overall 7,000ha of land obtained. *Figure 4.5* provides the conceptual layout of these facilities and the boundary of the Afungi Project Site.

Near Shore Project Location

The Near Shore components of the Project will be located on the coastline adjacent to the LNG Facility. *Figure 4.5* provides the conceptual layout of the Near Shore components including the Pioneer Dock, Multi-Purpose Dock (MPD), LNG Export Jetty and marine access routes. These facilities will be located in such a way that they take advantage of existing deeper water channels or proximity to deeper water. The natural channels will likely need to be deepened and widened by dredging to accommodate the Project vessels.



- Legend**
- Villages / Settlements
 - Local Roads
 - Near Shore Project Footprint
 - ▭ Onshore Project Footprint
 - ▭ Afungi Project Site



TITLE:
**Figure 4.5:
 Indicative Onshore and Near Shore
 Project Layout**

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ERM

Projection: UTM Zone 37 S, Datum: WGS84
 Source: Promap, 2012. AMA1, 2011.
 Inset Map: Esri Data & Maps

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4.2.3 *Project Time Frame*

The current estimated duration of the design, construction and commissioning of the first LNG Train for the Project is approximately 48 to 54 months from Project sanction. This estimate is based on a scheduled initial start-up for the LNG Facilities in early 2018 and first export shipment of LNG by the fourth quarter of 2018 (*Figure 4.6* provides an overview of the indicative Project schedule). The following section provides information on the timing of the planned Project activities.

In parallel to exploration and appraisal and the EIA, the Project basic design will be developed through the FEED process. FEED began in late 2012 and is still ongoing. After FEED, the detailed Project design will be carried into the Engineering, Procurement and Construction (EPC) phase.

The following sections provide detail on activities that are planned for construction and operation of the Project.

4.3 *OFFSHORE PROJECT DESCRIPTION*

4.3.1 *Introduction*

The Offshore Project components will consist of the Area 1 and Area 4 offshore production wells, the infrastructure necessary to produce the offshore gas reserves, and the offshore pipeline system to convey natural gas from the offshore production fields to the onshore LNG Facility. The Offshore Project will be designed to initially produce and deliver 6 billion cubic feet (BCF) of natural gas per day to the LNG Facility located onshore. This is based on the initial development of approximately 60 production wells. Gas will be transported from the offshore gas fields to the LNG Facility via multiple subsea pipelines. The pipeline routes for Area 1 and Area 4 will join in deep water and be routed in a single corridor to the LNG Facility onshore.

Up to 120 subsea wells may ultimately be drilled in the gas fields in Areas 1 and 4 during the life of the Project. These subsea production wells will become part of the Subsea Production System (described in *Section 4.3.4*) and will be the source of the gas to be delivered to the onshore LNG Facility. The production wells will be drilled at an anticipated frequency of one well every 75 days, potentially using multiple drilling rigs.

Dynamically positioned ⁽¹⁾ (DP) drill ships - *Saipem 10,000*, *Deepwater Millennium* and *Bedford Dolphin* - have been performing exploratory drilling activities within Area 1 and Area 4 and are proposed to conduct the drilling of the production wells. The final choice of rigs depends on the availability of technically capable drilling rigs and the timing for commencement of production drilling activities. However, in any event, drill rigs with similar performance specifications to those currently in use will be used. An example of these DP drill ships is provided in *Figure 4.7*. These vessels are self-propelled and well site positioning is maintained using both acoustic beacons and satellite-based global positioning systems. DP drill ships provide a number of advantages over conventional semi-submersible drill rigs, including self-propulsion, capability for storing large amounts of equipment, faster mobilisation compared to the semi-submersible rigs, and operating where mooring and anchoring are not feasible. Since no anchoring is required, there will be no direct impact to the seafloor associated with anchor placement or dragging.

The drill ships will be mobilised to site either under tow by a vessel or under own propulsion in open navigable seaways. At this time, it is not anticipated that the vessels will enter any of the ports in Mozambique, except if needed to clear customs. Supplies to the drill ships will be primarily routed through the AMA1 and eni supply bases at Pemba. Typical supplies include fuel, water, food, drilling fluid chemicals, oil well cement and chemicals, well tangibles (drill pipe, wellheads), equipment, tools and other items. Some supplies may be delivered directly to the rig.

(1) The term dynamically positioned means that the location or position of the vessel is maintained by the vessel's specialised propulsion/station-keeping system.

Figure 4.7 Example of a Dynamically Positioned Drill Ship



A shallow hazard study will be carried out to provide a pre-drilling assessment of shallow geological hazards at each proposed production well location. This assessment will be based on 3-D exploration seismic data and will be limited to the seafloor and shallow geologic section. Before drilling commences, a remotely operated vehicle (ROV) will be launched from the drilling vessel to scan the area approximately within a 500m radius around the location at the seabed. The main objective is to identify the presence of potential obstructions and environmentally sensitive features. Such features are described in the marine ecology study of this EIA. Environmentally sensitive features will be avoided, to the extent practical, to minimise impact to the environment during drilling operations.

4.3.3 *Drilling and Commissioning of Offshore Wells*

Prior to drilling all production wells, a drilling programme will be prepared. This will contain all the technical information regarding the drilling and safety systems and procedures in place for the well. This document will be provided to the Government of Mozambique (INP, 2012) for review and comment prior to commencing drilling. The drilling process will be conducted by means of a standard top drive rotary system suspended from the derrick of the drilling vessel. The drill string is fastened to the rotary top drive and consists of uniform lengths of hollow steel pipe, screwed together with a drill bit at the bottom end. The drill string is lowered from the derrick into the borehole. Once the bit reaches the bottom of the borehole, rotation is applied by the top drive.

Wells are drilled in sections, with the diameter of each section decreasing as depth increases. At the start of the drilling operations, the top or surface

section of the well is drilled 'open hole'; that is, the drilling mud and cuttings are not returned to the drilling rig. Before drilling the lower sections of the well, a marine riser is run between the drilling rig and the seabed, with the drill string passing down the centre of the riser.

Once the Blowout Preventer (BOP) is in place on the wellhead, the marine riser is connected from the rig to the BOP. The BOP is a series of valves and diverters that are designed to deal with erratic pressures and uncontrolled flow, should these be encountered within the reservoir. Once a marine riser and BOP have been installed, the drilling mud can flow back up to the rig where it is cleaned before reuse.

Drilling mud continuously circulates down the drill pipe and back to the drillship. Drilling mud serves several functions, including maintaining the hydrostatic pressure on the fluid column, lubricating the drill bit and drill string, and stabilising the well bore. The recirculation of the mud brings the cuttings from the bottom of the well to the surface, where they are removed from the mud system. The composition of the drilling mud is constantly changing during the drilling process, both from the addition of natural materials from the cuttings and from additives introduced to maintain the desired mud properties. Depending on different wells and on different drilling phase water based mud or synthetic and low toxic oil based muds might be used.

As stated above, once the cuttings and drilling mud reach the drill ship, the cuttings are separated from the mud system and the clean drilling mud is circulated back down the hole. Drill cuttings are cleaned by passing them through the solids control equipment, which separates the cuttings from the drilling mud.

A process known as casing is carried out to isolate portions of the well to protect the aquifers of groundwater, as well as to provide a support structure to the well itself. Casing also serves to guarantee safety and efficiency during drilling operations. It involves placing a string of protective steel pipe (casing) in the well and setting it in place by pumping specially formulated cement between the outside of the casing pipe and the well bore wall. After a string of casing is in place, a smaller drill bit is used to drill a narrower well section. The process of drilling then continues until the desired depth is reached.

The length and diameter of each section of the well will be established prior to drilling in the drilling programme. The exact details are determined by the geological conditions through which the well is drilled.

After the drilling phase the well is completed making the well ready for production. This activity principally involves preparing the bottom of the well to the required specifications, installing the production tubing and 'down hole' tools associated with the safety valve.

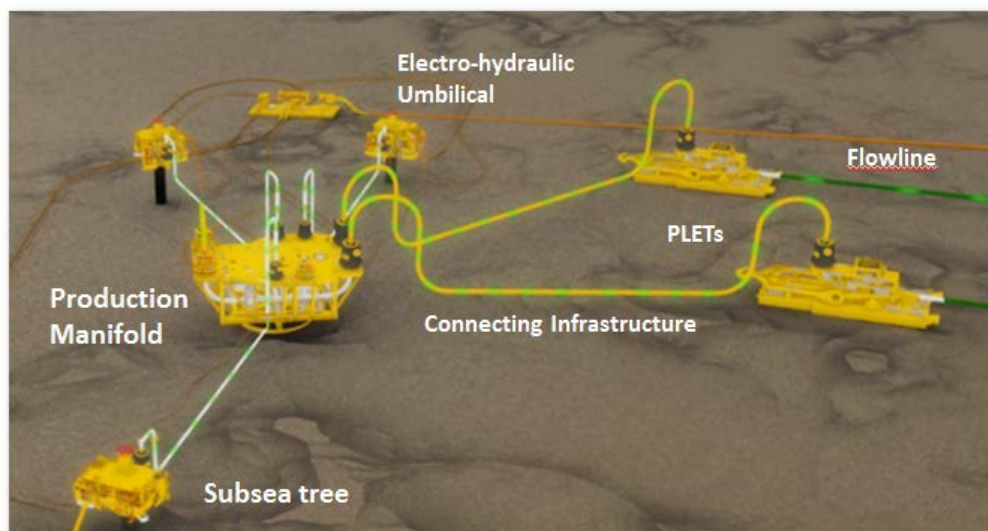
4.3.4

Subsea Production System Process Overview

Natural gas from the subsea production wells flows through the subsea production system and connecting infrastructure to a manifold that mixes flow from other wells and directs the gas into the pipelines to shore. These components are depicted in *Figure 4.8* below, and the associated process is described in more detail in the sections that follow.

Figure 4.8

Indicative Layout of the Subsea Production System



Source: Anadarko, 2012.

Preliminary reservoir model results indicate the reservoirs will initially have enough volume and pressure to deliver sufficient gas volumes to shore to feed the LNG Facility in a so called “field-to-shore” configuration. A Floating Production Unit (FPU) could be needed, at a later stage of production life to be defined, within the field-to-shore development scenario. Its function would be to boost production and compensate the reservoir pressure decline. Based on these factors, a FPU will not be required for the initial development of the gas field. A FPU is therefore not included in the scope of the EIA. If offshore compression and processing are required in the future, an EIA process will be followed to permit the installation of an FPU.

4.3.5

Components of the Subsea Production System

The Subsea Production System consists of a manifold design connecting subsea production wells. In some cases a design with clustered wells could be used. This design allows for multiple wells to originate from a single location, thereby limiting disturbance to the seabed by reducing the number of drill centre locations. This design simplifies the flowline layout, and allow for future expansion. The gas reservoir target depths for the production wells are based on current reservoir simulations developed from information gathered during the exploration and appraisal phase of the Project. Further optimisation of well locations and refinement of the subsea architecture will

be made as reservoir engineering work continues. The current subsea layout includes the following primary components, described in more detail below:

- subsea production trees;
- chemical injection distribution network;
- subsea flowline infrastructure;
- electro-hydraulic control umbilicals; and
- subsea pipeline.

Subsea Production Trees

Subsea production trees are the assembly of control valves, gauges and chokes (to regulate gas flow pressure) that control gas flow in a completed well. The trees are installed at the wellhead to guarantee security barriers in case flow interruption is necessary. The valves act as a fail-safe, and are hydraulically operated by means of a spring return to close automatically in case of hydraulic system depressurisation.

The subsea trees will be designed for remote installation and control through the assistance of a ROV. The subsea control system will be located onshore within the LNG Facility. Electro-hydraulic controls connect to the trees via the umbilicals to control and regulate the flow of each well. Chokes allow the production flowlines to be operated at a consistent pressure. The trees are connected to the chemical injection distribution network to prevent hydrate formation, as described below.

Chemical Injection Distribution Network

The gas reservoir is water saturated. Once extracted, the gas cools rapidly and the water condenses. This can result in problems for downstream equipment. The water can form hydrates with CO₂ and hydrocarbons, which can potentially impede gas flow within the subsea production system and pipelines. To avoid the risk of interrupted gas flow due to hydrate formation, a monoethylene glycol (MEG) injection and recovery system is required. MEG is used to inhibit the formation of hydrates by altering the freezing point of the water found in the raw natural gas. Although MEG is the selected inhibitor for hydrate control of the subsea production, it is possible that during well start-up, and/or in the event of pipeline blockage, hydrate control will be achieved by discontinuous injection of methanol⁽¹⁾. Hydrate control methods will be further assessed during FEED.

In this closed-loop process, lean MEG (ie MEG with a water concentration of approximately 10 percent) is delivered to the wellhead via a dedicated pipeline connected to umbilicals, and is injected to prevent hydrate formation. The rich MEG (MEG with a higher concentration of water) flows to the onshore through pipelines together with the natural gas and is separated in

(1) The use and storage of methanol shall be object of a risk assessment.

the slug catcher ⁽¹⁾. The natural gas continues through the LNG processing system while the MEG is routed through a recovery system to separate water, dissolved salts and any solids and is recirculated through the closed-loop system. Storage for rich and lean MEG will be provided to handle variations in production and provide hydrate mitigation during minor maintenance intervals.

The primary waste effluents from the MEG recovery system are salt and water. The anticipated salt generation is expected to be approximately 2,200kg/day and the water generation will likely be 1,600 barrels (bbl)/day for each LNG Train. This saline fluid can be handled separately or combined into a single stream for discharge into the bay. This approach and alternative methods for the disposal of saline fluid and any solids resulting from treatment of the MEG wastewaters will be investigated and finalised during FEED, in accordance with good international industry practice.

Subsea Connecting Infrastructure

The subsea production infrastructure will be connected by manifolds, pipeline end termination structures (PLETs) and jumpers. A production manifold is a steel structure that gathers the flow from several wells and merges them into the main subsea pipeline, thus reducing the number of flowlines necessary. Each flowline will begin and end at a PLET connection. PLETs include jumpers, which are rigid or flexible pipes used to connect subsea trees to flowlines and flowlines to manifolds.

Electro-hydraulic Control Umbilicals

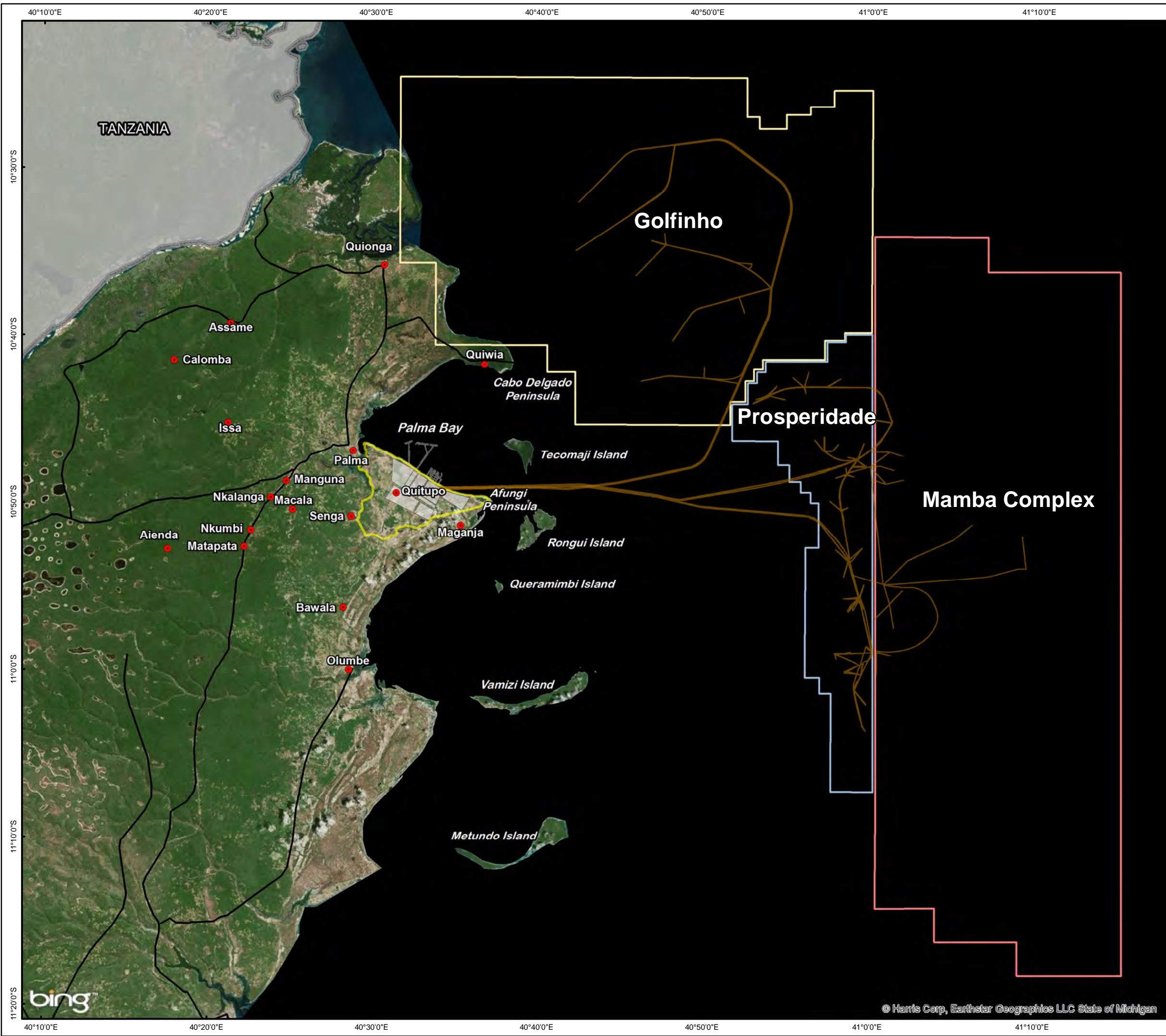
Umbilical cables control the subsea equipment remotely. They transfer hydraulic pressure and electrical power to operate subsea equipment and retrieve data through electrical and/or optical fibre cables. Umbilicals will also provide chemical injection into the subsea wells to ensure flow by preventing hydrate formation and corrosion. The chemical injection process occurs within a closed system; therefore there is no chemical loss to the marine environment.

Subsea Pipeline Corridor

Produced gas from the subsea wells will be transferred to the onshore LNG Facility via subsea gas gathering pipelines travelling within the selected gas pipeline corridor. As the pipelines approach the coastline, they will be routed in a single pipeline corridor and enter Palma Bay between the islands of Rongui and Tecomaji. Based on the alternative routes investigated (see *Alternatives Analysis, Chapter 5*) and studies conducted to date, this is the

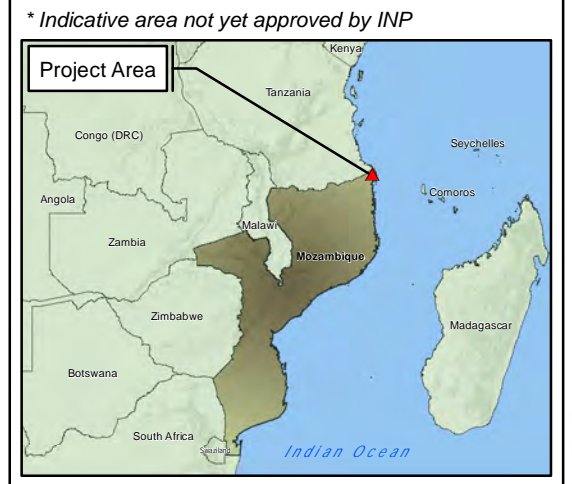
(1) Liquids and gas do not form a homogeneous mixture as they flow through the pipeline. Liquids tend to pool in low areas of the pipeline until a sufficient volume accumulates to impede the flow of gases. Once this occurs, pressure is built up behind the liquid and the liquid is pushed through the pipeline. This phenomenon is referred to as slug flow. A slug catcher is a device that receives the slugs of liquid that accumulate over time and are pushed through the pipeline intermittently.

preferred route to bring the pipeline from deep water into the shallow bay. The approximate alignment of the pipeline corridor is indicated *Figure 4.9*.



Legend

- Villages / Settlements
- Regional Roads
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- ▭ Onshore Layout
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- Proposed Pipeline Corridor Route
- ▭ Prosperidade Gas Field
- ▭ Golfinho Gas Field *
- ▭ Mamba Complex Gas Fields



TITLE:
Figure 4.9:
 Alignment of Gas Gathering Pipelines
 and Main Gas Pipeline Corridor into
 Palma Bay

CLIENT:

Moçambique Área 1, Lda

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DRAWN: AB	APPROVED: KG	SCALE: 1 : 400 000
DRAWING: Alignment of Gas Gathering Pipelines.mxd		REV: A

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Projection: UTM Zone 37 S. Datum: WGS84
 Source: Bing Maps ©2010 Microsoft Corporation
 AMA1, 2012. Inset Map: Esri Data & Maps

SIZE:
 A3

Prior to construction, several activities will be performed during the FEED phase. A number of meteorological and oceanographic (metocean) buoys have been deployed within Palma Bay and the offshore development area to gather wind, wave and current information. In addition, geotechnical investigation will be conducted to characterise the seafloor and soil strata down to approximately 60m below the seafloor. Locations for subsea equipment and pipeline routes will be mapped and assessed to identify environmental and design constraints. This information will be used to define the optimum pipeline route within the identified corridor and placement of the Subsea Production System infrastructure. This routing will be finalised during FEED.

It is anticipated that a workforce of 400 to 750 construction workers and equipment technicians could be involved during the subsea system construction phase. These personnel will be housed on the offshore construction vessels or in the construction camps associated with the onshore component (discussed in *Section 4.4.4*). The construction of the Subsea Production System will last approximately 18 to 24 months and is scheduled to commence in the fourth quarter of 2015. During this construction phase, there could be 10 to 20 construction vessels active in the field at any given time.

A temporary exclusion zone will be required during construction in order to maintain the safety of the workforce and the community. The extent of this exclusion zone is anticipated to be a 500m radius around all construction vessels and construction corridors.

Installation Vessels

The installation of the Subsea Production System will be performed either DP drill ships or by purpose-built installation vessels (known as Light Construction Vessels or LCVs) common to the industry. The subsea equipment and materials will be transported to Mozambique either by Heavy Lift Vessels (HLVs), installation vessels or both. Some components may be transported by commercial freight vessels as needed.

Support services for the LCVs will be responsibility of the installation contractors. The vessels will require periodic refuelling and replenishment of provisions. It is expected that the larger LCVs will make their own fresh water but the smaller vessels may require the delivery of fresh water. All construction vessels will be compliant with the International Convention for the Protection of Pollution from Ships (MARPOL 73/78) regulations. *Figure 4.10* below provides an example of the type of vessels to be used for the construction and installation of all components of the Subsea Production System.

Figure 4.10 *Typical Installation Vessel*



Light Construction Vessel



Deepwater Pipelay Vessel



Flexible Pipe and Umbilical Lay Vessel

Source: Anadarko, 2012.

LCVs are generally 100m to 120m in length, equipped with a 150t and 200t capacity cranes and operate with a DP system. It is envisioned that all

construction vessels will be DP so that no anchoring is required, thereby limiting potential impact to the seabed.

At the subsea well locations, infrastructure will likely be supported by mudmat structures ⁽¹⁾ and suction piles ⁽²⁾ installed by the LCV. The LCVs will use specialised connection systems to connect the manifolds, jumpers and PLETs.

Similar to the pipelines, the umbilicals will be laid with a purpose-built, DP vessel. The shore approach for the umbilicals will be located within the pipeline corridor.

Installation of Subsea Pipelines and Umbilicals

The production pipelines and umbilicals will be laid in predetermined corridors; the pipeline will terminate at the LNG Facility and the umbilicals will terminate at the onshore control centre. The pipeline can be installed in segments and later tied in to ready the system for commissioning. The pipelines will be installed by using purpose-built, DP lay barge, and the S-lay and J-lay methods are anticipated to be employed. The S-lay method is the traditional method for installing offshore pipelines in relatively shallow water. It is commonly referred to as the S-lay method because the profile of the pipe as it is laid forms an elongated 'S' between the vessel and seafloor. In deeper water, near the well field locations, the J-lay method may be used to install the pipelines. The choice of installation methods is dependent on ambient conditions such as the flow velocity of the currents in the area.

In the shallow areas of the shore approach, from the islands shoreward, it is anticipated that a dredged channel, approximately 300m wide by 5m deep, will be required to accommodate access by the lay barge to install the pipelines. Approximately 6.6 million m³ of dredge material is expected. The area of disturbance for the lay barge dredge channel will lie within the designated pipeline corridor. The specific methods for dredging this channel will be determined once the seabed substrate composition is defined during detailed engineering. In water depths of greater than 25m at Lowest Astronomical Tide (LAT), the pipelines will be laid directly onto the seabed without the need for dredging.

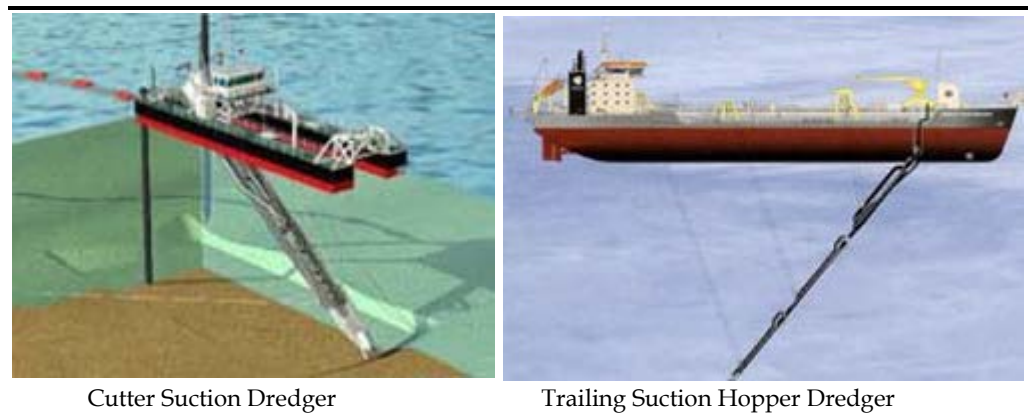
It is anticipated that trailing suction hopper dredgers will be used for the majority of the dredging within Palma Bay. These dredging vessels can load their own holds using centrifugal pumps with pipes that drag along the bottom while the ship is moving. A cutter suction dredger will likely be used to dredge the channel between the islands of Rongui and Tecomaji, as a harder

(1) A mudmat is a support foundation designed and installed to provide additional support. Mudmats are used when seabed soil is too soft to bear the load of subsea structures. The commonly used plate mudmats, often made with carbon steel, consist of a top plate and a number of perpendicular vertical stiffeners that function as load-bearing beams.

(2) Suction piles are tubular piles driven into the seabed. A pump is used to suck water out at the top of the pile, thereby pulling the pile further down to anchor it in place.

rocky substrate is expected in this area. Dredging with a cutter suction dredger takes place while the vessel is anchored in place, and combines a powerful cutting action with suction to remove the debris. *Figure 4.11* illustrates the characteristics of the two types of dredgers likely to be used.

Figure 4.11 *Types of Dredgers*



Three options are being considered for the disposal of the dredge material:

- disposal of dredge material at a predetermined offshore location;
- temporary stockpile of dredge material adjacent to the pipeline corridor for future backfill; and
- storage and dewatering of dredge material onshore in sediment ponds.

4.3.7 *Commissioning of the Subsea Production System and Pipeline*

The commissioning activities specified herein are the base case to be further optimised during FEED. Commissioning entails numerous systematic conformity checks to verify that each component is correctly installed and ready for operation. All subsea structures and equipment are pressure tested at the place of fabrication to verify that they will function as intended in the deepwater environment. Once installed, the commissioning activities are organised by subsystem, following an approved sequence that optimises the start-up phase. Commissioning of the subsea facilities comprises the following main activities:

- post-installation surveys;
- integrity testing; and
- dewatering and nitrogen purging.

Post-installation Surveys

A visual inspection of the subsea infrastructure and pipelines will be conducted to ensure there has been no damage during installation. The

post-installation survey will likely be conducted by ROV, due to the water depths associated with the Subsea Production System.

Integrity Tests

Integrity testing will be conducted to verify that the control systems are fully functional. These tests will confirm that the mechanical, electrical, hydraulic, fibre optic, chemical injection and emergency shutdown controls operate properly.

During pipeline construction, all welds will be tested to check integrity. Pipelines will be cleaned and internal diameters checked using a pipeline inspection gauge (commonly referred to as a 'pig'). The pipelines will undergo pressure testing (hydrotesting ⁽¹⁾) using seawater, with the possible additions of chemicals ⁽²⁾ such as biocides and corrosion inhibitors. In this process, the pipeline is flooded and held at a predetermined test pressure for a predetermined period to check for material defects or leaks.

A plan for the disposal of water used for hydrotesting will be developed with careful consideration given to the impact, if any, of remaining chemicals on the environment. To the extent possible, hydrotest water will be reused to hydrotest the onshore facilities. In the event this is not practical (due to the timing of the various construction phases of the overall Project), the hydrotest water used in the testing of the Subsea Production System will only be discharged ⁽³⁾ after treatment to the guideline standards provided by the International Finance Corporation (IFC) ⁽⁴⁾.

Dewatering and Nitrogen Purging

Following the completion of hydrotesting, the system will be dewatered. Drying of the pipeline is essential to prevent corrosion and hydrate formation. It is also necessary to meet operational requirements. Air drying will likely be conducted by foam pigs pushed through the pipelines by filtered, oil-free, super-dry air. Upon completion of the dewatering operations, the pipelines will be purged with nitrogen to remove all air. The line pressure will be regularly monitored and recorded during the interval between the completion of purging and start-up.

4.3.8

Operation of the Subsea Production System

Once operational, the Subsea Production System will supply the natural gas to the onshore LNG Facility for treatment, liquefaction and storage prior to

(1) Hydrotesting is a frequent activity with well-established industry practices for testing the integrity of pipelines, both onshore and offshore.

(2) Dyes and additives such as corrosion inhibitors and biocides are usually added to hydrotest fluids to allow the identification of leaks and to protect the pipelines against corrosion. The chemicals to be used are widely employed in pipeline testing worldwide, and are selected for low toxicity in the aquatic environment.

(3) In this case, the expected volume of hydrotest water is approximately 120,700m³ (55,700m³ for the Prosperidade gas field and approximately 65,000m³ for Mamba) and will be discharged at the manifolds in water depths of approximately 1,500m.

(4) IFC Environmental, Health and Safety Guidelines for LNG Facilities.

shipment. The Subsea Production System is controlled by an onshore control system, which operates valves and chokes, monitors sensors and gathers data. All necessary utilities will be supplied by the onshore control system. Pressurised biodegradable hydraulic control fluid, necessary to open subsea valves on the trees and manifolds, will be delivered through tubes in the umbilicals. Chemicals injected in the gas stream subsea to inhibit hydrate formation, corrosion and scale build-up will similarly be distributed by the umbilicals. The chemical injection is a closed loop process and will be contained within the production system.

4.3.9 *Future Expansion of Offshore Components*

Future expansion of the Subsea Production System may be needed, based on future exploration activities, global demand for LNG and potential cooperation with other oil and gas operators within the region. As the Subsea Production System is being designed to match the capacity of the onshore LNG Facility, expansion of the production capacity of the Project may require the expansion of the Subsea Production System.

The initial onshore control system is designed to accommodate the delivery of up to 6 BCF/day via the supply pipelines. The pipeline system will be designed to allow for the tie-in of additional pipelines to accommodate future expansion. But should additional pipelines be tied in, the maximum delivery rate of 6 BCF/day will be exceeded, which will necessitate the upgrade of the onshore control system. Present assessments indicate the earliest possibility for such expansion would be 10 years after the start of production (2028). In the event that supply and demand necessitates the need for the expansion of this system, an EIA process will be initiated to permit such activities.

As discussed previously, the reservoir and fluid properties of the gas fields indicate the Project will not require the offshore compression and processing capabilities of an FPU for the initial development. If necessary, the installation of an FPU will be defined at a later stage of production life. Therefore, a floating processing facility is not included in the scope of the EIA. If required for future expansion, an EIA process will be followed to permit the installation of an FPU.

4.4 *ONSHORE PROJECT DESCRIPTION*

4.4.1 *Introduction*

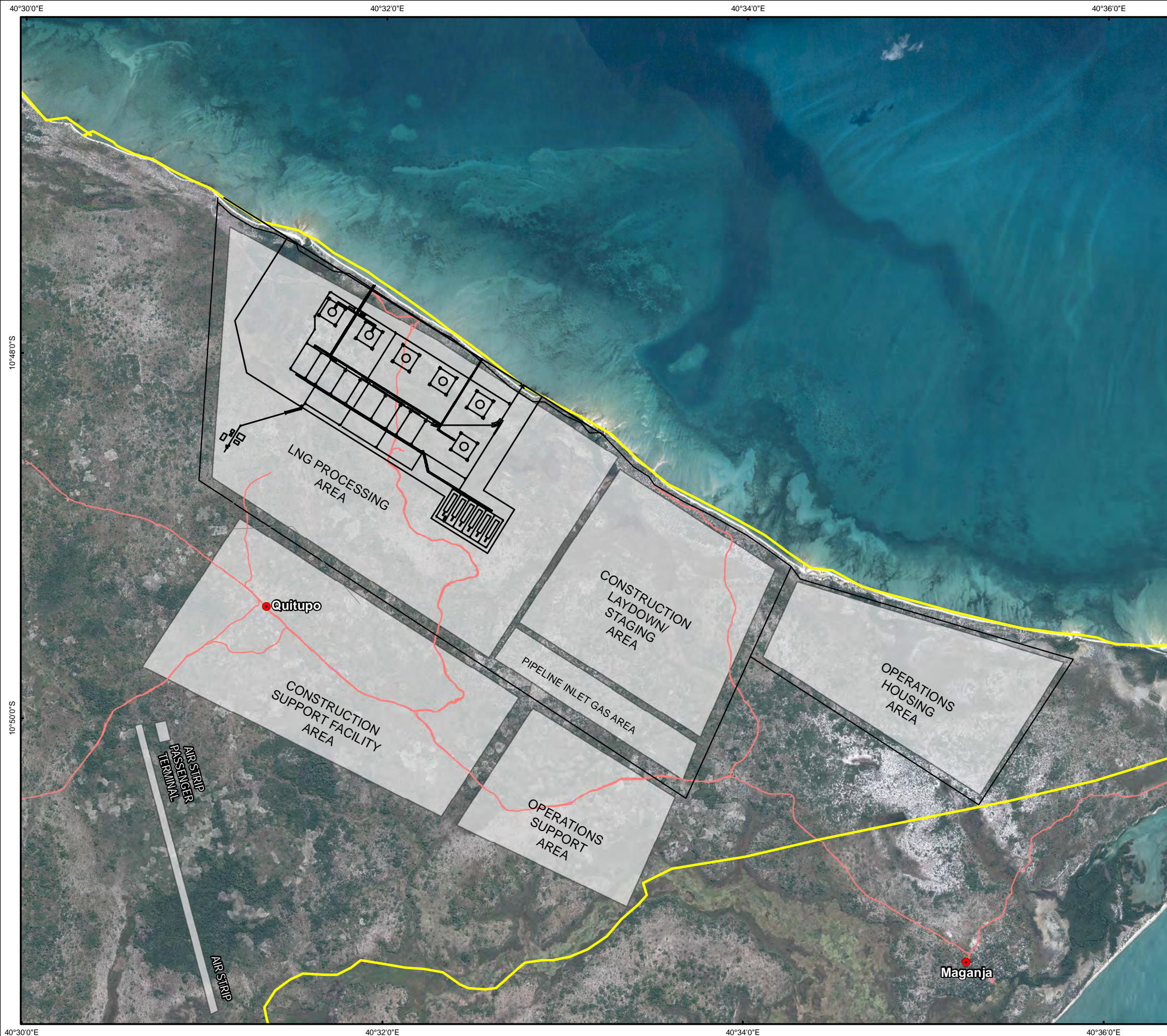
The Onshore Project component will include the LNG processing facilities and supporting infrastructure (eg worker accommodation facilities, construction areas, access roads, utilities, control systems and airport). The onshore component of the Project will be initially designed to receive, pretreat and liquefy lean offshore gas sufficient to supply the LNG Facility. The current plan is initially to construct two Trains and ramp up to six Trains (with a total nominal capacity of approximately 30 MTPA) as gas production increases,

although the size of the individual Trains could vary. The construction schedule will be further defined.

4.4.2 *Overview of Onshore Facilities*

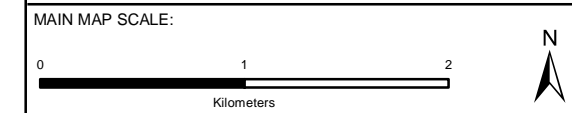
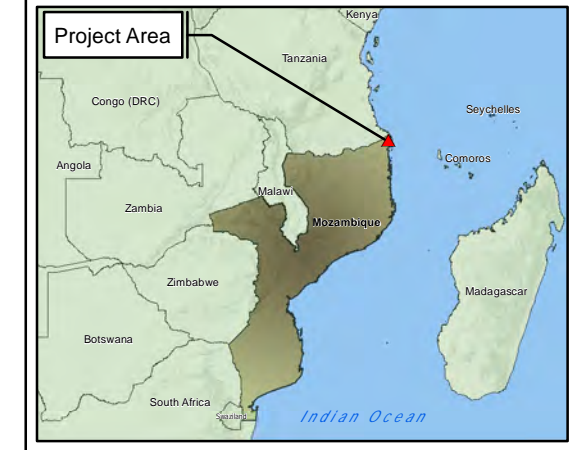
The LNG Facility will convert natural gas, supplied via pipeline from the Subsea Production System, into a liquid ⁽¹⁾ and store it for delivery for export via LNG Carriers. AMA1 and eni intend to initially construct two LNG trains, with the construction of additional trains at a later stage. It is anticipated that construction will begin towards the end of 2014. While this EIA covers up to 6 trains (which is a reasonably foreseeable number of trains), space for the construction of up to 14 LNG Trains (in total) has also been allocated. This is to cover any future growth on the Afungi Project Site and is aligned with ENH's plans for consolidating future gas projects into one LNG Park. This area will include laydown space, warehouses, fabrication shops and office space. Therefore, the land allocation includes space for up to 14 LNG Trains, the other associated utility systems, operations/maintenance work areas, a 7,000 to 10,000 person construction camp, and an airport consisting of a 3.5km airstrip and associated infrastructure. The total area granted for the Project is approximately 7,000ha. A conceptual image of the proposed Onshore Project Footprint Area is provided in *Figure 4.12* and is discussed in the section that follows. As discussed throughout this EIA Report, AMA1 and eni have strived to minimise the Project layout. The final LNG Facility layout will be produced as part of FEED.

(1) The process of converting the gas to a liquid, referred to as cryogenic liquefaction, involves treatment of the gas followed by a refrigeration process that will reduce the temperature of the gas (to -163 degrees Centigrade) until it condenses into a liquid.



Legend

- Villages / Settlements
- Local Roads
- Onshore Project Footprint
- Afungi Project Site



TITLE:
**Figure 4.12:
 Indicative Onshore Project Footprint Area**

CLIENT:

Anadarko
 Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: KG	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 37 000
DRAWING: Indicative Onshore Project Footprint Area.mxd		REV: A

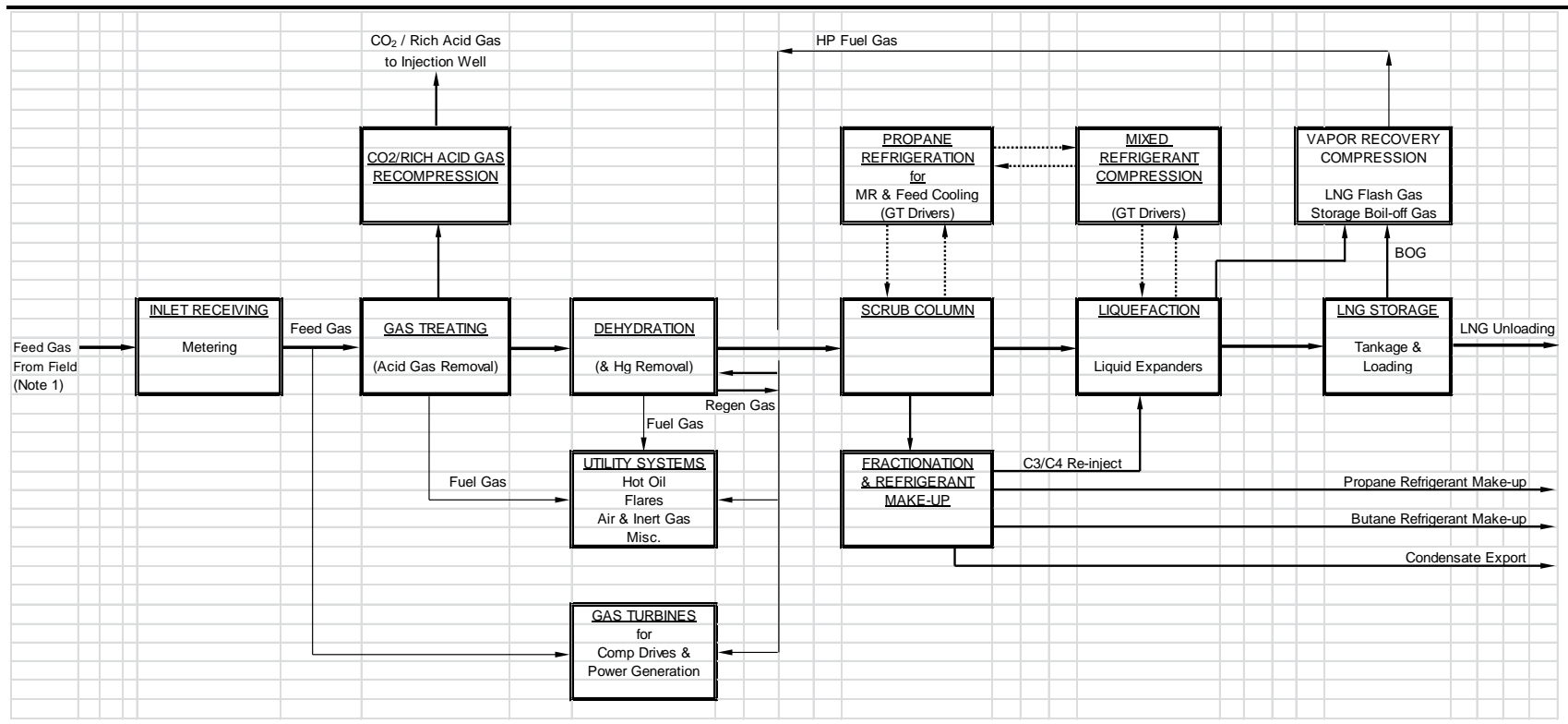
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Projection: UTM Zone 37 S, Datum: WGS84	SIZE:
Source: Promap, 2012. AMA1, 2011.	A3
Inset Map: Esri Data & Maps	

LNG is produced by cooling natural gas below its condensing temperature of negative 163°C and storing it at near atmospheric pressure. Once liquefied, the gas volume is one six-hundredth of its volume in its gaseous form, making it more economical to transport and store.

The LNG Facility will receive raw natural gas and associated liquids from the subsea gas pipelines. This raw gas will undergo pre-treatment to remove acid gas (carbon dioxide - CO₂ - and possible presence of hydrogen sulphide - H₂S), heavier hydrocarbons, water (dehydration) and mercury. The equipment to remove mercury is a precautionary measure, as tests to date do not indicate mercury will be of concern in the gas produced from the offshore reservoirs. The treated and dehydrated gas stream will then be routed to a liquefaction unit in which it will undergo multiple stages of chilling, with each sequential stage resulting in the gas stream being cooled and partially liquefied at the lower temperatures provided by the refrigeration cycle. The product from the final chilling stage will be higher pressure LNG, which will then be transferred, after pressure reduction to LNG storage tanks for storage prior to export. *Figure 4.13* provides a diagrammatic representation of the LNG process.

Figure 4.13 Typical LNG Process Flow



Inlet Facilities and Slug Catcher

The inlet facilities and slug catcher includes facilities required to receive gas supplied by the offshore pipeline transport systems (feed gas) and separate them into gas, heavy hydrocarbon liquid (mainly condensate) and rich MEG, and regulate the pressure to that required by the processing facilities. The actual gas composition from the offshore fields will determine the quantities of liquids that are produced. Depending upon the quantities produced, the heavier hydrocarbons may be used as plant fuel or exported. In light of this uncertainty, the current plan is to develop process and storage facilities for condensate.

Condensate Handling System

Current assessments of the gas composition indicate the production of approximately 3,000 to 5,000 barrels per day (bpd) of condensate per LNG Train is likely to be derived as a by-product of gas processing. Gas and liquids entering the facility from the gas pipelines are received in the inlet slug catchers and separated into individual streams. The liquid (condensate) is mixed with other liquid hydrocarbons collected from latter stages of the LNG liquefaction process described below. The condensate then undergoes further processing prior to storage in dedicated condensate storage tanks. Preliminary planning is for up to three condensate storage tanks, each with 300,000 to 650,000bbl capacity. Condensate will ultimately be offloaded to marine tankers for export.

Gas Pretreatment

Following condensate separation, the feed gas will be directed to the acid gas removal unit. This unit will remove potential impurities, such as CO₂ and H₂S, from the feed gas stream to produce a gas stream suitable for further processing. If present, these compounds would otherwise freeze when the gas is liquefied, and could impede the liquefaction process.

Dehydration

Prior to liquefaction, all moisture needs to be removed from the gas stream to prevent hydrate formation, which would result in freezing and the blockage of flow in the liquefaction process. Treated gas from the acid gas removal unit will be cooled to condense and remove the bulk of the water, which will then be returned to the acid gas removal unit. The gas will then be treated further to remove the remaining water to below 1 part per million by volume (ppmv) in the gas.

Mercury Removal

Should there be any mercury in the gas, it will be removed in the Mercury Guard Bed Unit to prevent aluminium in downstream equipment from becoming brittle. Mercury that is removed is captured on the absorbent bed

and remains there until the saturated bed is ultimately changed out and disposed of by the bed supplier during regularly scheduled maintenance.

Liquefaction

Liquefaction of natural gas into LNG will be performed using one of the two proprietary liquefaction process technologies common to the industry ⁽¹⁾. While the desired technology is at present unknown, the processes are similar to the extent that neither introduces a new aspect into the Project that would result in the potential for additional impacts – therefore any potential impacts will not be dependent on the liquefaction process technologies.

The decision on the preferred technology will be a product of the FEED studies. The Air Products and Chemicals Incorporated process uses propane and multi-component refrigerants ⁽²⁾ and a main cryogenic heat exchanger to liquefy the gas into the LNG product. The ConocoPhillips Optimized Cascade™ process uses a cascade process where natural gas is chilled in successively colder heat exchangers that use propane, ethylene and methane as refrigerants.

After liquefaction, the product leaving the process is LNG ready for storage.

LNG Storage

The LNG tanks will store the final liquefied product until it is transferred, via insulated pipeline, to specially designed LNG carrier vessels for shipping to global markets. Studies are presently ongoing to determine total LNG storage tank capacity. At present, it is estimated three LNG storage tanks of approximately 180,000m³ net capacity will be installed for up to four trains. All tanks will be of full-containment design. ⁽³⁾

Flare System

High pressure/low pressure flare systems including flare headers will be incorporated into the LNG Facility design to, in the event of an emergency:

- provide over pressure protection of the equipment and piping;
- direct all flammable or toxic gas releases to a safe and environmentally acceptable disposal route;

(1) Air Products or ConocoPhillips liquefaction technologies are used at 90 percent of all LNG facilities. Both technology options are technically acceptable and will be evaluated further during the ongoing engineering design stage.

(2) Within the Air Products and Chemicals Incorporated suite of technologies, there are several options: Single Mixed Refrigerant (SMR), Dual Mixed Refrigerant (DMR) and Propane Pre-cooled Mixed Refrigerant (C3MR).

(3) Full-containment tanks typically feature a primary liquid containment open-top inner tank and a concrete outer tank. The outer tank provides primary vapour containment and secondary liquid containment. In the unlikely event of a leak, the outer tank contains the liquid and provides controlled release of the vapour.

- dispose of flammable or toxic gas releases in a manner that poses minimum risk to personnel or to the environment;
- provide non-emergency depressurisation capabilities for offshore associated gas and non-associated feed gas pipelines; and
- provide depressurisation capabilities for routine maintenance and start-up and shutdown activities.

4.4.4 *Onshore Components of the Project – Supporting Project Infrastructure*

The LNG Facility will be supported by the following key facilities and infrastructure:

- temporary and permanent accommodation facilities;
- temporary and permanent utilities:
 - fuel gas system,
 - power generation and distribution,
 - water desalination plant,
 - water wells and water treatment,
 - sewage and waste treatment facilities, and
 - communication infrastructure;
- buildings to accommodate:
 - administration,
 - recreation,
 - training facilities,
 - health facilities,
 - control rooms,
 - warehouses,
 - maintenance shop, and
 - security;
- infrastructure to support logistics:
 - roads, and
 - airport;
- storage facilities for the following:
 - refrigerants,
 - water, and
 - fuel.

While exact locations and layouts are unknown at this stage, the above infrastructure will be within the LNG processing area, operations housing area, construction support facility area and operations support area, as indicated in *Figure 4.12*.

Construction of the Onshore Project

A phased approach to construction will be employed for the Onshore Project. The Engineering, Procurement and Construction (EPC) Contractor will be responsible for the detailed final design of the LNG Facility (Onshore and Near Shore Projects) and supporting infrastructure, in addition to the procurement and delivery to site of nearly all equipment and materials. In addition, the EPC Contractor will provide all required fabrication, supervision, inspection, testing, project management, commissioning and start-up. The Contractor will provide experienced personnel and be responsible for compliance with all applicable Mozambican safety and environmental regulations, standards and permit conditions, as well as adherence to AMA1 and eni policies to comply with all legal requirements applicable during the construction phase of the Project. Moreover, all contractors and subcontractors will be contractually obliged to comply with relevant management measures in the Environmental and Social Management Plan (EMP) (*Annex D*), with monitoring and reporting at both Contractor and AMA1/eni levels. The following text provides a description of the phases of construction in the order in which they will occur.

Afungi Site Improvements

The site improvement activities are intended to upgrade existing infrastructure and make minor preparations to facilitate the construction phase, should the Project be approved. The site improvement activities are part of the Usage Plan presented under the scope of Land Use and Benefit Rights (DUAT) process (and hence outside the scope of this EIA), but are noted here to provide an understanding of the initial site activities. At present, it is envisioned that this scope of work will include the following activities:

- limited clearance of vegetation and unexploded ordinances (UXOs) in the site improvement areas;
- improvement of the existing Afungi Peninsula access road from the main road (247) into the centre of the LNG site;
- improvement of Palma Hill Road (from the city centre to the old dock);
- improvement of existing roads on Afungi Peninsula;
- establishment of a radio tower for communication purposes;
- drilling of six water wells on the site;
- establishment of a concrete block production facility; and
- establishment of a Pioneer Camp.

During the Afungi Site Improvement phase, the Project will establish the rudimentary infrastructure necessary to support a limited workforce. It is currently envisioned that the following utilities will be established for the Pioneer Camp:

- electrical power generation;
- potable water (to be sourced from wells or desalination plant);
- sewage treatment;
- waste handling and disposal; and
- fuel storage for power generation, construction equipment and vehicles.

A Pioneer Camp area of approximately 3.5 ha will be established to accommodate approximately 400 personnel. This Camp is anticipated to be constructed in the southern portion of the Afungi Project Site and will be self-sufficient in power, communications, water treatment, sewage treatment and waste management. The majority of this infrastructure is anticipated to be modular. Therefore limited site preparation activities will be required in advance of the establishment of these components. The modular equipment will be transported to site (likely by road), assembled in place, and be in an operational state in a matter of days or weeks.

Road transport is anticipated for the delivery of raw materials necessary for foundations such as aggregate and gravel. Given the uncertainties associated with volumes of traffic and transportation routes at this early stage, the Project will develop a Methods Statement that addresses traffic and safety issues associated with the road transport of materials. This will be developed once there is more certainty on the origin of materials, volume of traffic and associated transportation routes.

The establishment of a block manufacturing facility was identified as a crucial activity for this phase of the Project. This will create training and job opportunities in the area, while allowing the Project to develop a stockpile of locally produced building materials for Early Works construction (discussed in the next section). An additional block manufacturing facility may be constructed in the town of Palma. This facility will manufacture the pavers to be used for Palma Hill Road, and blocks that can be used for possible construction projects to improve the Palma community as well as for the LNG Facility and associated infrastructure.

The Afungi Site Improvement phase of the Project is anticipated to require a workforce of approximately 400, which may include more than 200 Mozambican nationals.

Early Works

Site preparation activities will be required in advance of the primary construction phase. This phase of work will expand on the activities started in the Afungi Site Improvement phase and are anticipated to begin following MICOA approval of this EIA. The aim of the Early Works activities include

site preparation to create a stable and level platform on which the Project infrastructure can be erected, and the development of logistical infrastructure (marine and airport facilities) to bring materials and personnel to the site. The site preparation work will comprise land drainage, site clearance, site reclamation and the construction of infrastructure. Planned activities include:

- clearing vegetation and UXOs within the Project Footprint Area;
- erecting security fencing;
- expansion of the Pioneer Camp/ establish Construction Camp;
- establishment of the Pioneer Dock;
- establishment of preliminary framework for Multi-Purpose Dock;
- dredging of an access channel and turning basin in Palma Bay;
- site levelling and grading;
- constructing access and haul roads; and
- establishment of a Pioneer Airstrip (1,700m improved grass airstrip).

Before the area can be safely developed by the Project, it must be completely cleared of UXOs through the use of mechanical flails ⁽¹⁾. In order to verify the Project Footprint Area is free from explosives, the vegetation will be removed down to ground level, and will include the excavation and removal of all stumps larger than 10cm in diameter. The removal of grass and scrub vegetation will effectively occur simultaneously with flailing activity, as the flail will uproot this vegetation and remove vegetation less than 20cm in diameter. The trees that remain after the passing of the flail will be removed by mechanical means such as bulldozers or excavators. *Figure 4.14* indicates the area subject to this degree of UXO and vegetation clearance. The remainder of the Afungi Project Site will undergo limited UXO clearance without the removal of trees or the use of mechanical flails.

(1) UXO clearance will normally employ a combination of mechanical flails followed by mine detection dog teams. A flail works by rotating a band of chains and/or spines, which strike the ground and serve to detonate or disable any surface UXO present. Any detonations during flailing as well as any indications by the mine detection dog teams will require a manual clearance team to cover the immediate area. Once the flailing is completed, mine clearance teams will work the area using electronic current detection equipment to a depth of 2.5m to ensure that the area is free from explosives.

40°30'0"E

40°32'0"E

40°34'0"E

40°36'0"E

10°46'0"S

10°46'0"S

10°48'0"S

10°48'0"S

10°50'0"S

10°50'0"S

10°52'0"S

10°52'0"S

40°30'0"E

40°32'0"E

40°34'0"E

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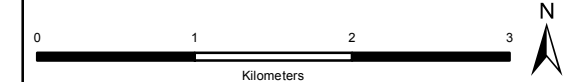


Legend

- Villages / Settlements
- Local Roads
- Onshore Project Footprint
- Afungi Project Site
- UXO Clearance Area



MAIN MAP SCALE:



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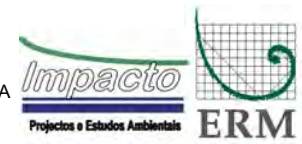
Figure 4.14:
Early Works Layout –
UXO Clearance Areas

CLIENT:



DATE: Oct 2013	CHECKED: KG	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 48 000
DRAWING: Early Works Layout – UXO Clearance Areas.mxd		REV: A

ERM
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 240 Main Road
 Rondebosch, 7725
 Cape Town, SOUTH AFRICA
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 Fax +27 21 686 073



Projection: UTM Zone 37 S, Datum: WGS84	SIZE:
Source: Promap, 2012. AMA1, 2012.	A3
Inset Map: Esri Data & Maps	

Following the clearance of vegetation and UXOs, the site will be graded and levelled. During this process, topsoil will be stripped and stockpiled separately from subsoil for future use in rehabilitation and revegetation. Simultaneously, the Pioneer Dock will be established to allow the import of heavy equipment and materials to the site ⁽¹⁾, and dredging will be conducted in Palma Bay to provide marine access to the Pioneer Dock. This is discussed in detail in *Section 4.5.4* but bears note here as the dredged material from the creation of these access channels may be hydraulically placed in settling basins onshore. Once dewatered, the dredge material may be used onsite to provide additional fill material (sand) for the construction of the Near Shore Project infrastructure, and to achieve the required height and stability to allow the construction of the LNG Facility and ancillary supporting infrastructure.

As the initial stages of the site preparation works commence (ie UXO clearance and vegetation removal), it will be important to define the boundary of the proposed facility area. Fencing will be erected for security and safety purposes and signs will be posted around the perimeter of the construction area advising the public not to enter the site. In addition, security staff will be used to prevent unauthorised access to the site.

A heavy-haul road from the MPD will be developed to transport materials and equipment shipped in for the construction phase of the Project at the site. This road will be located entirely within the Project Footprint Area and is proposed to be approximately 3km to 5km in total length and 12m to 16m wide. The road will connect the construction areas to the Pioneer Dock and MPD.

Site-specific best management practices will be developed to prevent erosion, manage stormwater, facilitate insect control and reduce the likelihood of adverse environmental impact during this and future phases of construction and permanent operations.

The early works phase of the Project is anticipated to require a workforce of approximately 1,000; 400 of whom are planned to be Mozambican nationals.

Construction Phase

The timing of the construction phase will be further refined during FEED, and the construction and installation procedures will need further development through discussions with potential EPC Contractors. However, the current estimated duration of the construction phase is anticipated to span approximately 48 to 54 months and is planned to begin in 2014. The primary objective of the Project during this phase of construction will be to develop the infrastructure necessary for the development and operation of the Project.

(1) Once the Pioneer Dock has been established, it is envisaged that the majority of material and equipment will arrive on site via sea; however, the network of improved roads may still be used, although to a lesser degree.

Constructing the onshore facilities includes, but is not limited to, earthworks; piling; concrete foundations; welding; installation of pipe racks, tanks, piping, power and control systems; construction of the permanent airport; all roads; erection of permanent buildings; and utilities and services. Large cranes will be used to offload and assemble large equipment items on site. Tower cranes will be assembled on site for the erection of various facility items, particularly piping erection and equipment setting. Smaller mobile cranes will move construction materials and equipment around the site. Essentially, all major construction equipment and components required will be imported into Mozambique. Portions of the LNG Facility are likely to be constructed using modules prefabricated at other locations, transported to site and interconnected. The following discussion provides an overview of the activities associated with the construction phase.

Concurrent with site preparation, foundations will be installed to support the facilities and equipment. Various laydown areas, workshops and other temporary buildings will be required. Piles or ground improvement methods will likely be used during the construction of the LNG Facility and tank foundations, to support the heavy equipment and modules. Lighter structures and equipment will be supported by foundations laid directly on compacted soil. Concrete for these foundations will likely be supplied by onsite concrete batching plants. It is expected that the requisite raw materials, such as aggregate and gravel, may be sourced from an existing quarry in Mozambique. In the event that no existing quarry is identified, the materials may be sourced from a foreign market. In either case, the material will likely be transported to the site by sea ⁽¹⁾. Once foundations have been established, the piping, electrical and mechanical installations for the process equipment and ancillary facilities will begin.

Materials and equipment required for construction of the LNG Facility include processing equipment such as heat exchangers, gas turbines, gas compressors and power generators; steel for onsite construction of the LNG storage tanks, flares, pipe racks and insulation; and package utility plants such as the water treatment plant. Some of the components of the LNG Facility, power generation unit and primary utilities may be modularised and arrive onsite as skid-mounted packages, while others will be constructed completely onsite using a stick-build ⁽²⁾ construction approach. The interconnecting pipe racks, utilities and other equipment may also be either modularised or erected onsite using a stick-build approach.

Supporting infrastructure such as worker accommodations, offices, health facilities, warehouses and similar structures will likely be constructed using a stick-build process. Virtually all of the building materials and prefabricated modules will be brought to the site by sea.

(1) In the event that sea transport of aggregate and gravel is not feasible, a Method Statement and transportation safety analysis will be conducted for the road transport of raw materials.

(2) The stick-build process refers to construction onsite from the ground up.

An airport will be developed within the Afungi Project Site. The airport will include a 3.5km runway designed to accommodate commercial jet airliners and heavy transport aircraft such as the Antonov-124 ⁽¹⁾. The airport will include a control tower, terminal, administrative buildings, hangers, refuelling areas and access roads connecting the airport to the LNG Facility and to Palma. However, much of this infrastructure will be added over time as the Project expands beyond the first two LNG Trains. The location of the airport was selected for safety reasons and takes prevailing wind directions into account.

A supply of water will be required for all phases of construction for dust control, soil compaction, concrete works and for the hydrotesting of storage tanks and other equipment and piping. A supply of potable water for the construction workers is also required. Surface water run-off will likely be stored for use in dust control, as fire water and for hydrotesting purposes. This water source will be supplemented by desalinated seawater as necessary.

Virtually all material transported into the area during the construction phase will be transported to the site by sea. Most of the on-land vehicle traffic will be within the Project Footprint Area. The local transportation system may see some heavy-haul vehicles and light truck traffic. However, volumes are expected to be minimal. There will also be traffic from the local labour force and non site-related travel of the onsite staff.

The construction phase of the Project is anticipated to require a workforce of approximately 7,000 to 10,000. Approximately 20% of the workforce for the construction of the first LNG Train is envisaged to be Mozambican nationals. The construction of subsequent LNG Trains will see an increase of local labour as training and capacity of the workforce is enhanced.

4.4.6 *Commissioning of the Onshore Project*

It is anticipated that the commissioning period for the LNG Facility may extend as long as six to eight months, including a two-month start-up. The key issues during commissioning are flaring (discharge of burned gas), venting (discharge of unburned gas), and the disposal of hydrotest water used in integrity testing.

Flaring and Venting

Flaring occurs during the commissioning period as separate components of the LNG Facility are tested. Until the final gas quality is reached, all hydrocarbons entering the production facility must be flared or vented to the atmosphere. Venting of the pipe system may be necessary during commissioning. Such venting will be conducted in a manner that does not

(1) The Antonov-124 is a large, heavy-load aircraft requiring specific airstrip design standards.

cause undue risk to the environment and local community (ie when atmospheric conditions will carry the unburned gas away from populated areas). Venting will be minimised wherever practical, and will be conducted in a manner that reduces the likelihood of adverse impacts on the environment to ALARP (as low as reasonably practicable) levels.

A limited amount of flaring will be inevitable during the commissioning phase. The largest flare volumes will occur during the start-up period. The amount of flaring will be confirmed during the ongoing FEED process. Anecdotal evidence from similar projects indicates flaring during commissioning and start-up may initially occur for roughly 50 hours per week, falling to 30 hours per week by the end of the first month and 10 hours per week by the end of the second month. Thereafter, commissioning and start-up will be complete and the operational phase will ensue.

Once operational, there will be no routine flaring or venting during standard operating conditions. However, facilities for the immediate release of gas, through venting and/or flaring, are necessary to ensure the safety of the facility in emergency situations as well as during shutdown, start-up and maintenance activities. Gas flared from non-routine flaring is expected to be less than 1 percent of the total emissions.

Hydrotesting

A large volume of water is required to hydrotest the LNG storage tanks during the commissioning phase. To the maximum extent possible and depending upon timing of offshore and onshore construction, the water used for integrity testing of the subsea pipeline system could also be used for hydrotesting of the LNG storage tanks, LNG processing system, pipelines and other facility components. If necessary, additional water will be sourced from either impounded stormwater or desalinated sea water. After testing, the water will be returned to storage ponds and may be used for dust control and for making concrete in the batch plant operations. The remaining hydrotest water will undergo treatment prior to discharge into Palma Bay.

4.4.7 *Operation of the Onshore Project*

LNG processing requires a series of feed gas pretreatment stages, followed by liquefaction, storage and finally export. The pretreatment process is standard for LNG applications and includes inlet gas treatment, acid gas removal, dehydration and mercury removal. Impurities (including CO₂, water and mercury) are removed before the gas enters the liquefaction section of the LNG Facility. Liquefaction of natural gas into LNG will be performed using one of the two proprietary liquefaction process technologies common to the industry. After liquefaction, the product leaving each process is LNG ready for storage and eventual transport to the global market.

The LNG Facility will be designed for a 30-year minimum service life. During that time, operations will be continuous and operated in compliance with

applicable Mozambican regulations and relevant IFC Environmental, Health and Safety Guidelines ⁽¹⁾. Activities associated with LNG production over the life of the Project will include:

- operation and maintenance of the LNG processing equipment and supporting facilities (power, water and waste management);
- operation and maintenance of the permanent operations camp;
- operation and maintenance of logistics facilities (to and from the Project area via land, sea and air); and
- site security.

It is anticipated that the LNG Facility will be routinely operated by two 12-hour or three eight-hour shifts per day. Typical operational staff will consist of approximately 400 personnel; the facility will be manned and operational 24 hours per day. In addition to the core operational workforce, personnel will be required to perform shutdowns of the LNG Trains for maintenance. Routine maintenance will occur once every two to three years and will result in the shutdown of a single Train for up to a month for maintenance. During this time, gas flow will be reduced and routed to the remaining Trains for processing, storage and export. Major shutdowns are generally scheduled every few years and will require an additional workforce of 300 to 500 personnel, depending on scope. Minor shutdowns may occur more frequently and will require an additional staff of approximately 50 to 100 personnel.

The LNG Facility is expected to reach 98 to 99 percent reliability, excluding planned maintenance. Therefore, the facility would be down due to unplanned shutdowns only 1 to 2 percent of the time. To minimise flaring during shutdowns, the LNG Facility is being designed to stop the production coming from the Subsea Production System. Gas would be routed to the flare for only a fraction of the time (only if needed), while the facility is shutting down or being brought back up. Additional design features are included to minimise flaring (eg installation of spare equipment to allow continuous operation when individual units are down). Purge gas for the flare will be regulated to provide a minimum flow and prevent the entrance of air, which can create an explosive mixture.

Air traffic volume for construction and operational requirements will average two to three flights per week. Additionally, it is possible that the Project may provide bus transport for Mozambican workers from the surrounding area to

(1) Including the Environmental, Health and Safety Guidelines for Liquefied Natural Gas (LNG) Facilities; Environmental, Health and Safety Guidelines for Offshore Oil and Gas Development and the Environmental, Health, and Safety Guidelines for Ports, Harbors, and Terminals.

the Project site. Aside from these buses, Project vehicles are likely to be predominately confined to the Afungi Project Site.

Permanent worker accommodations will be designed and constructed to comply with the relevant Mozambican Codes and Standards as a minimum. These facilities will provide accommodation for approximately 400 workers. The camp will be operational at least six months prior to LNG production start-up. Facilities and buildings associated with the operational phase of the Project are anticipated to include:

- worker accommodation;
- kitchen and dining areas;
- laundry facilities;
- lounge area, game rooms, fitness centres and recreational areas;
- medical clinic;
- camp office and reception area;
- maintenance workshop;
- training centre;
- warehousing; and
- guard house.

Operation of the LNG Facility will require a high level of skilled and semi-skilled personnel. Initially, it could be expected that some of these jobs will be filled by Mozambique citizens, with an increase in the proportion of local workforce in each subsequent year as training and experience enhance local capacity.

4.4.8 *Future Expansion*

The Project intends to pre-invest in key components of infrastructure (such as pipelines and additional space for onshore facilities) to facilitate the safe construction of future expansion without requiring the operational facilities to be shut down. Similar to the expansion of the Subsea Production System, the timeline for future expansion of the Project and the construction of additional LNG Trains is dependent on supply and demand. The timing of this development will be dictated by a number of factors, such as the results of future exploration campaigns, potential collaboration with other oil and gas operators, and global demand for LNG. However, current estimates presume this expansion may begin as early as 2020. Where required, such expansion actions will undergo an EIA process to satisfy regulatory requirements.

4.5 *NEAR SHORE PROJECT DESCRIPTION*

4.5.1 *Introduction*

The Near Shore Project components comprise the marine facilities associated with the export of LNG, and logistics support facilities needed for construction and to maintain the operational effectiveness of the Project infrastructure. The marine facilities will evolve over time to support the operational phases of the Project.

The final Near Shore Project design will also be developed as part of the same FEED process used for the design of the Onshore Project components. The designs of the jetties, mooring and dolphin systems ⁽¹⁾ will be in alignment with industry-recognised codes and standards.

4.5.2 *Near Shore Facilities System Overview*

The Near Shore Project comprises the interconnection of the marine facilities in Palma Bay (not associated with bringing gas to shore) and Onshore components of the overall Project. This component of the Project includes the MPD, LNG Export Jetty', mooring dolphins, navigation channel, navigation aids and the LNG loading facilities and serves as the central hub for the development of all aspects of the Project, from construction to the eventual export of LNG to the global market. The proposed locations of these components are depicted in *Figure 4.15*.

(1) A dolphin is an isolated marine structure for the berthing and mooring of vessels.

40°32'0"E

40°34'0"E



10°48'0"S

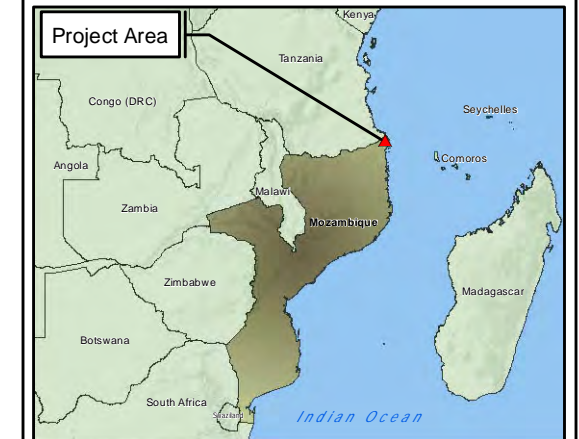
10°48'0"S

40°32'0"E

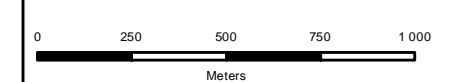
40°34'0"E

Legend

- Local Roads
- Near Shore Components
- Onshore Project Footprint
- Afungi Project Site



MAIN MAP SCALE:



TITLE:

Figure 4.15:
Layout of Near Shore Components

CLIENT:

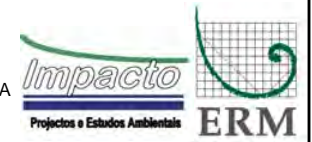


DATE: Oct 2013	CHECKED: KG	PROJECT: 0133576
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DRAWN: AB	APPROVED: KG	SCALE: 1 : 20 000
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DRAWING: Layout of Near Shore Components.mxd	REV: A
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Projection: UTM Zone 37 S, Datum: WGS84
Source: Promap, 2012. AMA1, 2012.
Inset Map: Esri Data & Maps

SIZE: A3

During the construction phase of the Project, the marine facilities will be developed to accommodate the import of construction materials. The MPD will be located adjacent to the proposed LNG Facility; this will serve as a heavy-load construction dock. The MPD will be designed to accommodate vessel mooring, equipment offloading, laydown and storage areas, as well as routine vessel maintenance. However, the Project will contain no dry dock facilities.

During the operational phase of the Project, the MPD will include facilities to accommodate the marine harbour fleet. It is anticipated that the marine harbour fleet will consist of escort tugs, line handlers, pilot boats and response boats/equipment necessary to provide safe navigation and manoeuvring of the LNG Carriers and, potentially, other offshore infrastructure support vessels.

The LNG Export Jetty will be located along the Afungi coastline north of the LNG Facility. It is anticipated ultimately to comprise two 2,000 to 3,000m long causeway and trestle jetty structures with associated berthing and LNG loading facilities. The LNG Export Jetty will initially include two independent berths located at the end of the first trestle; a second trestle with up to four additional berths will be added in the future. Each berth will be designed to accommodate the LNG Carriers and will have a minimum water depth alongside of 15m at Lowest Astronomical Tide (LAT).

Support vessels, including a pilot boat, tug boats and general support vessels, will be active in the area during normal operations to assist with the safe navigation and manoeuvring of the LNG Carriers.

A safety exclusion zone of 500m will be established around the Near Shore facilities during construction. Once operational, a permanent safety exclusion zone of 500m will be established around the MPD and LNG Export Jetty and moving exclusion zones of 1,000m in front and 500m to each side will be established around all LNG carrier vessels during transit. No transport vessels or fishing will be allowed within the safety zones.

4.5.3 *Components of the Near Shore Facilities*

The Near Shore Facilities will comprise the following elements:

Pioneer Dock

The Pioneer Dock may be a temporary facility or it may be expanded or incorporated into the permanent Near Shore infrastructure. In the event that this is a temporary structure, it will be decommissioned and removed once the permanent facilities are developed.

Multi-Purpose Dock

The MPD will be established to support the primary construction phase of the Project and will avoid the need to transport heavy, large or unwieldy loads by road. The MPD is anticipated to be approximately 600m wide, extend 800m to 1,500m from the shoreline and stand approximately 10m above LAT. Vessel handling and materials offloading equipment will likely consist of 14 25t safe working load bollards (to facilitate vessel mooring) and two 80t bollards for Roll-on Roll-off vessels (to accommodate the offloading of large modular equipment).

The MPD will likely include a marine services facility on the eastern side of the MPD and will be sheltered by a breakwater. This area will accommodate the marine harbour fleet consisting of escort tugs, line handlers, pilot boats and response boats/equipment. Refuelling of support vessels will occur within the protected breakwater area of the marine services facility. It is expected that support vessels will be refuelled at a dedicated fuelling berth for both diesel (tugs) and gasoline (utility boats). No fuel storage tanks are proposed on the MPD itself; fuel will be transferred to the fuelling berth, via dedicated pipelines, from onshore fuel storage tanks. LNG Carriers will not be refuelled at the MPD.

LNG Export Jetty and Berthing Area

The LNG Export Jetty will link the LNG and condensate storage tanks with the LNG export berths. The design of the LNG Export Jetty will comprise up to two LNG berths connected to the onshore facilities by a combination causeway/trestle. The causeway will extend from the shoreline to the approximately 2m LAT depth contour, at which point an elevated roadway/pipeway trestle structure will extend to a water depth of approximately 15m LAT. The trestle is likely to be approximately 7 to 10m above LAT and have a total width of approximately 14m to accommodate a roadway and pipe rack, separated by concrete barriers. The causeway and trestle will be designed to support a minimum of:

- LNG loading and vapour return lines;
- condensate loading and vapour return lines;
- utilities;
- roadway capable of accommodating trucks carrying heavy loads, ambulances, small cranes and pedestrian traffic; and
- mooring and berthing facilities.

The vessel berthing area will be designed such that the largest vessels anticipated can moor without tidal restrictions. The LNG berth is proposed to comprise a loading platform, four breasting dolphin systems and six mooring

dolphins, designed in accordance with industry standards. These structures will be supported on piles, and access to the dolphins will be provided by catwalks. Loading of LNG will be conducted using multiple loading arms and one vapour return line, to allow vapours to flow back into onshore storage tanks for recovery instead of venting to the atmosphere. Each berth shall be fully outfitted with all processes and utilities, piping systems and equipment, so that either berth can be used to load LNG. For safety reasons, only one ship at a time will be loaded with LNG; however, a second vessel will be allowed to move to the berths.

The LNG Export Jetty will be designed to load one LNG carrier at a time initially. A second Export Jetty will be constructed to facilitate the loading of two LNG Carriers at the same time. The LNG Export Berth will be able to load LNG Carriers corresponding to approximate loading frequencies of:

- Train 1 – 5 MTPA: average one vessel per week;
- Train 2 – 10 MTPA: average two vessels per week;
- Train 3 – 15 MTPA: average four vessels per week;
- Train 4 – 20 MTPA: average six vessels per week;
- Train 5 – 25 MTPA: average eight vessels per week; and
- Train 6 – 30 MTPA: average 10 vessels per week.

Condensate will be offloaded to marine tankers of up to 650,000bbl capacity through either a berth in the MPD or the LNG Export Jetty. The offloading system options will be evaluated to minimise interference with other marine traffic, dredging requirements and overall cost. The frequency of condensate offloading is assumed to be once in two to three weeks.

Turning Basin and Access Channel

The LNG Export Jetty will be accessed by an approximately 15m LAT deep and 160m wide approach navigation channel, constructed by widening and deepening an existing channel in Palma Bay. The turning basin and areas access the channel will be dredged to a depth and size sufficient to enable LNG Carriers to manoeuvre safely and moor at the facility. The turning basin is likely to require the dredging of a 600m turning circle to allow large vessels to be positioned, by support vessels, to the berthing area of the LNG Export Jetty.

Vessels

The LNG carrier vessels typically range between 125,000 and 267,000m³ in capacity, with typical dimensions of length of 350m, beam width of 50m and draft of approximately 12m. Support vessels, including a pilot boat, up to four tug boats and general support vessels, will be active in the area during normal operations to assist with the safe navigation and manoeuvring of the LNG Carriers. Support vessels from the marine harbour fleet will be used during the operation of the LNG Facility and will be based at the adjacent MPD. Anticipated vessel types include:

- escort tugs;
- line handlers;
- pilot boats; and
- security and response boats.

4.5.4 *Construction of the Near Shore Project*

The construction of the Near Shore Project is anticipated to begin the first quarter of 2014 and extend for a duration of approximately 18 months. The activities associated with this development are discussed in the text below.

Dredging

The coastline of the Afungi Project Site is subject to a daily tidal fluctuation of approximately 4m. This, in addition to the shallow depth of Palma Bay, necessitates dredging to provide continuous vessel access. Dredging will be required to deepen and widen the existing natural channel to create a shipping approach channel to accommodate LNG vessel traffic. Dredging will also be required for construction of the export terminal facilities and MPD. A turning basin will be established to enable vessel access to the MPD and the berthing area adjacent to the export terminal facilities. As discussed in *Section 4.3.6*, dredging will also be required for the pipeline shore approach. Dredge material from these areas will likely be used for the development of the MPD and associated causeways. On completion of the dredging works for the turning basin and shipping channel, new permanent navigation aids for the shipping approach channel and turning basin will be installed.

It is anticipated that trailing suction hopper dredgers will be used for the majority of the dredging in the area of the access channel, turning basin, MPD and berthing area, as preliminary investigations indicate the seabed is primarily composed of sand. A portion of the dredged materials will be pumped ashore via a pipeline into purpose-built settling basins. Once dewatered, the dredge material may be used onsite to provide additional fill material (sand) for construction of the Near Shore Project infrastructure, and onsite to achieve the required height and stability to allow the construction of the LNG Facility and ancillary supporting infrastructure. The remainder will be disposed of in a predetermined offshore location.

While final dredging volumes will be established during further engineering, Pre-FEED estimates indicate that dredge volumes for the Near Shore Project are likely to be approximately 5.3 million m³. The equipment choice for dredging will be dependent on future planned geotechnical characterisation of the ocean floor within Palma Bay. Preliminary estimates indicate that maintenance dredging requirements will be minimal and occur at the most in the order of every three to five years.

Multi-Purpose Dock

Preliminary design for the MPD proposes a 300m-wide, dredge-filled causeway, rising from ground level at the shoreward end to approximately 2m above LAT at the seaward end; this will be confirmed during FEED. The MPD is likely to be constructed via dredge material mechanically placed into a sheet pile ⁽¹⁾ barrier. The sheet piles used in the construction of the MPD (and other components of the Near Shore Project) will be brought to site via barge. Conventional pile-drivers (impact or vibratory) will be used to drive sheet piles into the seafloor. Dredged material will initially be pumped into an onshore placement area, dewatered and mechanically placed into the causeway (ie by truck haul and/or conveyor system). To account for likely erosion, bunds may be over-constructed and maintained during construction until the final rock armouring is complete ⁽²⁾. The causeway surface will be finished with concrete to provide a cambered surface to support the movement of heavy cargo.

As the MPD will provide for the offloading of heavy cargo, it will require a dredged depth of approximately 10m below LAT to accommodate the heavy lift and Roll-on Roll-off vessels. Dredge requirements for the support vessel staging and mooring areas are likely to be 6m LAT.

LNG Export Jetty and Berthing Area

The LNG Export Jetty will consist of a combination causeway/trestle structure. As with the MPD, the causeway will likely be constructed via use of dredge material mechanically placed into a sheet pile barrier. The trestle will be a pile-supported structure with either steel pipe or concrete piles located at 15 to 30m spacing. The piles will be driven to a depth of 20 to 35m below LAT with conventional hydraulic or diesel impact hammers mounted on barges. Pile driving will move progressively seawards from the causeway; the surface of the trestle will be formed by connecting prefabricated sections to the top of the piles. These sections will be lifted into place by barge-mounted cranes and attached to brace the structure. The trestle will extend to the LNG vessel berthing area, which will consist of four breasting dolphins, six mooring dolphins and an approximately 40 x 30m loading platform.

The LNG export berth will be built at the seaward end of the trestle once the trestle is complete. The breasting and mooring dolphins will be supported by piles driven into place by barge. Once the piles are in place, a barge-mounted crane will be used to install precast supporting structures followed by decking, catwalks and mechanical and electrical works, as well as the LNG loading arms, vapour return lines and associated export berth utilities.

(1) Sheet piling is a construction form that utilises interlocking sheets of steel to create a continuous barrier in the ground. Primary applications of sheet piles include retaining walls and cofferdams erected to enable permanent works to proceed.

(2) Rock source to be determined - requires input from Quarry Study.

4.5.5 *Future Expansion*

The timeline for future expansion of the Near Shore Project (eg additional berthing areas) and the construction of additional LNG Trains is at present unknown and will be dictated by the results of future exploration campaigns, potential collaboration with other oil and gas operators, and global demand for LNG.

4.5.6 *Commissioning of the Near Shore Project Facilities*

The commissioning activities planned for the Near Shore Project components will be similar to those proposed for the Offshore and Onshore components of the Project. The piping system used to deliver LNG to the export facility will be commissioned at the same time as the LNG Facility and will simultaneously undergo hydrostatic, integrity and systems control testing. The boil-off gas recovery system will be tested to verify capability to recover vapours associated with the LNG storage, holding and loading operations; these vapours will either be routed to the fuel system or compressed and recycled back to the process. Occasionally, an LNG vessel would need to be cooled before accepting LNG. This usually happens when the vessel comes from a dry dock. In such a case, before cooling the vessel, a mixture of methane and inert gas would be flared for a few hours. Venting or flaring of boil-off gas is not expected during routine marine loading operations; however, limited amounts of venting and/or flaring are likely during commissioning.

4.5.7 *Operation of the Near Shore Project Facilities*

During the operational phase of the Project, the Near Shore components will serve primarily as the point of export for the processed LNG. However, this component of the Project is also essential to maintain the operational effectiveness of the overall Project infrastructure. As such, it will continue to serve as the primary hub for the import of materials necessary for the maintenance and future expansion of all aspects of the Project.

Multi-Purpose Dock

During operation of the LNG Facility, the MPD will be used only occasionally to unload equipment and materials for maintenance activities and construction of new LNG Trains. Normal quarantine and customs procedures will apply. The MPD will serve as a port, fuelling and staging area for support vessels ⁽¹⁾. These vessels will be active in the area during normal operations in order to assist with the safe navigation and manoeuvring of LNG Carriers.

(1) All waste from the vessels will be handled in accordance with MARPOL 73/78 requirements. Solid waste will be delivered to the onshore facilities as an integrated part of the onshore waste management system.

It is anticipated that each LNG Carrier will have service vessels that provide support for operations in the form of tugs ⁽¹⁾ and supporting vessels. The main tug activities will include:

- providing potential escort services for the LNG Carriers as they transit to the facilities;
- providing assistance to the LNG Carriers during berthing and unberthing operations at the LNG Export Jetty; and
- providing firefighting, rescue services and spill response as required.

The supporting vessels will likely consist of small utility boats to facilitate general operations and provide security. The main functions of the utilities boat(s) will include:

- mooring line transfer (depending on terminal operating procedures);
- general maintenance of facilities; and
- security.

Besides assisting during the LNG carrier berthing and unberthing operations, the utility boats may be in operation on a daily basis, fulfilling the various functions outlined above. It is conservative to assume that four utility boats may be required to support operations. Dedicated patrol boats will enforce the moving exclusion zone around LNG carrier vessels during the time that they are under pilot control.

LNG Export Jetty and Berthing Area

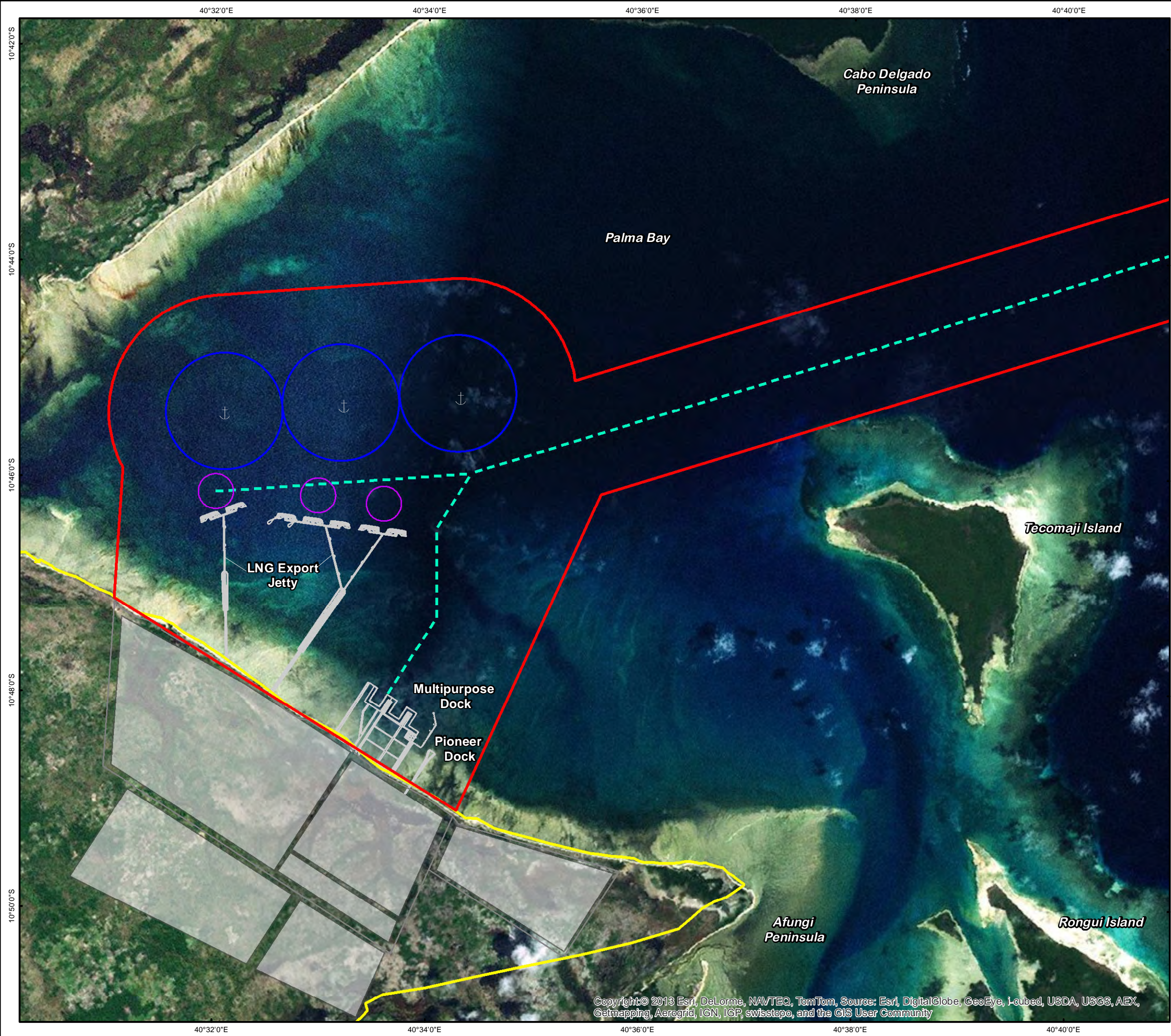
By the fourth quarter of 2018, the first LNG Train is expected to be operational. Initially, it is anticipated that the LNG Export Jetty will receive about four or five LNG Carriers and one or two marine tankers (for condensate export) per month. As LNG production increases, export vessel traffic will follow.

LNG Carriers will be met by pilot vessels before entering Palma Bay through the natural deepwater channel between Tecomaji Island and the Cabo Delgado Peninsula. The LNG Carriers will be escorted by pilot vessels to the LNG Export Jetty, where they will be manoeuvred into the berthing area by a fleet of tugs. This proposed route is illustrated in *Figure 4.16*. Fixed navigational aids (buoys) will be in place to delineate the channel boundaries and to mark shallow areas to be avoided. For marine safety reasons, only one LNG carrier at a time will be allowed to move to and from the LNG Export Jetty.

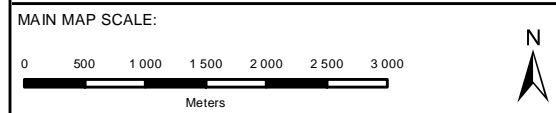
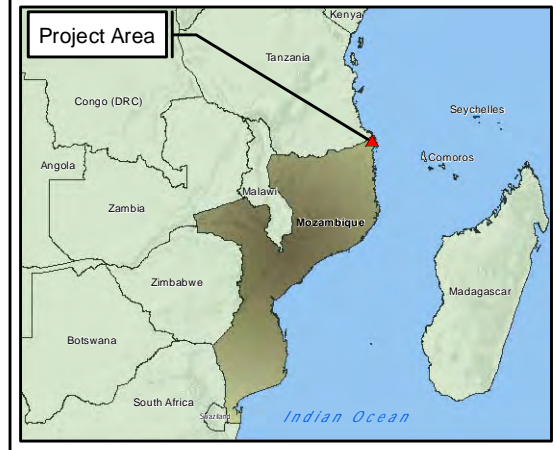
(1) Although the need for tug escort has not yet been verified, for the purposes of this document it is conservative to assume that it will be required. Tugs will likely be stationed at the MPD. At least three to four harbour tugs will be required for berthing and unberthing the LNG carriers. In addition, it is conservative to assume that two escort tugs may be required to assist LNG carriers as they transit to and from the LNG Export Jetty berthing area.

For safety and security reasons, vessels will be required to maintain a state of readiness for immediate departure at all times while moored at the LNG Export Jetty. While vessels are berthed, the Project will enforce a safety and security exclusion zone of 500m around the moored LNG Carriers. During LNG loading, this exclusion zone may be increased to 1,000m.

Once at the LNG Export Jetty berthing area, the terminal systems will load the LNG Carriers at approximately 12,000m³/h, resulting in an average turnaround time (from entrance to exit of Palma Bay) of approximately 24 hours. The loading of LNG will be conducted using three loading arms and one vapour return line, to allow vapours to flow back into onshore storage tanks. Once loaded, LNG will be stored aboard the LNG Carrier in insulated tanks located within the hull of the vessel, at -158°C.



- Legend**
- Near Shore Components
 - Onshore Project Footprint
 - ▭ Afungi Project Site
 - Vessel Turning Areas
 - - - Vessel Approach Route
 - Vessel Anchoring Areas
 - Limits of the Marine Operations



TITLE:
**Figure 4.16:
 LNG Carrier Access Route and
 Manoeuvring Areas**

CLIENT:

Anadarko
 Moçambique Área 1, Lda

DATE: Oct 2013	CHECKED: KG	PROJECT: 0133576
DRAWN: AB	APPROVED: KG	SCALE: 1 : 62 500
DRAWING: LNG Carrier Access Routes & Manoeuvring Areas.mxd		REV: A

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Projection: UTM Zone 37 S, Datum: WGS84
 Source: Bing Maps ©2010 Microsoft Corporation.
 AMA1, 2012. Inset Map: Esri Data & Maps

SIZE:
A3

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The management strategies presented herein have been based on conservative estimations generated by the Pre-FEED Contractors. The emissions, discharges and waste streams will change as the Project progresses through its life cycle and are, therefore, described here per Project phase. It should be noted that the optimum methods to address all Project emissions, discharges and wastes will be further investigated during FEED. The facilities will be designed to avoid and, if not possible, minimize all potential impacts on the environment and its surroundings.

4.6.1

Management of Emissions to Air

The emissions inventory provided below is based on input from the Pre-FEED engineering studies conducted to date. Evaluations will be made during FEED on all aspects of the Project design to ensure all components are designed to maximise efficiency to the most practicable extent. These studies will be undertaken to optimise the efficiency of the Project and develop options for built-in mitigation measures to be implemented to reduce the rate and/or duration of air emissions throughout the life cycle of the Project.

Key Sources of Construction Emissions

Emissions during construction will vary in magnitude, frequency and duration for the various construction activities required. It is therefore difficult to accurately quantify emissions associated with construction of the Project components ⁽¹⁾. The main sources of air emissions (continuous and non-continuous) during the construction phase will be from the exhausts of machinery associated with construction equipment, both onshore and offshore, as well as vessels used for supply and logistics. Air emissions will be associated with the following activities:

- combustion emissions from the operation of construction machinery and generators;
- particulate (dust) emissions from exposed areas;
- marine vessel emissions and generator operation; and
- welding operations.

These activities will result in the following main emissions during construction:

- sulphur dioxide (SO₂);
- nitrogen oxides (NO_x);
- carbon monoxide (CO);
- carbon dioxide (CO₂);

(1) In order to provide a concise emissions inventory for the construction phase of the Project, all components would need to be identified. The present stage of the Project does not allow for such an assessment, as the Project will be built by various construction and installation contractors using equipment and methodologies yet to be identified.

- hydrocarbons; and
- particulate matter (PM).

Key Sources of Operational Emissions

The main sources of normal operating atmospheric emissions include combustion products from:

- gas turbines used as compressor drivers;
- gas turbines used for power generation;
- incinerators; and
- process heaters.

Other emission sources include:

- combustion products from flares;
- compressor seal losses;
- fugitive emissions from piping system components and hydrocarbon storage tanks; and
- miscellaneous sources such as losses and venting at analysers, sampling points and the routine testing of back-up or emergency diesel engines etc.

The key potential pollutants of environmental concern to be emitted from the Project include NO_x, SO₂, CO, CO₂ and aromatic hydrocarbons such as benzene, toluene, ethyl benzene and xylene (collectively known as BTEX).

The Mozambican requirements and IFC EHS Guidelines will be provided to the FEED Contractors as guidance so the Project will be designed to meet the required emission standards.

Table 4.1 provides an overview of the expected annual emissions for one, two and six Trains ⁽¹⁾, while *Table 4.2* provides a more detailed breakdown by source for a single Train per year. The data is based on information available at Pre-FEED. The Pre-FEED study estimates emissions from all normally operational combustion sources for one Train. These estimates have been scaled up to consider additional Trains (multiplying estimated emissions for one Train by two and six respectively). These estimates will be verified during the FEED phase.

(1) The table provides estimated emissions for the trains and not the associated facilities, machinery and equipment associated with the operational phase.

Table 4.1 *Estimated Emissions for One, Two and Six LNG Trains*

Number of Trains	Estimated Annual Emissions (t/yr)						
	NO _x ⁽¹⁾	SO ₂ ⁽²⁾	CO ⁽³⁾	PMT ⁽³⁾	PM ₁₀ ^{(3) (4)}	VOC ⁽³⁾	CO ₂ ⁽⁵⁾
1	490.99	67.93	133.95	42.83	41.79	14.79	1,035,135.00
2	936.63	135.87	235.75	82.29	80.22	27.89	1,998,540.00
6	2,719.18	407.60	642.94	240.16	233.95	80.30	5,852,155.00

Note:

(1) NO_x emissions estimates based on the following:

(a) Gas turbine drives: 51mg/Nm³, dry basis at 15% oxygen, per World Bank/IFC standards.

(b) Acid gas incinerator and hot oil heater: AP-42 emission factor assuming low NO_x burners.

(c) Flares: AP-42 emissions factor.

(2) SO₂ emissions by material balance based on 100% conversion of vent/fuel gas sulphur to SO₂.

(3) Pollutant emissions per United States Environmental Protection Agency (USEPA AP-42 emission factors for respective emission source.

(4) Flares/incinerator assumed to be smokeless - PM emissions considered negligible.

(5) CO₂ emissions by material balance based on 100% conversion of vent/fuel gas carbon to CO₂.

It should be noted CO₂ emissions differ from CO₂e emissions (which are used in the GHG assessment in Section 12.3). CO₂e means "CO₂ equivalent" and is a common unit of measurement for all greenhouse gases (eg methane, CO, etc)

(6) Four generators operating at 100% load.

Source: Anadarko, 2012.

Table 4.2 *Estimated Annual Emissions for LNG Trains by Source*

Source	Duty (HHV) MW	Estimated Emissions (t/yr) ⁽¹⁾						
		NO _x ⁽¹⁾	SO ₂	CO	PMT	PM ₁₀	VOC	CO ₂
MR compressor turbine drive	47	99.21	Negligible	21.09	9.27	9.27	2.94	175,480.00
PR compressor turbine drive	47	99.21	Negligible	21.09	9.27	9.27	2.94	175,480.00
Power generator (Train 1)	4 x 29	278.96	Negligible	52.02	22.92	22.92	7.31	433,093.00
turbine drives (Train 2-6)	3 x 33	238.08	Negligible	44.40	19.56	19.56	6.23	369,623.00
Acid gas incinerator	3.5							
From acid gas		2.58	67.93	4.29	0.39	0.09	0.26	186,811.00
From fuel gas			Negligible					27,331.00
Hot oil heater	15	6.56	Negligible	10.93	0.97	0.24	0.73	56,009.00
Flare header purge gas								
Warm flare	0.94	1.93	Negligible	10.42	Negligible	Negligible	0.26	3,513.00
Cold flare	0.95	1.93	Negligible	10.60	Negligible	Negligible	0.26	3,565.00
LP flare	0.15	0.35	Negligible	1.75	Negligible	Negligible	0.09	578.00
Warm flare	0.10	0.18	Negligible	1.05	Negligible	Negligible	0.00	368.00

Source	Duty (HHV) MW	Estimated Emissions (t/yr) ⁽¹⁾						
		NO _x (1)	SO ₂	CO	PMT	PM ₁₀	VOC	CO ₂
liquid flare Cold	0.06	0.09	Negligible	0.70	Negligible	Negligible	0.00	237.00
liquid flare TOTAL for Train 1		490.99	67.93	133.95	42.83	41.79	14.79	1,062,467.00
liquid flare TOTAL for Trains 2-6		450.11	67.93	126.33	39.47	38.43	13.72	998,996.00

(1) Based on 8,760 operating hours per year (on-stream factor of 100%).

Source: Anadarko 2012.

4.6.2 Management of Effluent Discharges

The following provides an overview of potential options the Project is considering to manage the effluent discharges resulting from construction and operational activities.

Key Sources of Construction Discharge

During the construction phase, the Project will have the following sources of discharge:

- sewage treatment plant effluent;
- concrete batch plant effluent;
- equipment and vehicles washdown pad effluent;
- brine and filter backwash from desalination plant;
- potentially contaminated stormwater and washdown water from waste management area; and
- hydrotest wastewater from the tanks and pipelines testing.

Table 4.3 provides estimated effluent rates from various sources during construction.

Table 4.3 *Estimated Effluent Rates during Construction of the First Two Trains*

Source	Flow Rate (for Construction of Two Trains)	Frequency
Treated effluent from the Sewage Treatment Plant	2-60m ³ /hr	Continuous
Concrete batch plant effluent	0.5-1m ³ /hr	Continuous from month 7 to month 25
Equipment and vehicles washdown pad effluent	1-2m ³ /hr	Intermittent
Brine and filter backwash from Desalination Plant	433m ³ /hr	Continuous
Potentially contaminated stormwater and washdown water from waste management area	5m ³ /hr	Intermittent
Hydrostatic test wastewater from the tanks and pipelines testing	70m ³ /hr when routed through the sedimentation pond	Intermittent

Source: Bechtel Pre-FEED Documents.

During the construction phase, sewage will be treated by a temporary sewage treatment system (potentially a modular treatment system). Effluent from the tanks will be treated to meet all the applicable standards, regulations (national and international) and/or approval or authorization prior to discharge into Palma Bay via a pipeline attached to the Pioneer Dock. If required, some treated effluent can be used for dust suppression and/or site-required irrigation.

The brine rate from the desalination plant will be at the peak during the first 18 months of filling and compaction activities. Brine and filter backwash may also be discharged from the Pioneer Dock into Palma Bay. A potential option for brine discharge includes a high pressure discharge to facilitate quick mixing with marine water, stormwater and/or sewage effluent, minimising any effects associated with the high salt concentration.

The optimum methods to address all Project discharges will be further investigated during FEED.

It is currently planned that hydrotest water from the first LNG tank will be used for testing the second tank and pipelines, and returned back to the hydrotest pond. Water from the pond may be used for dust control and concrete batch plant, if uncontaminated. AMA1 and eni will develop a hydrotest Water Management Plan for the discharge of hydrotest water. Such a plan will be aligned with the IFC guideline on the discharge of effluents ⁽¹⁾. The quality of hydrotest water will be monitored to achieve the targets in *Table 4.4*.

(1) IFC Environmental, Health and Safety Guideline for LNG Facilities, Table 1.

Table 4.4 *Hydrotest Water Quality Guideline*

Parameter	Guideline
Total hydrocarbon content	10mg/l
pH	6-9
Biochemical Oxygen Demand (BOD)	25mg/l
Chemical Oxygen Demand (COD)	125mg/l
Total Suspended Solids (TSS)	35mg/l
Phenols	0.5mg/l
Sulphides	1mg/l
Heavy metals (total)	5mg/l
Chlorides	600 mg/l (average) 1,200mg/l (maximum)

Source: IFC Environmental, Health and Safety Guideline for LNG Facilities.

A water management system will be in place to capture potentially contaminated stormwater run-off and keep it separate from normal clean water run-off. Clean water run-off will be channelled into existing natural drainage channels. Potentially contaminated water will be captured and treated for reuse or discharge into Palma Bay. The optimum solution will be further investigated during FEED.

Key Sources of Operational Discharge

The Offshore Project will operate in a closed loop whereby chemical injections will be contained within the production system. The only discharge from the Subsea Production System will be small quantities of water-based biodegradable hydraulic fluid.

Key sources of operational discharge are constrained to the Onshore and Near Shore aspects of the Project and consist of the following sources:

- process wastewater and drains;
- treated sewage effluent;
- brine and filter backwash from the desalination plant;
- salt and produced water from the MEG Unit; and
- run-off water from process areas.

Table 4.5 shows estimated effluent rates from identified sources of discharges from onshore facilities.

Table 4.5 *Estimated Effluent Rates during Onshore Operations*

Source	Flow Rate (m ³ /hr)	Frequency	Estimated Characteristics
Process wastewater	5-51 ¹	Continuous (peak flows include stormwater)	pH: 6-7 BOD ₅ : 10-20mg/l TSS: 5-10mg/l Oil: 5-15mg/l

Source	Flow Rate (m ³ /hr)	Frequency	Estimated Characteristics
Sewage Treatment Plant	3.5-15	Continuous	pH: 6.5-7.5 BOD ₅ : 10-20mg/l Oil and grease: 5-10mg/l Total nitrogen: 30-40mg/l as N Total Kjeldahl nitrogen: 1-5mg/l Ammonia nitrogen: 1-5mg/l Total phosphorus- 5-10mg/l TDS: 250 mg/l
Brine and filter backwash from Desalination Plant	62-93	Continuous	pH: 6.5-7.5 units TDS: 55,500-60,000mg/l N ⁺ : 17,000mg/l Alkalinity: 170mg/l Cl: 30,650mg/l Mg ⁺⁺ : 2,000mg/l TSS: 0mg/l SiO ₂ : 16mg/l
Salt and produced water from the MEG Unit	1,600bbl water/day/ LNG Train	Continuous	2,200kg of salt/day/LNG Train
Contaminated run-off	80-160	Intermittent	TSS: 50-100mg/l Oil: 5-15mg/l

Note: Peak rates provided are based on maximum pumping rates from the effluent treatment equipment.

Source: Anadarko Pre-FEED Documents.

Treated domestic sewage will meet all the applicable standards, regulations (national and international) and/or approval or authorization before discharge.

In the operational phase, a water management system will be in place to capture run-off from potentially impacted areas and process wastewater, and keep this separate from normal clean water run-off. Clean water run-off will be channelled into natural drainage channels. Potentially contaminated water will be captured and treated for reuse or discharge.

Brine, from desalination and the MEG Unit, may be discharged through a piped outfall located on the LNG Export Jetty. A diffuser may be used at the end of the pipe to achieve maximum dilution and dispersion within a short distance from the outfall.

Stormwater

Potentially contaminated surface water (PCSW) run-off includes stormwater, fire water and washdown water originating from dirty, industrial areas. With the exception of the LNG processing areas, all surface run-off from the affected areas will be collected by a PCSW sewer system, which will drain directly to a stormwater retention basin and will undergo subsequent treatment.

Due to the potential for run-off from the LNG processing areas to be impacted, all the LNG processing areas will be constructed with a perimeter bund and the contained area sloped to one or more internal collection sumps. .

PCSW from LNG processing areas that exhibit evidence of an oil sheen will be directed to a stormwater retention basin. This basin will be lined with suitable materials to prevent groundwater impacts. Run-off collected in the stormwater retention basin originating from both the LNG processing and non-processing areas will be pumped at a reduced controlled rate to an oil-water separator for treatment prior to discharge in accordance with all the applicable standards, regulations (national and international) and/or approval or authorization. Two 100% stormwater return pumps will be provided. Pump capacity will be established during FEED to empty the basin completely in a reasonable period of time.

Clean Surface Run-off

Clean surface run-off is run-off from areas deemed not at risk to oil or chemical contamination. Clean surface run-off will be allowed to discharge to the surrounding environment.

4.6.3 Management of Solid Wastes

A Waste Management Plan (WMP) has been developed for the Project (*Annex E*). This Plan outlines the waste management philosophies and framework for how the Project will manage wastes associated with the various phases of the Project. The following provides an overview of the expected types and potential volumes of waste to be generated in each phase of the Project. This waste inventory is based on input from the Pre-FEED engineering studies conducted to date. Evaluations will be made during FEED on all aspects of the Project design, construction and operation to avoid and, if not possible, minimise the generation of waste.

Offshore Construction Phase Wastes

There will be several different activities associated with the construction of the Offshore Project, including:

- drilling and installation of production wells;
- Subsea Production System installation;
- pipeline construction; and
- pre-commissioning and commissioning of pipelines and the Subsea Production System.

Whenever a well is drilled, fragments of rock, known as cuttings, are created. These cuttings are coated with the drilling mud that is used to lubricate the drill bit and transfer the cuttings to the surface. The drilling muds are recycled by separating the muds from the cuttings using vibrating screens, known as shale shakers. Some drilling fluids will remain adhered to the cuttings, but the majority will be separated by the shale shakers and returned

to the drilling fluid system. Drilling fluids will therefore be recirculated continuously. Following treatment, the cuttings will be discharged to the sea unless site-specific drilling and mud cuttings dispersion modelling indicates unacceptable environmental impacts, in which case the cuttings will be sent to shore for treatment and disposal either at Pemba or the Afungi Project Site. If the cuttings need to be transferred to shore for disposal, they will be stored in 25t skips. The collection, treatment and recycling of the returned drilling muds are part of the standard drilling process. The optimum alternative solution for the final disposal of cuttings will be further investigated and GIIP will be applied.

Along with drill cuttings, the drilling operation will generate a range of other wastes such as:

- tubing caps;
- waste lube oil;
- wood wastes;
- packaging wastes (plastics, cardboard, paper);
- fluorescent tubes;
- contaminated rags;
- waste paints and solvents;
- metal wastes (steel cuttings, metal wires, pipe cuttings);
- domestic waste; and
- wet/dry cell batteries.

These wastes will be segregated and stored in different containers on board the drilling vessel, and will be transported back to shore at either Pemba or the Afungi Project Site (depending where the supply vessels are based) for treatment and disposal, with the wastes generated onshore in accordance with the WMP.

Based on aggregated data for the waste returned to shore from one of the drilling rigs (eg *Bedford Dolphin*) over a 48-day period, estimates have been made for the rate of waste generation from the drilling rigs, as shown in *Table 4.6* (this assumes that two rigs are operational).

Table 4.6 Estimated Wastes Generation from One Drill Ship

Types of Wastes	Waste from <i>Bedford</i> <i>Dolphin</i> rig over 48 days	Unit mass (t)	Tonnes per rig (48 days)	Annual generation rig (t)	Waste generation over planned 900-day drilling programme (t)
Uncompressed bulk bags of general waste	108.00	0.30	32.40	246.40	607.62
Metal drums	24.00	0.02	0.48	3.70	9.12
1,000l tote tanks	19.00	0.05	0.95	7.20	17.76
1,000l totes of waste oil/sludge/liquid hazardous waste	10.00	1.00	10.00	76.00	187.42
Plastic drums	8.00	0.01	0.08	0.60	1.48
Baskets of scrap wood	7.00	0.70	4.90	37.30	91.98
Baskets of scrap metal	6.00	2.00	12.00	91.30	225.15
Sections of drill line/crane cable/other cable	3.00	1.00	3.00	22.80	56.22
Pallet box of shaker screens	1.00	1.00	1.00	7.60	18.74

Source: AMA1, based on manifest of waste generated during AMA1 exploration drilling activities; similar quantities are anticipated per drill ship for production drilling activities in Areas 1 and 4.

Pipeline construction activities will typically generate the following types of wastes:

- end millings from the pipe end bevelling process;
- flux and welding rods from the welding process;
- offcuts and waste process materials from the pipe-laying process;
- lubricating oils (from machinery and lifting equipment, etc);
- contaminated rags/materials/containers;
- waste paints and solvents;
- wet cell batteries;
- chemical wastes;
- steel cuttings wastes; and
- coating wastes.

Other wastes such as household wastes (food wastes; packaging wastes; and wood, paper and cardboard wastes), sewage and grey water will also be produced by construction vessels.

No specific data are available for expected quantities of wastes from pipeline construction activities (these will be generated during FEED), but it is anticipated that a workforce of up to 750 construction workers and equipment technicians will be involved during the subsea construction phase. These personnel will be housed in offshore construction vessels or in the Construction Camps associated with the onshore development. The construction of the Subsea Production System will last approximately 18 to 24

months. Based on these estimates, and in the absence of Project-specific data, waste generation for the workforce involved in the offshore construction has been estimated, as indicated in *Table 4.7*.

Table 4.7 *Estimated Waste Generation for Offshore Construction Workforce*

Types of Wastes	Classification	Approximate Annual Waste (t)	Approximate Total Waste (t)
Food	Non-hazardous	130	200-270
Miscellaneous combustibles	Non-hazardous	14	21-27
Textiles	Non-hazardous	14	21-27
Paper and cardboard	Non-hazardous	44	62-82
Plastics	Non-hazardous	28	41-55
Glass	Non-hazardous	14	21-27
Metals	Non-hazardous	14	11-15
Miscellaneous non-combustibles	Non-hazardous	14	21-27
Kitchen oil/grease	Non-hazardous	2.6	4-6
Medical	Hazardous	0.13	0.2-0.3

All vessels involved with the construction of the Offshore Project will be compliant with MARPOL 73/78 regulations.

Commissioning of the Offshore Project components will include pipeline integrity testing, followed by dewatering and nitrogen purging. The pipelines will undergo pressure testing using filtered sea water, with the addition of chemicals such as biocides and corrosion inhibitors. A plan for disposal of the water used for the hydrotesting will be developed, with careful consideration given to the impact, if any, of remaining chemicals on the environment. It is currently envisaged that the water used for the pipeline hydrotesting will also be used to hydrotest the onshore facilities. Any discharge of hydrotest fluids to sea will be in compliance with IFC guidelines in the absence of a Mozambican standard.

Onshore and Near Shore Construction Phase Wastes

The types and quantities of wastes that will be generated over the planned 48 to 54-month construction period for the LNG Facility have been estimated during Pre-FEED.

From these data, the annual waste generation during construction has been estimated as presented in *Table 4.8*. This table also indicates the provisional classification of each waste type and the planned method of managing each type of waste. The estimates assume an average workforce of 4,490, so the amounts of domestic waste have been adjusted to take into account the current estimate for the workforce.

Table 4.8 Onshore and Near Shore Construction Phase: Wastes Inventory

Types of Wastes	Estimated Total Quantity (t)	Approx. Annual Generation (t)	Classification	Management Method
Sewage treatment solids	14,900.0	3,400.0	Hazardous	Landfill or incineration
Food	6,600.0	1,500.0	Non-hazardous	Compost, landfill or incineration
Paper	3,500.0	790.0	Non-hazardous	Recycle or incineration
Plastic	1,100.0	260.0	Non-hazardous	Recycle or landfill
Glass	580.0	130.0	Non-hazardous	Recycle or landfill
Metal	760.0	170.0	Non-hazardous	Recycle
Others	4,000.0	900.0		Landfill
Vehicle batteries	20.0	4.4	Hazardous	Recycle
Construction debris – inert	5,000.0	1,130.0	Inert (non-hazardous)	Recycle or landfill
Containers – metal (used)	210.0	48.0	Non-hazardous	Reuse or recycle
Containers – plastic (used)	60.0	13.0	Non-hazardous	Reuse or recycle
Filters – oil (used)	8.0	2.0	Hazardous	Landfill or incineration
Filters – air (used)	100.0	22.0	Non-hazardous	Landfill
Gas cylinders (empty)	20.0	4.0	Non-hazardous	Reuse
Grit from sand blasting operations	20.0	4.0	Non-hazardous	Landfill
Medical wastes	10.0	2.0	Hazardous	Incineration
Packaging material – cellulose	480.0	110.0	Non-hazardous	Incineration
Tyres – used	85.0	20.0	Non-hazardous	Recycle, incineration or landfill
Welding rods (used)	80.0	17.0	Non-hazardous	Landfill

Source: AMA1, Air Emissions, Liquid Effluents and Solid Wastes – Construction Phase, Document EV-AAA-EV1-0003 (adjusted to account for increased workforce and including Near Shore Project contribution).

Offshore Operational Phase Wastes

During the operational phase, there will be very little waste generated offshore, and this will comprise primarily maintenance and repair wastes. It is expected that very little pigging will need to be undertaken during the operational phase. If it is required, only small quantities of hydrates, hydrocarbon sludge, oily water, contaminated rags and damaged pigs will be generated.

It is anticipated that the total amount of wastes generated offshore will not amount to more than a few tens of tonnes per annum.

Onshore Operational Phase Wastes

The following wastes will be generated from operation of the LNG Facility:

- liquid sludge, dehydrated sludge and waste cake;
- used filter cartridges, oil-absorbing media;
- filtration media or catalysts;
- used mercury guard ⁽¹⁾;
- potentially hazardous chemical packaging;
- non-hazardous packaging from chemical products and equipment (eg wood pallets, steel drums, plastic containers);
- salts from MEG units;
- waste from power generation unit;
- packaging and food wastes; and
- paper and used print cartridges from the process and office areas.

Quantities of process wastes and their management routes have been determined from discussion with the Pre-FEED Contractors; these data are presented in *Table 4.9*. The Project will place emphasis on developing strategies to minimise waste generation. Details will be developed to quantify these waste quantities further during FEED.

Table 4.9 *Anticipated Process Materials and Resulting Wastes per LNG Train*

Waste Source	Material	Quantity	Replacement Period	Estimated Annual Waste Generation (t)
Feed gas dehydration	Molecular sieve - 3A type (or equivalent), 1/8" beads	45,000.0kg/65.5m ³	3 years	15.0
Feed gas dehydration	Molecular sieve - 3A type (or equivalent), 1/16" beads	45,000.0kg/65.5m ³	3 years	15.0
Feed gas dehydration	Silica gel beads - 2-5mm	3.7kg/5.4m ³	3 years	-
Acid Gas Removal Unit	Activated carbon	21.2m ³	6 years	1.2
Mercury Removal Unit	Catalyst (sulphur impregnated activated carbon)	42,500.0kg/74.3m ³	3 years	14.2
Plant instrument air driers	Activated alumina	3,500.0kg	2 years	1.8
Oily sludge	Oil and sludge	Dependent on site run-off rate	N/A	-
Oily Water Treatment Unit filters	Activated carbon	10.0m ³	Annual	3.2

In addition, there will be very small quantities of potentially hazardous wastes from maintenance and repair activities such as:

- waste lubricating oil;
- seals, insulating wool, empty paint drums from pipe maintenance;
- chemical reagents, drums from sampling and instrument calibrations; and
- used fluorescent tubes and cleaning products from building maintenance.

There will also be some wastes generated by the operation of the gas turbine units that will be used to generate power for the Project. These wastes will comprise mainly gas turbine washings (isopropanol or equivalent) and lubricating oils from the maintenance of turbines.

The various offices associated with the Project will generate relatively small amounts of a limited range of wastes. These will include non-hazardous materials, such as paper and cardboard, as well as wood/metal furniture, which can be recycled if suitable facilities are available, and very small quantities of more hazardous wastes such as printer cartridges and fluorescent lamps (containing mercury).

Accommodation facilities will give rise to wastes from food preparation and consumption, maintenance and recreational activities. These wastes will include food, plastic bottles, paper and cardboard, and sewage. There will also be some hazardous waste such as fluorescent bulbs, used batteries and medical waste.

There will be approximately 400 personnel for standard operations (working two 12-hour or three eight-hour shifts per day). Major shutdowns will generally be scheduled every few years and will require an additional workforce of 300 to 500 personnel, depending on scope. Minor shutdowns may occur more frequently and will require an additional staff of approximately 50 to 100 personnel. For the purposes of estimating the amount of waste that will be generated, it has been assumed that, on average, there will be approximately 450 staff during the operational phase.

Using typical rates of waste generation per employee for similar projects, estimated rates of waste generation for the operational phase of this Project have been developed as shown in *Table 4.10*.

Table 4.10 *General (Non-process) Operational Wastes*

Types of Wastes	Source	Classification	Approximate Rate of Waste Generation (t/yr)
Food	Accommodation areas	Non-hazardous	82.00
Miscellaneous combustibles	Accommodation areas	Non-hazardous	8.00
Textiles	Accommodation areas	Non-hazardous	8.00
Paper and cardboard	Offices and accommodation areas	Non-hazardous	49.00
Plastics	Accommodation areas	Non-hazardous	16.00
Glass	Accommodation areas	Non-hazardous	8.00
Metals	Accommodation areas	Non-hazardous	8.00
Miscellaneous non-combustibles	Accommodation areas	Non-hazardous	8.00
Kitchen oil/grease	Accommodation areas	Non-hazardous	2.00
Printer cartridges	Offices	Hazardous	0.20
Batteries (small)	Offices and accommodation areas	Hazardous	0.02
Fluorescent and sodium lamps	Offices and accommodation areas	Hazardous	0.10
Medical	Clinic/First Aid posts	Hazardous	(included in previous table)
Tyres	Vehicles	Non-hazardous	0.80
Lead-acid batteries	Vehicles	Hazardous	0.80
Waste oil	Vehicles	Hazardous	0.70
Oil filters	Vehicles	Hazardous	0.10

An incinerator will be used onsite for the treatment of medical and combustible wastes in accordance with an approved Waste Management Plan. In this case, the onsite waste incinerator will be designed to provide an organic destruction removal efficiency of ≥ 99 percent for a resulting ash organic content of ≤ 1 percent carbon by weight. The incinerator will be of the two-stage type, with a minimum combustion temperature of 815°C in the primary stage and 982°C in the secondary stage. The incinerator shall be designed in accordance with GIIP. The inert ash will be disposed of at the onsite landfill.

Near Shore Operational Phase Wastes

During the operational phase of the Project, the Near Shore infrastructure will serve as the point of export for the processed LNG and as the hub for the import of materials necessary for the operation and maintenance of all aspects of the Project.

There will be small amounts of waste generated by the operation fleet (tugs and other vessels), such as lubricating oils and lead-acid batteries.

At this stage, the frequency of dredging to maintain the navigation channel and the quantities of material likely to be dredged are not known but are expected to be minimal, based on sediment modelling conducted within

Palma Bay. Maintenance dredging is likely to occur approximately every three to five years.

4.6.4 *Noise and Light Emissions*

Onshore lighting requirements will be developed during the FEED phase and will incorporate site safety requirements, while taking measures to minimise the impact on the surrounding community. The lighting design and illumination requirement will be restricted to the minimum required for security and safe working conditions. The specific design criteria for lighting will be developed during detailed engineering, when the required design data and site equipment arrangement plans become available for such development.

IFC noise standards will be applied for the operational phase of the Project. Noise abatement measures will be implemented to achieve ambient noise levels, indicated in *Table 4.11* below, or will not result in a maximum increase in the background level of 3dB(A) at noise receptors during operations. The indicated noise standards apply at the nearest offsite receptor (community).

Table 4.11 *Noise Standards*

Receptor	One Hour LAeq (dBA)	
	Daytime 07:00 to 22:00	Night-time 22:00 to 07:00
Residential, institutional, educational	55	45
Industrial, commercial	70	70

Source: KBR Pre-FEED Documents.

Measures will be taken during design to minimise the potential adverse environmental and social impacts associated with noise and light.

4.7 *DECOMMISSIONING AND CLOSURE*

Decommissioning refers to the process of dismantling the operating assets after completion of the operating life cycle of the Project. This process will be in accordance with the Decommissioning and Rehabilitation Plan (*Annex F*). Due to the long-term operation of the LNG Facility (30 years), the Project will review and update the decommissioning plan as the Project nears the end of its lifespan.

Typical decommissioning of the subsea system would encompass flushing the pipelines and umbilical tubes clean, removing subsea manifolds and plugging the wells, and retrieving the subsea trees and jumpers. The pipeline and umbilicals are likely to be capped and abandoned in place.

For the Near Shore and Onshore infrastructure, decommissioning entails the demolition of buildings, removal of infrastructure, and rehabilitation and

revegetation. Where contaminated soil is found, this will be rehabilitated or disposed of appropriately. Decommissioning and demolition will also be influenced by the needs of local communities. Where buildings or infrastructure (eg roads, jetties) can be utilised by local communities, they will be left intact. All other infrastructure will be demolished and removed. Land will be shaped, scarified and revegetated as appropriate.