CHAPTER 9

ENVIRONMENTAL BASELINE: MARINE RECEIVING ENVIRONMENT
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ENVIRONMENTAL BASELINE – MARINE RECEIVING ENVIRONMENT

This section of the ESIA describes the existing marine (offshore) environmental characteristics of the Tema LNG project. It provides a description of the baseline environment conditions, for both nearshore and offshore activities, against which the potential impacts of the proposed Tema LNG project development can be assessed and future changes monitored. It provides a description of the nature, value and sensitivity of the physical, biological and socio-economic resources and receptors potentially affected by the project.

The intent of the Marine study is to assess the present state of the marine environment from an environmental as well as social use perspective. As indicated in the project description, the proponent wishes to develop an offshore facility (FSRU) to transfer Liquefied Natural Gas (LNG) via a pipeline on the seabed to an onshore metering station.

9.1 PROJECT LOCALITY AND AREAS OF INFLUENCE

The proposed project involves the installation of a 24 inch gas pipeline extending from the shoreline to approximately 10 km offshore where a Floating Storage and Re-gasification Unit (FSRU) will be permanently moored. Approximately two vessels per month will berth at the FSRU and unload Liquid Natural Gas (LNG), which will be re-gasified and pumped ashore to a metering station prior to distribution to power generating companies.

The pipeline and FSRU will mostly be located within the existing inshore fishing and anchoring exclusion zone for the West African Gas pipeline route, with the possibility of only small sections extending beyond the exclusion servitude (< 50 m out of servitude). The landfall section and nearshore section of the pipeline to ca. 6 m water depth will be trenched and backfilled with rock to cover the pipeline. The remaining pipeline extending to the FSRU in approximately 40 m of water will be laid and secured on the seafloor.

The 20 km² study area is therefore located approximately 6 km south west of Tema Port (Figure 9-1). Quantum Power appointed INTECSEA (Worley Parsons) to perform a metocean study for four potential locations for the LNG terminal / mooring, of which two were selected for additional analysis (Point 1 and Point 3 as shown in the figure below). The water depth ranges between approximately -20 m at Point 1, while Point 3 is ca. -40 m).

As a part of the INTECSEA study (INTECSEA, 2014) a preliminary (Stage 1) uptime assessment was required to assess the implication of the metocean conditions on the facility functional viability. Points 2 and 4 (Figure 9-1) were also analysed, but were excluded from further analysis.

Three mooring types were then analysed with regard uptime (average annual % time that facility could be operational, undisturbed by ocean conditions and there is gas demand and gas is exported) for each of the remaining localities as follows:

- Option 1: FSRU on soft yoke mooring
- Option 2: FSRU and LNGC on double berth jetty
- Option 3: FSRU on spread moor and LNGC on single berth jetty.
9.2 RELEVANT LEGISLATIONS

The relevant legislation pertaining to the marine environment are listed below:

- Fisheries Act 2002 (Act 62)
- Fisheries Regulation 2010 (L.I. 1968)
- Ghana Maritime Authority Act 2002 (Act 630)
- Ghana Shipping (Protection of Offshore Operations and Assets) Regulations 2011
- Oil in Navigable Waters Act, 1964, Act 23
- Beaches Obstruction Ordinance, 1987 (Cap 240)

Of particular importance is the fishing activities within Ghanaian waters that are regulated by the Fisheries Act of 2002. The Act allows for the establishment of the Fisheries Commission, the organisation responsible for the regulation and management of the fishery resources in the territorial waters.

Under the Act the Fisheries Commission may declare:

- Closed seasons (or international bodies to which Ghana is a member).
- Types and sizes of fishing gears and fishing activities, including prohibited nets.
- May declare marine reserves.
With regard this study is the establishment of fishing zones and regulation of fishing activities within these zones. The Inshore Exclusive/Economic Zone is defined as the area inshore of the -30 m depth contour or within 6 nautical miles (±11 km) off the coastline, whichever is farther. This zone is set aside for the exclusive use by small semi-industrial vessels, canoes and recreational fishing vessels, thus no large semi-industrial or industrial vessels may be used inside this zone. Furthermore, towing fishing gears are not to be used in areas shallower than the -30 m depth contour.

Section 93 describes Fisheries Impact Assessments, which requires that any agency planning to undertake an activity other than fishing which may impact on fishery resources informs the Commission prior to commencement, with a view to the conservation and protection of resources. This study aims to assess the available information for local fisheries in the Tema area and assess the likely impacts on fish and fisheries in order to fulfil this requirement.

The following international laws are also applicable to this project:

- Convention on Biological Diversity (CBD)
- Convention on Migratory Species (CMS)
- The Basal Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal, 1989
- Bamako Convention
- International Convention for the Prevention of Pollution from Ships and Protocol (MARPOL)
- The Rotterdam Convention on Prior Informed Consent (PIC) for certain Hazardous Chemicals and Pesticides in International Trade
- Stockholm Convention on Persistent Organic Pollutants (POPs)
- Vienna Convention for the Protection of the Ozone Layer
- Cartagena Protocol on Bio-safety to the Convention on Biological Diversity
- Framework Convention on Climate Change (FCCC)
- Kyoto Protocol of the Climate Change Convention, 1997
- Montreal Protocol on Substances that Deplete the Ozone Layer, 1987

9.3 **MARINE STUDY METHODOLOGY**

A marine benthic survey was undertaken aboard the MV Marry Elizabeth over two sea-days on the 21st – 27th November 2014. A Lowrance HDS Gen 2 Touch echo sounder with side scan module was used to survey four transects within and to the east of the existing Inshore Exclusion Zone declared for the WAGP Tema Lateral pipeline servitude. Depth data was logged on the sonar unit at a speed of 5-10 km/h and the side scan imaging was used to observe for large and high relief reefs adjacent to the transect lines. Sonar charts were reviewed and depth
data exported to GIS software which was used to generate seafloor bathymetry\(^1\) of the project area using Inverse Distance Weighting interpolation.

A remote video camera (Plate 9-1) was deployed at selected sites along each transect to observe the seafloor habitats and verify substrate composition through visual observation. Grab sampling (Plate 9-2) was undertaken at a subsample of sites in order to collect samples for the identification and assessment of macro-faunal communities and to obtain sediments for analysis of particle size distribution as well as screening for selected contaminants.

Three grab samples were collected at each site using a weighted Van Veen grab (Plate 9-2). Two samples were sieved through 500 µm mesh and the remaining sediment preserved in 95% ethanol and stored for the identification and assessment of the benthic infauna. These samples were exported to the South African Institute for Aquatic Biodiversity for further sieving and identification of benthic infauna.

The third grab sample was stored in a plastic bag and was used for particle size and contaminant analyses.

Water quality samples were collected at the same site, at surface and bottom depths using a Niskin Bottle. The samples were immediately stored in cool box and delivered for analysis at an accredited laboratory (SGS Laboratories Tema) within 4 hours of the samples being taken. In situ analyses such as temperature, pH and conductivity were taken using a calibrated Lovitech handheld meter.

A range of assessment criteria or guidelines were reviewed for use in this study, with the focus being on African Development Bank (AfDB) and World Bank guidelines. However, the only AfDB guidelines that could be accessed were related specifically to mining, with a focus on drinking water and not marine activities. The focus of the World Bank guidelines is on processing wastewaters, stormwater run-off and domestic sewage, rather than activities impacting on the marine environment. Where available, results were therefore compared to the World Bank General Environmental Guidelines (World Bank Group, 1998). Where no World Bank standards were available, results were compared to the Australian Water Quality Guidelines for Fresh and Marine Waters (AWQGFMW, 1992), and to the general composition of seawater (Turekian, 1968).

Plate 9-1: Observing the seafloor habitats using a remote video camera

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\(^1\) Bathymetry maps were generated to provide an overview of the study area depth range and habitat and are not to be used for engineering or navigation purposes.
Plate 9-2: Collecting sediment samples using a Van Veen grab.

The assessment of fisheries in the Tema area was based on a review of existing scientific literature available for the region, and interviews with key fishery leaders and stakeholders (Annexure B) between the 20th and 27th of November 2014. Additional consultation with fishery representatives was undertaken following the site visit in order to obtain further information. The meetings were structured to first introduce stakeholders to the project, and then to obtain information on any issues and concerns they had. Information regarding their specific fishing activities/involvement in the fishery was obtained so as to assess potential impacts. Field observations of sea and harbour based fisheries activities were also undertaken during the offshore marine survey.

9.4 OCEANOGRAPHY

Ocean weather's West Africa Normals and Extremes (WANE) dataset was acquired by Quantum Power Ghana Gas BV for a location offshore Tema and licensed to this project. The offshore hindcast metocean conditions were transformed to determine nearshore metocean conditions at the two locations of interest.

The nearshore wave climate is dominated by the offshore swells that arrive from a southerly direction (see Figure 9-2).
At Point 1 (Figure 9-2) virtually all swell waves lie in the 165°N to 225°N direction. Approximately 1.9% of significant wave heights exceed 2.5 m. Peak wave periods exceeding 12 s occur approximately 38% of the time. Significant wave heights exceeding 2 m with periods in excess of 12 s occur approximately 4.8% of the time (INTECSEA, 2014).

At Point 3 (Figure 9-2) virtually all swell waves also lie in the 165°N to 225°N sector. Approximately 1.3% of significant wave heights exceed 2.5 m. Peak wave periods exceeding 12 s occur approximately 33% of the time. Significant wave heights exceeding 2 m with periods in excess of 12 s occur approximately 2.2% of the time (INTECSEA, 2014).

Currents direction and speed were not assessed in the present study (INTECSEA, 2014); however, these were estimated based on the with the understanding that offshore currents in Ghana are in the order of 1.5 knots, and mostly in a westerly direction associated with the Guinea Current (Figure 9-3). Ocean temperatures range between 26 – 28 °C (average annual temperature in the nearshore environment) based on NOAA AOML (National Oceanic and Atmospheric Administration) Drifting Buoy Data Assembly (DAC) Centre near-surface buoys, archived data from 1978 to 2003 (Figure 9-3). Specific measurements conducted by a once of survey by Kombat et al. (2013) indicated that sea temperature range from 28.5 ± 0.2 to 30.7 ± 0.3°C in Tema area. Seasonal drops in temperature have also been recorded as low as 25°C (Anang, 1979). During the survey, temperatures ranged between 28.7 and 29.3 at the surface while at depths the water temperatures ranged from 27.3 (-40 m) to 28.7 (-6 m). Very little variability was shown between the sites due to the strong winds and currents experienced during the survey period.
9.5 BATHYMETRY

As previously mentioned, data has been made available based on the Metocean data, that has included C-MAP bathymetric data for Ghana (INTECSEA, 2014). The study area (square box shown in Figure 9-4), ranges from 0 to -40 m depth (Chart Datum). During the biological studies depth recordings were also taken to verify or update the data that has been provided.

Figure 9-4: Preliminary bathymetric chart for the study area (grey box) as C-MAP data
9.6 SHIPPING MOVEMENT

Shipping movement (traffic) is dominated by vessels calling on Tema Port, the busiest port in Ghana. The port is operated by Ghana Port & Harbours Authority (GPHA) and receives an average of over 1650 vessel calls per year. Vessels include container vessels, general cargo vessels, tankers, Roll-on/roll-off (Ro-Ro) and cruise vessels. The port is thus divided into three sections or basins, namely commercial cargo, commercial fishing and the Canoe Basins. The 1650 vessel calls per annum does not include daily shipping movements by the commercial and artisanal fishing fleets.

During this study, it was also noted that OMA Ghana (a private company) holds the concession license to manage and operate the Ship to Ship (STS) transfer zone for the port and is located in close proximity to the proposed Tema LNG facility (Figure 9-5) and also results in additional shipping traffic.

Commercial restrictions also apply to the present West Africa Gas Pipeline tie in (pipeline to shore) with regard mooring, i.e. no offshore mooring is allowed 1 Nautical Mile either side of the pipeline (Figure 9-5).

Figure 9-5: The locality of the OMA STS zone and WAGP tie in pipeline

The Tema LNG could also result in increased shipping movement; however this though unlikely as the project only anticipates one vessel every 13 days that will berth at the FSRU. This is low when compared to the 42 - 53 boats and ships observed at anchor during survey, approximately 12 - 15 km offshore. The proposed pipeline route is however within an area that is used by the canoes as a route to access the eastern fishing grounds.

9.7 AIR QUALITY AND NOISE EMISSIONS

This section presents results related to the emissions in the atmosphere (particulate and gases) as well as sound propagation from main sources during the operations stage in connection with
activities for regasification of liquefied natural gas (LNG) in the Floating Storage Regasification Unit (FSRU), located offshore as well as the metering station in the coastal zone.

9.7.1 Applicable Regulations

According to IFC criteria (2007b), the main atmospheric emissions (continuous or discontinuous) include combustion from power generation and heating sources, the use of compressors, pumps and engines (boilers, turbines and other engines). The main atmosphere pollutants from these sources include nitrogen oxides (NO\textsubscript{x}), sulphur oxides (SO\textsubscript{x}), carbon monoxide (CO) and particulate matter (IFC, 2007b). Table 9-1 shows the environmental air quality standards that regulate the maximum allowable concentrations in the environment.

Table 9-1: Environmental Air Quality Standards

<table>
<thead>
<tr>
<th>Type</th>
<th>Average period</th>
<th>Guideline concentration (µg/m\textsuperscript{3})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>WHO/IFC\textsuperscript{2}</td>
</tr>
<tr>
<td>Particulate matter (PM\textsubscript{10})</td>
<td>1 year</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>30 days during Harmattan</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>24 hours</td>
<td>50</td>
</tr>
<tr>
<td>Particulate matter (PM\textsubscript{2.5})</td>
<td>1 year</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>24 hours</td>
<td>25</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO\textsubscript{2})</td>
<td>1 year</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>24 hours</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1 hour</td>
<td>200</td>
</tr>
<tr>
<td>Sulfur dioxide (SO\textsubscript{2})</td>
<td>1 year</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>24 hours</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>1 hour</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>10 minutes</td>
<td>500</td>
</tr>
<tr>
<td>Ozone (O\textsubscript{3})</td>
<td>8 hours (daily maximum)</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Environmental Philosophy Report (Genesis, 2014).

As indicated in the report prepared by Genesis (2014) “Environmental Philosophy”, the noise emission sources are associated with construction activities, which may temporarily impact marine fauna (fish and marine mammals). During operations, the main noise sources from new facilities would be (Genesis, 2014):

- Flares
- Generator set diesel engines; and
- Control valves

\textsuperscript{2} IFC Environmental, Health and Safety (EHS) Guidelines, General EHS Guidelines (IFC, 2007a).
As indicated in “Environmental Philosophy” report (Genesis, 2014), the noise emissions from the Quantum Power Project will not be higher than 85 dB(A) at 1 m distance from equipment. The IFC criteria (IFC, 2007a) indicates that no employee should be exposed to noise levels higher than 85 dB(A) for more than 8 hours a day without ear protection, for which the maximum limit (LAmx, fast) is 110 dB(A). For the Project, a careful selection of valves is required to mitigate generation of high noise (Genesis, 2014); therefore, different scenarios have been considered.

In accordance with IFC guidelines (IFC, 2007a), the noise impacts should not exceed levels shown in Table 9-2, or that result in a maximum increase of background level of 3 dB in the vicinity of the receptor location outside the Project facilities.

### Table 9-2: Noise Guideline Levels

<table>
<thead>
<tr>
<th>Receptor</th>
<th>One hour L\text{eq} (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Daytime</strong></td>
</tr>
<tr>
<td></td>
<td>07:00 – 22:00</td>
</tr>
<tr>
<td>Residential, Institutional and</td>
<td>55</td>
</tr>
<tr>
<td>Educational</td>
<td></td>
</tr>
<tr>
<td>Industrial, Commercial</td>
<td>70</td>
</tr>
</tbody>
</table>


### 9.7.2 Project Representative Data

The Tema LNG Project envisages a system for regasification of liquefied natural gas (LNG) installed in a ship moored at sea at 10.8 km approximately from Tema coast edge. The LNG required by the system will be supplied by ships visiting the FSRU every 8 days.

The regasification process involves heating of LNG up to its changing to gaseous state. For such purpose, the system feeds hot seawater into the recirculation system to provide heat required for changing LNG to the gaseous state. Energy required for LNG regasification is provided by boilers that, with generation of natural gas as steam is conveyed to turbines for power generation. Since the system is designed for processing 750 million standard cubic feet per day (MMscfd) of LNG, it is expected that the amount of fuel required for operation of the FSRU (boilers and turbines) will represent ~0.9% of the LNG processing (750 MMscfd).

Emission sources of gases and particulate to the atmosphere as well as noise are associated with the operation of the FSRU system, LNG transfer to the FSRU and ships required for transport of crews as well as tugboats to be used in positioning manoeuvres of ship for LNG supply to FSRU. On the other hand, additional noise emissions in the coastal zone originate from the gas pressure regulation system (controlled by valves) at the metering station (Genesis, 2014).

#### 9.7.2.1 FSRU System

The amount required for operation of the Project regasification process is estimated at ~0.9% with respect to the LNG processing volume (750 MMscfd); therefore, it is expected that an approximate amount of 6.75 MMscfd of LNG will be available. For the purposes of this study, the heating capacity was considered based on the molecular content of natural gas in British thermal units (Btu) per standard cubic feet (scf) volume, which is 1,020 Btu/scf on average (USEPA, 1995). The heating capacity value takes into account the natural gas composition consisting of a high methane percentage (usually above 85%) and varied amounts of ethane,
propane, butane and inert gases (typically nitrogen, carbon dioxide and helium); therefore, heating values range from 950 to 1,050 Btu/scf (USEPA, 1995, sec. 1.4 Natural Gas Combustion).

Within the assumptions considered for estimation of atmospheric emissions (gases, particulate matter and noise), it is expected that the FSRU will operate round the clock for 365 days a year.

**9.7.2.2 FSRU Support Vessels**

For evaluation purposes of the main atmospheric emissions, it is considered the use of vessels for transport of LNG, crews and use of tugboats.

In the case of the LNG carrier, the type of fuel used generally presents two options according to the fuel burner type: (i) using heaters (burners of boil-off gas, BOG) and steam turbines (ST Boilers); as well as (ii) dual fuel diesel and natural gas engines (DFDE) (Afon & Ervin, 2008). Mix percentages for each type of fuel are indicated below (Afon & Ervin, 2008):

- **ST Boilers**: 33% fuel oil (FO) and 67% natural gas
- **DFDE**: 1% marine gas oil (MGO) and 99% natural gas

Fuel consumption by the LNG carrier will occur during transfer of LNG to the FSRU system. For evaluation purposes it has been considered representative data from LNG carrier with capacities from 138,000 to 155,000 m$^3$ during transfer operations (Afon & Ervin, 2008). They are representative for the planned storage capacity of 127,104 m$^3$. The assumptions included scenarios related to fuel use options according to the type of equipment (ST Boilers and DFDE) during LNG transfer operations to the FSRU. The LNG average transfer time to the FSRU per shipload was assumed to be 13 hours, for which there is available average fuel consumption rates based on historical data from similar operations as shown below (Afon & Ervin, 2008):

- **ST Boilers**: 11 tons of FO and 53.9 m$^3$ of LNG; this consumption represents a heat value of 124 MMBtu/hr.
- **DFDE**: 451 m$^3$ of LNG and 0.28 m$^3$ of MGO; this consumption represents a heat value of 77 MMBt/hr.

It is planned that the supply frequency of the LNG carrier to the FSRU will be, in worst-case-scenario, every 8 days; therefore, there will be approximately 598 hours per year of LNG transfer time to the FSRU.

Other related auxiliary activities correspond to the use of vessels for transport of FSRU crews and tugboats for positioning support to the LNG carrier. Assumptions are based on waiting times and number of trips of vessels; in the case of the crew vessel, it is expected it will make 6 trips a week with 1 hour waiting times for each trip, under the assumption that power generation engines will use fuel during waiting times. In the case of tugboats, it is assumed that four tugboats will be used to carry out the positioning manoeuvres for the LNG carrier and, according to the visit frequency of the latter; approximately 46 towing events are estimated for 1 year, with each event lasting 2 hours. Thus, there will be approximately 365 hours of towing operations per year. Based on available data from tugboat suppliers$^3$, a power capacity of 4,400 kW is assumed for each tugboat.

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$^3$ Available in http://svitzer.com/sustainability/tug-designs
Potential noise sources in the regasification system are associated with power generation by turbines, gas compressors and pumps. It is planned to install equipment in closed spaces and noise emissions are expected to be no higher than 85 dB(A) at 1 m distance from the equipment location. LNG transfer activities from the carrier to the FSRU as well as auxiliary activities for crew transport and tugboat operations are also considered to be noise emission sources.

9.7.3 Emissions Inventory

The scenarios considered for estimation of particulate and gas atmospheric emissions are based on FSRU operations, LNG transfer to FSRU and auxiliary support vessels:

- Scenario 1: Emissions from FSRU operations (heaters, turbines, pumps and engines) together with operations (arrival, offloading and exit) of the LNG carrier (use of heaters and turbines – ST Boilers) as well as the use of tugboats and crew transport vessel.
- Scenario 2: Emissions from FSRU operations (heaters, turbines, pumps and engines) together with operations (arrival, offloading and exit) of the LNG carrier (use of dual fuel diesel engines - DFDE) as well as the use of tugboats and crew transport vessel.
- Scenario 3: Emissions from FSRU operations only (heaters, turbines, pumps and engines).

Noise emissions from the zone where the FSRU is located correspond to the use of equipment (generator sets, turbines, engines, pumps) that is part of the liquid gas regasification system. The LNG carrier would use engines (generator sets and turbines) that will emit noise to the environment. As the most unfavourable condition, it is estimated that noise emissions originate at the deck of the FSRU Plant and the LNG carrier. On the other hand, gas exiting the FSRU Plant will pass through a pressure regulation system at the metering station, which would generate various noise emission levels at source (between 76 and 104 dBA approximately\(^4\)). This metering station that regulates gas pressure is located in Tema industrial area. Noise emissions variation at the metering station would be related to the incoming gas pressure (Knight Piésold, 2013); therefore, two scenarios were considered:

- Scenario 1: Equivalent maximum noise emission (LAEqT) of 104 dB(A) at metering station (gas pressure regulation), FSRU operation, LNG carrier and tugboats.
- Scenario 2: Equivalent noise emission (LAEqT) of 82.3 dB(A) at metering station (gas pressure regulation), FSRU operation, LNG carrier and tugboats.

9.7.3.1 Particulate and Gas Atmospheric Emissions Inventory

Emission factors from international environmental guidelines were used to calculate atmospheric emissions:

- Section 1.4 Natural Gas Combustion

---

\(^4\) Measurement of noise emissions at natural gas pressure regulation stations performed by Knight Piésold specialists as part of Project Estudio Acústico en 23 Estaciones de Regulación de Presión (ERP) del Sistema de Distribución de Gas en Lima y Callao for the Gas Natural de Lima y Callao S.A. company (Cálidda).
- Section 3.1 Stationary Gas Turbine
- Scientific article, An Assessment of Air Emissions from Liquefied Natural Gas Ships Using Different Power Systems and Different Fuels (Afon & Ervin, 2008)

A general equation was used to estimate emissions, with the following mathematical expression:

$$E = A \times EF \times \left(1 - \frac{ER}{100}\right)$$

In the equation above, $E$ are atmospheric emissions (in mass/time units, g/sec or kg/year), $A$ is the activity rate (i.e. fuel consumption per year), $EF$ is the substance emission factor (i.e. emitted mass per fuel consumption amount) and $ER$ is the reduction efficiency percentage due to application of atmospheric emission control technologies.

Table 9-3 shows a summary of particulate and gas atmospheric emissions for the three scenarios under consideration.

### Table 9-3: Particulate and Gas Atmospheric Emissions

<table>
<thead>
<tr>
<th>Substance</th>
<th>Scenario 1 (ton/year)</th>
<th>Scenario 1 (kg/hr)</th>
<th>Scenario 2 (ton/year)</th>
<th>Scenario 2 (kg/hr)</th>
<th>Scenario 3 (ton/year)</th>
<th>Scenario 3 (kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO&lt;sub&gt;x&lt;/sub&gt;</td>
<td>378.3</td>
<td>84.9</td>
<td>381.8</td>
<td>90.7</td>
<td>344.9</td>
<td>0.039</td>
</tr>
<tr>
<td>VOC</td>
<td>14.4</td>
<td>2.1</td>
<td>4.9</td>
<td>8.9</td>
<td>13.6</td>
<td>0.002</td>
</tr>
<tr>
<td>PM&lt;sub&gt;2.5&lt;/sub&gt;</td>
<td>10.4</td>
<td>5.8</td>
<td>9.8</td>
<td>4.7</td>
<td>8.0</td>
<td>0.001</td>
</tr>
<tr>
<td>PM&lt;sub&gt;10&lt;/sub&gt;</td>
<td>11.1</td>
<td>7.1</td>
<td>10.0</td>
<td>5.4</td>
<td>8.0</td>
<td>0.001</td>
</tr>
<tr>
<td>SO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>37.0</td>
<td>78.9</td>
<td>19.2</td>
<td>49.1</td>
<td>1.5</td>
<td>0.000</td>
</tr>
<tr>
<td>CO</td>
<td>211.0</td>
<td>9.0</td>
<td>215.8</td>
<td>17.0</td>
<td>207.0</td>
<td>0.024</td>
</tr>
</tbody>
</table>

### 9.7.3.2 FSRU Regasification Process

The FSRU fuel capacity is estimated at 750 MMscfd (million standard cubic feet per day) according to the Project description. The FSRU regasification system requires approximately 0.9% of the fuel capacity (750 MMscfd). According to the AP-42 guide (USEPA, 1995), the natural gas heat ratio is 1 020 Btu/scf.

Also, from a more conservative approach it is considered that FSRU operations will proceed continuously, 24-hour daily during 365 days for a representative year.

Therefore, it has been estimated that for power generation, in Btu units, approximately 2 513 025 MMBtu will be required for each operation year; this value represents the activity rate of the FSRU regasification process.

Emission factors used are based on sections 1.4 Natural Gas Combustion and 3.1 Stationary Gas Turbines of USEPA’s AP-42 guidelines (1995). Since operation fuel will be used for power generation in heaters and turbines, both operations are represented by average emission factors (Table 9-4).

---

5 Available in http://www.epa.gov/ttnchie1/ap42/
Table 9-4: Particulate and Gas Emission Factors – FSRU Regasification System

<table>
<thead>
<tr>
<th>Sources</th>
<th>Units</th>
<th>PM (1)</th>
<th>SO₂</th>
<th>NOₓ</th>
<th>CO</th>
<th>VOC (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heaters</td>
<td>lb/10⁶ scf</td>
<td>7.6</td>
<td>0.6</td>
<td>140</td>
<td>84</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>lb/MMBtu</td>
<td>7.45E-03</td>
<td>5.88E-04</td>
<td>1.37E-01</td>
<td>8.24E-02</td>
<td>5.39E-03</td>
</tr>
<tr>
<td>Turbines</td>
<td>lb/MMBtu</td>
<td>6.60E-03</td>
<td>3.40E-03</td>
<td>3.20E-01</td>
<td>8.20E-02</td>
<td>2.10E-03</td>
</tr>
<tr>
<td>Average</td>
<td>lb/MMBtu</td>
<td>7.03E-03</td>
<td>1.99E-03</td>
<td>2.97E-01</td>
<td>8.22E-02</td>
<td>3.75E-03</td>
</tr>
</tbody>
</table>

Notes:
(1) Diameter less than 1 micrometer, therefore PM is equal to PM₁₀ and PM₂.₅.
(2) Volatile Organic Compounds.

The emissions were estimated by multiplying the activity rate by the average emission factor. For example, nitrogen oxides were estimated as follows:

\[
E = \frac{\text{MM Btu}}{\text{year}} \times 0.229 \times \frac{\text{lb NO}_x}{\text{MM Btu}} = 574 \times 547 \frac{\text{lb NO}_x}{\text{year}} = 344.9 \frac{\text{tonne NO}_x}{\text{year}}
\]

Table 9-5 shows the emission results for PM (PM₁₀ or PM₂.₅), SO₂, NOₓ, CO and VOC based on representative data for the LNG regasification process in the FSRU system. Figure 9-6 and Table 9-6 show particulate and gas emissions.

Table 9-5: Particular and Gas Atmospheric Emissions - FSRU Regasification Process

<table>
<thead>
<tr>
<th>Parameter description</th>
<th>Units</th>
<th>Value</th>
<th>Source information and criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Capacity of the FSRU system</td>
<td>MMscfd</td>
<td>750</td>
<td>Description Project</td>
</tr>
<tr>
<td>Heating ratio of the natural gas</td>
<td>Btu/scf</td>
<td>1,020</td>
<td>AP-42 Guidelines (USEPA, 1995)</td>
</tr>
<tr>
<td>Fuel percentage for give power to FSRU operation</td>
<td>%</td>
<td>0.9</td>
<td>Background on Tema FSRU Project</td>
</tr>
<tr>
<td>Quantity of LNG for give power to FSRU operation</td>
<td>MMscfd</td>
<td>6.8</td>
<td>Background on Tema FSRU Project</td>
</tr>
<tr>
<td>Heat input for to give power to FSRU operation</td>
<td>MMBtu/d</td>
<td>6,885</td>
<td>Estimated</td>
</tr>
<tr>
<td>Days of operation during the year</td>
<td>day/year</td>
<td>365</td>
<td>Conservative scenario</td>
</tr>
<tr>
<td>Emission factors -EF</td>
<td>lb/y</td>
<td>2,513,025</td>
<td>Estimated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Units</th>
<th>Parameter emitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boilers (2)</td>
<td>lb/10⁶ scf</td>
<td>PM (3)</td>
</tr>
<tr>
<td></td>
<td>lb/MMBtu</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.45E-03</td>
</tr>
<tr>
<td>Stationary gas turbine (3)</td>
<td>lb/MMBtu</td>
<td>6.60E-03</td>
</tr>
<tr>
<td>Average EF</td>
<td>lb/MMBtu</td>
<td>7.03E-03</td>
</tr>
</tbody>
</table>

Notes:
(1) MMscfd: Million standard cubic feet per day, is commonly used a measure of natural gas. Btu: British thermal unit (Btu) is a traditional unit of energy. scf: standard cubic feet.
(2) AP-42 Guidelines, Section 1.4 Natural Gas Combustion. Maximum emissions of NOₓ (Controlled - Low Nox burners).
(3) AP-42 Guidelines, Section 3.1 Stationary Gas Turbines. Natural Gas-Fired Turbines for uncontrolled emissions.
(4) All PM is assumed to be less than 1.0 micrometer in diameter (Section 1.4 Natural Gas Combustion). Emission factors are based on combustion turbines using water-steam injection (Section 3.1 Stationary Gas Turbines).
Quantum Power Ghana Gas Limited

Knight Piésold Consulting

Environmental and Social Impact Assessment

Table 9-6: Particulate and Gas Emissions from FSRU

<table>
<thead>
<tr>
<th>Emitted parameter</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pounds/year</td>
</tr>
<tr>
<td>PM</td>
<td>17 655</td>
</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>5 011</td>
</tr>
<tr>
<td>NO\textsubscript{x}</td>
<td>574 547</td>
</tr>
<tr>
<td>CO</td>
<td>206 512</td>
</tr>
<tr>
<td>VOC</td>
<td>9 414</td>
</tr>
</tbody>
</table>

9.7.3.3 LNG Carrier

The LNG carrier will supply fuel to FSRU every 8 days. The LNG average transfer time to FSRU was assumed to be 13 hours (Afon & Ervin, 2008). Fuel consumption varies according to the type of technology for power generation (Afon & Ervin, 2008):

- ST Boilers: 11 tons of FO and 53.9 m\textsuperscript{3} of LNG; this consumption represents a heat value of 124 MMBtu/hr.
- DFDE: 451 m\textsuperscript{3} of LNG and 0.28 m\textsuperscript{3} of MGO; this consumption represents a heat value of 77 MMBtu/hr.

Based on fuel consumption data, annual values of 46 046 MMBtu and 74 152 MMBtu were estimated according to the combustion technology type: DFDE and ST Boilers, respectively.

Table 9-7 shows the heat values estimated according to fuel consumption options, the emission factors (Afon & Ervin, 2008) according to fuel type options as well as atmospheric emissions.

Table 9-7: Particulate and Gas Atmospheric Emissions - LNG Transfer to FSRU

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time \textsuperscript{(1)}</td>
<td>13</td>
<td>hr/cargo</td>
</tr>
<tr>
<td>Frequency of visit to FSRU</td>
<td>8</td>
<td>days</td>
</tr>
<tr>
<td>Number of visits in the year</td>
<td>46</td>
<td>days</td>
</tr>
<tr>
<td>Transit time in the year</td>
<td>598</td>
<td>hr/year</td>
</tr>
</tbody>
</table>
### Total heat input (DFDE, dual fuel) (1)
77 MMBtu/hr

### Total heat in the year (DFDE, dual fuel)
46,046 MMBtu/yr

### Total heat input (ST Boilers, dual fuel) (1)
124 MMBtu/hr

### Total heat in the year (ST Boilers, dual fuel)
74,152 MMBtu/yr

#### Option 1 - Using ST Boilers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Emission Factor - ST Boilers (lb/MMBtu)</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\textsubscript{x}</td>
<td>0.2200</td>
<td>16,313</td>
</tr>
<tr>
<td>VOC</td>
<td>0.0039</td>
<td>289</td>
</tr>
<tr>
<td>PM\textsubscript{2.5}</td>
<td>0.0260</td>
<td>1,928</td>
</tr>
<tr>
<td>PM\textsubscript{10}</td>
<td>0.0380</td>
<td>2,818</td>
</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>0.5400</td>
<td>40,042</td>
</tr>
<tr>
<td>CO</td>
<td>0.0620</td>
<td>4,597</td>
</tr>
</tbody>
</table>

#### Option 2 - Using DFDE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Emission Factor - DFDE (lb/MMBtu)</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\textsubscript{x}</td>
<td>0.5200</td>
<td>23,944</td>
</tr>
<tr>
<td>VOC</td>
<td>0.2000</td>
<td>9,209</td>
</tr>
<tr>
<td>PM\textsubscript{2.5}</td>
<td>0.0105</td>
<td>483</td>
</tr>
<tr>
<td>PM\textsubscript{10}</td>
<td>0.0105</td>
<td>483</td>
</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>0.0170</td>
<td>783</td>
</tr>
<tr>
<td>CO</td>
<td>0.3300</td>
<td>15,195</td>
</tr>
</tbody>
</table>

Notes:

(1) Source: An Assessment of Air Emissions from Liquefied Natural Gas Ships Using Different Power Systems and Different Fuels. ST Boilers = Steam Turbine and Boilers. DFDE = Dual-fuel diesel engines (DFDEs).

Estimated emissions (Table 9-8) were determined by multiplying the activity value by the emission factors according to the fuel consumption type (ST Boilers or DFDE).

### Table 9-8: Particulate and Gas Emissions from the LNG Carrier

<table>
<thead>
<tr>
<th>Emitted Parameter</th>
<th>ST Boilers (Option 1)</th>
<th>DFDE (Option 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM\textsubscript{10}</td>
<td>1.3</td>
<td>0.2</td>
</tr>
<tr>
<td>PM\textsubscript{2.5}</td>
<td>0.9</td>
<td>0.2</td>
</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>18.2</td>
<td>4.4</td>
</tr>
<tr>
<td>NO\textsubscript{x}</td>
<td>7.4</td>
<td>10.9</td>
</tr>
<tr>
<td>CO</td>
<td>2.1</td>
<td>6.9</td>
</tr>
<tr>
<td>VOC</td>
<td>0.1</td>
<td>4.2</td>
</tr>
</tbody>
</table>

### 9.7.3.4 Auxiliary Vessels

Estimation of emissions from use of auxiliary vessels (crew transport and tugboats) was based on the methodology of NPI guide (2012) “Estimation Technique Manual for Maritime Operations”. In order to apply the equation for emission estimation, it is assumed that the crew transport vessel has a power capacity of 600 kW (NPI, 2012), which will make 6 visits a week to the FSRU Plant, and 1 hour duration (TIW) for operation of engines during boarding of crew from the FSRU Plant.
\[ E_i = N \times EF_i \times P \times TIW \]

Where:

\( E_i \) = Emissions from auxiliary power engines (kg/year)
\( N \) = Number of ships visiting each year (ships/year)
\( EF_i \) = Emission factor for substance \( i \) from auxiliary engines (kg/kWh)
\( P \) = Auxiliary power (assumed at 600 kW according to guide) (kW)
\( TIW \) = Average waiting time per ship (hours/ship)

Table 9-9 shows the values assumed for emission estimation as well as emission factors for each substance emitted to the atmosphere. In the case of emissions generated by support tugboats (see
Table 9-10) for positioning manoeuvres of LNG carrier at FSRU Plant, it is assumed that four tugboats of 4 400 kW power will be used every 8 days. It is assumed that tugboat manoeuvring will last 2 hours in order to locate the LNG carrier in the final position for LNG offloading to the FSRU Plant.

Table 9-9: Particulate and Gas Atmospheric Emissions (Crew Transport Vessel)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Emission Factor - (kg/kWh)</th>
<th>Emissions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(t)</td>
<td>kg/year</td>
<td>tonne/year</td>
</tr>
<tr>
<td>NO\textsubscript{x}</td>
<td>1.45E-02</td>
<td>2,722</td>
<td>2.7</td>
</tr>
<tr>
<td>VOC</td>
<td>3.80E-04</td>
<td>71</td>
<td>0.1</td>
</tr>
<tr>
<td>PM\textsubscript{2.5}</td>
<td>8.60E-04</td>
<td>161</td>
<td>0.2</td>
</tr>
<tr>
<td>PM\textsubscript{10}</td>
<td>1.00E-03</td>
<td>188</td>
<td>0.2</td>
</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>9.70E-03</td>
<td>1,821</td>
<td>1.8</td>
</tr>
<tr>
<td>CO</td>
<td>1.10E-03</td>
<td>206</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Notes:

(t) Estimation Technique Manual for Maritime operations (NPI, 2012)
### Table 9-10: Particulate and Gas Atmospheric Emissions (Tugboats for LNG carrier support)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Emission Factor - (kg/kWh)</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(2)</td>
<td>kg/year</td>
</tr>
<tr>
<td>NO(_x)</td>
<td>1.45E-02</td>
<td>23,287</td>
</tr>
<tr>
<td>VOC</td>
<td>3.80E-04</td>
<td>610</td>
</tr>
<tr>
<td>PM(_{2.5})</td>
<td>8.60E-04</td>
<td>1,381</td>
</tr>
<tr>
<td>PM(_{10})</td>
<td>1.00E-03</td>
<td>1,606</td>
</tr>
<tr>
<td>SO(_2)</td>
<td>9.70E-03</td>
<td>15,578</td>
</tr>
<tr>
<td>CO</td>
<td>1.10E-03</td>
<td>1,767</td>
</tr>
</tbody>
</table>

Notes:
(2) Estimation Technique Manual for Maritime operations (NPI, 2012)

Table 9-11 shows a summary of emissions from auxiliary vessels.

### Table 9-11: Particulate and Gas Emissions from Auxiliary Vessels

<table>
<thead>
<tr>
<th>Emitted Parameter</th>
<th>Emissions (tons/year)</th>
<th>Crew Vessel</th>
<th>Tugboats</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM(_{10})</td>
<td>0.2</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>PM(_{2.5})</td>
<td>0.2</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>SO(_2)</td>
<td>1.8</td>
<td>15.6</td>
<td></td>
</tr>
<tr>
<td>NO(_x)</td>
<td>2.7</td>
<td>23.3</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>0.2</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>VOC</td>
<td>0.1</td>
<td>0.6</td>
<td></td>
</tr>
</tbody>
</table>

9.7.4 Noise Emissions
Table 9-12 presents a list of emission sources entered in the sound propagation model, which have been distributed in the area of FSRU (Figure 9-7) and metering station (Figure 9-8).

Two area type emission sources were located at the FSRU Plant with sound power levels (Lw) of 124.6 dB(A) (use of Wärtsilä L38 engines) and of 97 dB(A) (machine room). It is assumed that the LNG carrier presents an emission source from the use of Wärtsilä engines located on the south side of the ship. It was considered that four tugboats could be located near the LNG carrier; these tugboats could use noise emitting engines of the Wärtsilä brand.
Table 9-12: Noise Emission Sources in Octave Band Frequency

<table>
<thead>
<tr>
<th>Source</th>
<th>Pressure Levels in Octave Bands (Hz) in dB(A)</th>
<th>Global LAeqT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31</td>
<td>63</td>
</tr>
<tr>
<td>Wärtsilä L38 Engine⁶</td>
<td>-</td>
<td>85.0</td>
</tr>
<tr>
<td>Machine Room⁷</td>
<td>-</td>
<td>68.8</td>
</tr>
<tr>
<td>Electric Pump</td>
<td>-</td>
<td>44.8</td>
</tr>
<tr>
<td>Fuel Tank Pump</td>
<td>-</td>
<td>48.8</td>
</tr>
<tr>
<td>Diesel generator set</td>
<td>-</td>
<td>52.8</td>
</tr>
<tr>
<td>Pressure Regulation – Scenario 1⁹</td>
<td>30.0</td>
<td>46.1</td>
</tr>
<tr>
<td>Pressure Regulation – Scenario 2</td>
<td>36.6</td>
<td>50.1</td>
</tr>
</tbody>
</table>

Figure 9-7: Noise Emission Sources – FSRU and LNG Carrier

Five point sources of noise emission were located at the natural gas metering station. Figure 9-8 shows source distribution in the area where it is planned to install the metering station. Of all sources, the pressure entering the metering station in order to provide for constant pressure may produce different noise emission intensity levels, which may reach 104 dB(A).

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⁷ Source: Guideline Noise Emission from Industrial Facilities VDI2571. Published by the Association of German Engineers (VDI).
⁹ Source: Estudio Acústico en 23 Estaciones de Regulación de Presión (ERP) del Sistema de Distribución de Gas en Lima y Callao (Knight Piésold, 2013).
Summation of Sound Propagation Contributions and Baseline

The sum of noise contributions plus baseline levels is estimated with the following mathematical expression:

\[ L_T = 10 \log_{10}(10^{B/10} + 10^{P/10}) \]

Where:

- \( L_T \): Equivalent sound pressure level forecast in dB(A);
- \( B \): Equivalent noise level of baseline (without Project effects);
- \( P \): Equivalent noise level propagated from source to receptor.

9.7.4.1 Meteorological Data

Meteorological data entered in the CALPUFF dispersion model corresponds to 2013 in hourly resolution and comes from the following data sources:
- DGAA Meteorological Station Accra, located at the international airport.
- Database of National Aeronautics and Space Administration (NASA) – Giovanni Project: Satellite Data from Aqua and Terra Probes of MODIS (Moderate Resolution Imaging Spectro radiometer) and OMI (Ozone Monitoring Instrument) of Aura.
- Meteorological forecast data generated by Weather Research and Forecasting (WRF) model, 4 km resolution, 50 by 50 km domain and 35 vertical levels (modeled by Lakes Environmental Inc, 2014).

DGAA Meteorological Station Accra (Ghana)

Downloaded hourly data correspond to the following parameters: pressure (hPa or mbar), temperature (°C), relative humidity (%), wind direction (degrees) and wind speed (m/s).

Table 9-13: Meteorological Conditions – DGAA Meteorological Station (2013)

<table>
<thead>
<tr>
<th>Value</th>
<th>Pressure (hPa)</th>
<th>Temperature (°C)</th>
<th>Relative Humidity (%)</th>
<th>Wind Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>1 011.5</td>
<td>27.15</td>
<td>79.66</td>
<td>4.83</td>
</tr>
<tr>
<td>Maximum</td>
<td>1 025</td>
<td>37</td>
<td>100</td>
<td>13</td>
</tr>
<tr>
<td>Minimum</td>
<td>1 000</td>
<td>21</td>
<td>16</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: DGAA Meteorological Station Accra

Table 9-13 shows the variability range of meteorological parameters recorded by the DGAA meteorological station for 2013. On the other hand, Figure 9-9 shows wind directions prevailing from the southwest sector (directions between south and west), i.e. the meteorological station has been recording winds from the southwest towards the northeast. This behaviour has been entered in emission dispersion models for air quality (CALPUFF) and sound propagation (SoundPLAN).

Figure 9-9: Wind Rose - DGAA Meteorological Station (2013)

Cloudiness

Hourly cloudiness records (cover and height) were obtained from NASA satellite data, Geospatial Interactive Online Visualization ANd aNalysis Infrastructure (GIOVANNI) Project; an area with the following coordinates was selected:

10 Available in http://weather.uwyo.edu/surface/meteorogram/
Cloud cover is expressed in fractional units (between 0 and 1) and cloud ceiling height is expressed in pressure units (hPa). Based on the standard atmosphere model of the International Civil Aviation Organization (ICAO), the cloud height was estimated in meter units using the equation below, which is an approach of the annual average atmosphere for all latitudes under standard conditions (Lazaridis, 2011).

\[ z = 44.308 \left( 1 - \left( \frac{p}{1013.25} \right)^{0.19023} \right) \]

The equation is satisfactory up to an altitude of 11 km, where \( z \) is altitude in km and \( p \) is pressure in hPa or mbar. Figure 9-10 shows cloud height evolution throughout 2013. An increase of cloud height is observed from March to June. Likewise, the same behaviour is observed in Figure 9-11 during May and June, when cloud cover levels are high when compared to those recorded in January.

![Cloud Ceiling Height (2013)](source: Giovanni Project (NASA))
Figure 9-11: Cloud Cover (2013)

Source: Giovanni Project (NASA).

9.7.5 CALPUFF Dispersion Model

CALPUFF is a Gaussian puff non-stationary dispersion model developed at the end of the 1980s (Scire, Strimalis & Yamartino, 2000). The meteorological pre-processor for CALPUFF is CALMET (Scire, Robe, Fernau & Yamartino, 2000), which has algorithms required for estimation of dispersion generated by CALPUFF. This model is recommended by the United States Environmental Protection Agency (U.S. EPA) for applications where the distance from the source to the receptors exceeds 50 km as well as changes for non-stationary wind conditions (wind direction changes spatially) and calm winds.

The model configuration encompasses a domain area of 60 km width by 56 km height, delimited by the following coordinates (WGS 84, zone 31N):

- Southwest corner (SW): 149 500 m east and 590 643 m north
- Northeast corner (NE): 210 090 m east and 646 643 m north
Digital files of topographic relief from NASA database for Shuttle Radar Topography Mission (SRTM) Project were used, which have 90-meter resolution (Figure 9-12). Ground cover data were entered with 1-km resolution downloaded from the United States Geological Survey (USGS) web page. These two data sources served for characterization of geophysical factors involved in heat balance and its influence on pollutant dispersion (Visscher, 2013).

In order to determine ground level concentrations, discrete and grid receptors were assigned; they correspond to points where the model calculates concentration levels as a result of emission transport from sources. The receptors grid encompasses the entire model domain area; additionally, discrete receptors were assigned (Figure 9-13) and located in residential areas.

---

Figure 9-13: Discrete Receptors

The supply of meteorological data to the CALMET pre-processor includes hourly data for 2013 from the meteorological station located at Kotoka airport as well as forecast data from WRF model. CALMET processed geophysical and meteorological data (observed and forecast data), for which the following variables were determined and stored in the CALMET.DAT file:

- Ground roughness (zo)
- Ground elevation
- Wind vector components (3D) (Figure 9-14)
- Air temperature (3D)
- Surface friction speed (u*)
- Convective speed scales (w*)
- Mixing height (zi)
- Monin-Obukhov length (L)
- PGT stability classes
- Hourly values from meteorological station
- Cloud cover and height
Figure 9-14: Wind Variation in Study Area

A rectangle shape emission area was assigned and located at coordinates 179 047 m east and 618 643 m north (Datum WGS84, zone 31N). Figure 9-15 shows the assigned emission source (red colour rectangle) encompassing the FSRU Plant and the LNG carrier. The area source was assumed to be 413 m long and 116 m wide, covering an area of 48 020.6 m$^2$.

Figure 9-15: Atmospheric Emissions Source

Source: Ghana LNG Import Terminal Feed Study (Genesis): Drawing № J26240A-K-DW-10029.
9.7.6 SoundPLAN Sound Propagation Model

Preparation of the noise map generated by sources under consideration was based on the modelling methodology of ISO 9613 standard: Acoustics – Attenuation of sound during propagation outdoors, parts 1 and 2, which uses the principles of divergent attenuation along with additional attenuation introduced by obstacles and atmospheric attenuation. The ISO 9613 algorithms were used by executing the SoundPLAN 7.2 (software for noise propagation in the atmosphere). The SoundPLAN 7.2 is used by over 5,000 users including governments, consultants and researchers in more than 40 countries and is the leading program in the world for prediction of atmospheric propagation of noise (Hadzi-Nikolova, Mirakovski, Ristova, & Ceravolo, 2012). Variables that influence propagation and that have been included in the SoundPLAN program are the following:

- Geometric divergence;
- Atmospheric absorption;
- Ground effect;
- Surface reflections; and
- Shielding by obstacles.

The model input variables regarding noise emissions are the sound power of noise sources for each site considered. The exclusive contribution generated by the Project sources was modelled, based on data related to the spatial geometry of sources. Also, data from average meteorological behaviour was entered based on records from the meteorological station at Kokota airport for 2013. Calculation of sound propagation was configured in the model for a resolution of 10 m grid cell size.

In accordance with the ISO 9613 standard, propagation of noise generated by a given source towards a receptor is represented through the following mathematical expression:

\[
L_{fT} (DW) = L_w + D_c - A
\]

Where,

- \( L_{fT} (DW) \) : Equivalent sound pressure level by bands;
- \( L_w \) : Sound power level by octave bands in decibels produced by the point sound source relative to a reference sound power of 1 picowatt (1pW);
- \( D_c \) : Correction by directivity in decibels, describing the extent to which sound waves are diverted into a specific direction from the level of a point sound source.
- \( A \) : Attenuation by octave bands in decibels during propagation from a point source to the receptor.

The \( A \) attenuation term is given by the following equation:

\[
A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc}
\]

Where,
9.8 WATER QUALITY

No existing site specific water quality data has been collected directly within the study area in the past, thus 10 sites (surface and bottom) were collected for analysis (Table 9-14). It is understood that Ghana’s near-shore waters do contain pollutants that arise from human activities. Previous research has indicated that heavy metals that are discharged into the ocean from industrial, along with urban and agricultural runoff are significant problems within the Accra/Tema region (Pau et al., 2012). Trace metal and hydrocarbon concentrations were also detected. These have been attributed to industrial and residential area run-off, the latter aiding in nutrient enrichment (eutrophication) due to sewage discharge (GCLME, 2006).

The preliminary water quality was assessed during the baseline assessment, with specific reference to specific impacts related to the oil and gas industry, shipping activities accidental spills and the potential construction impacts (sediment disturbance) related to the seabed pipeline. It should be noted that the results are limiting due to being a once of survey, but do provide an indication of the current state of the environment. The survey results indicate that of the 14 parameters measured are either typical of the seawater within the region when compared to studies in adjacent areas (Pau et al., 2012). All samples were within the World Bank guidelines. The only exception being Total Suspended Solids that exceeded the World Bank guideline value of <50 mg/l at eight of the 20 sites.

Further no significant difference was observed between the sites and limited variability or stratification was shown with depth. There was no notable difference between the near shore (<20 m) or offshore sites (>20m), or at depth or surface. This was possibly as a result of the heavy swell and wind conditions experienced during the surveys that aided in “mixing” the inshore and near inshore environment. These particular conditions could also have led to the increased Total Suspended Solid concentrations that were observed.

Table 9-14 summarises the water quality results from the 20 sites sampled. As previously stated, the results were obtained from a once of survey and it is therefore recommended that pre-construction, construction-phase and post-construction surveys be conducted.

\[
\begin{align*}
A_{div} & : \text{Attenuation by geometric divergence (ISO-9613);} \\
A_{atm} & : \text{Attenuation by atmospheric absorption (ISO-9613);} \\
A_{gr} & : \text{Attenuation by ground effect (ISO-9613);} \\
A_{bar} & : \text{Attenuation by barrier effect (ISO-9613);} \\
A_{misc} & : \text{Attenuation by other similar effects (ISO-9613)}
\end{align*}
\]
<table>
<thead>
<tr>
<th>Description</th>
<th>Temperature</th>
<th>Depth</th>
<th>Conductivity</th>
<th>Analyte Name</th>
<th>pH</th>
<th>Total Suspended Solids at 103-105°C</th>
<th>Nitrates</th>
<th>Zinc total</th>
<th>Copper total</th>
<th>Lead total</th>
<th>Tin total</th>
<th>Cadmium total</th>
<th>Nickel total</th>
<th>Mercury total</th>
<th>Iron total</th>
</tr>
</thead>
<tbody>
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<td>29.2</td>
<td>6.</td>
<td>45.21</td>
<td>Result</td>
<td>8.</td>
<td>46</td>
<td>&lt;0.06</td>
<td>0.019</td>
<td>0.005</td>
<td>0.0034</td>
<td>0.002</td>
<td>&lt;0.0001</td>
<td>0.021</td>
<td>&lt;0.0001</td>
<td>0.1</td>
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<td>0.02</td>
<td>&lt;0.0001</td>
<td>&lt;0.1</td>
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<td>0.006</td>
<td>0.0007</td>
<td>0.001</td>
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<td>0.021</td>
<td>&lt;0.0001</td>
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<td>&lt;0.0005</td>
<td>0.001</td>
<td>&lt;0.0001</td>
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<td>0.1</td>
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<td>&lt;0.1</td>
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<td>0.006</td>
<td>0.0006</td>
<td>0.001</td>
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<td>&lt;0.0001</td>
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<td>46.21</td>
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<td>&lt;0.005</td>
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<td>&lt;0.0005</td>
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<td>&lt;0.0001</td>
<td>0.02</td>
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<td>&lt;0.0001</td>
<td>0.021</td>
<td>&lt;0.0001</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

**Water quality standards**

| World bank | 6 - 9 | < 50 | 2 | 0.5 | 0.1 | 0.1 | 0.5 |
9.9 BENTHIC ENVIRONMENT

Bathymetric mapping revealed a gently sloping seafloor from the nearshore to approximately 40 m in depth (Figure 9-16 and Figure 9-17). Although isolated rock piles and existing pipelines were observed on the side scan imaging, no major high relief reefs were observed in the project area or adjacent to the transects surveyed. A total of 18 benthic sites were observed using the remote video camera (Table 9-15). Observations revealed the predominance of rocky or mixed rock and soft substrata inshore in depths of below 20 m (Figure 9-16 and Figure 9-17). Offshore sites in deeper waters (>20 m) were observed to consist of soft sediments comprised of course grained sands to fine muds. These observations were supported through grab sampling. Obtaining sediment samples in shallower inshore waters proved difficult due to the hard nature of the substrata which prevented the grab from closing. In many instances numerous attempts (>10) were made to obtain sediment samples, however, the hard nature of the substrata prevented sediments from being collected.
Figure 9-16: Map of the project area illustrating the bathymetry, inshore exclusion zone and sites sampled during the marine offshore survey\textsuperscript{12}

\textsuperscript{12} FSRU sites originally proposed in the scoping report are also indicated (P1-4). (Sampling key: C= video camera only; CI= camera and infauna; CIS= camera, infauna and sediments; CS= camera and sediments)
Figure 9-17: Map of project area indicating substrate composition at each sampling site

Table 9-15: Benthic sites were observed using the remote video camera

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Description</th>
<th>Substrate Image</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site ID</td>
<td>Description</td>
<td>Substrate Image</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>-----------------</td>
</tr>
</tbody>
</table>
| Site 1  | Latitude: 5.672521  
Longitude: 0.057229  
Depth: 7 m  
Substrate: Rock and sand  
Sampling: Camera and Infauna | ![Image](CAM1.png) |
| Site 2  | Latitude: 5.665052  
Longitude: 0.051502  
Depth: 7 m  
Substrate: Rock and sand  
Sampling: Camera and Sediments | ![Image](CAM1.png) |
| Site 3  | Latitude: 5.651881  
Longitude: 0.058883  
Depth: 10 m  
Substrate: Rock and sand  
Sampling: Camera | ![Image](CAM1.png) |
| Site 4  | Latitude: 5.640016  
Longitude: 0.065884  
Depth: 18 m  
Substrate: Soft sediments – sands or muds  
Sampling: Camera and Infauna | ![Image](CAM1.png) |
<table>
<thead>
<tr>
<th>Site ID</th>
<th>Description</th>
<th>Substrate Image</th>
</tr>
</thead>
</table>
| Site 5 | Latitude: 5.657580  
Longitude: 0.047466  
Depth: 9 m  
Substrate: Rock and sand  
Sampling: Camera & Infauna | ![Image](CAM1.png) |
| Site 6 | Latitude: 5.648947  
Longitude: 0.053457  
Depth: 11 m  
Substrate: Rock and sand  
Sampling: Camera | ![Image](CAM1.png) |
| Site 7 | Latitude: 5.638782  
Longitude: 0.061158  
Depth: 17 m  
Substrate: Rock (dead coral)  
Sampling: Camera | ![Image](CAM1.png) |
| Site 8 | Latitude: 5.627181  
Longitude: 0.068060  
Depth: 23 m  
Substrate: Soft sediments – sands or muds  
Sampling: Camera, Infauna and Sediments | ![Image](CAM1.png) |
<table>
<thead>
<tr>
<th>Site ID</th>
<th>Description</th>
<th>Substrate Image</th>
</tr>
</thead>
</table>
| Site 9  | Latitude: 5.615776  
Longitude: 0.075190  
Depth: 27 m  
Substrate: Soft sediments – sands or muds  
Sampling: Camera, Infauna and Sediments | ![Image](CAM_1) |
| Site 10 | Latitude: 5.603963  
Longitude: 0.084198  
Depth: 31 m  
Substrate: Soft sediments – sands or muds  
Sampling: Camera | ![Image](CAM_1) |
| Site 11 | Latitude: 5.587897  
Longitude: 0.094773  
Depth: 38 m  
Substrate: Soft sediments – sands or muds  
Sampling: Camera, Infauna and Sediments | ![Image](CAM_1) |
| Site 12 | Latitude: 5.603560  
Longitude: 0.101463  
Depth: 34 m  
Substrate: Soft sediments – sands or muds  
Sampling: Camera, Infauna and Sediments | ![Image](CAM_1) |
<table>
<thead>
<tr>
<th>Site ID</th>
<th>Description</th>
<th>Substrate Image</th>
</tr>
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</table>
| Site 13 | Latitude: 5.617890  
Longitude: 0.089996  
Depth: 28 m  
Substrate: Soft sediments – sands or muds  
Sampling: Camera | ![CAM 1](image1) |
| Site 14 | Latitude: 5.628171  
Longitude: 0.080731  
Depth: 25 m  
Substrate: Soft sediments – sands or muds  
Sampling: Camera, Infauna and Sediments | ![CAM 1](image2) |
| Site 15 | Latitude: 5.638466  
Longitude: 0.074411  
Depth: 20 m  
Substrate: Rock  
Sampling: Camera | ![CAM 1](image3) |
| Site 16 | Latitude: 5.650673  
Longitude: 0.064423  
Depth: 14 m  
Substrate: Rock  
Sampling: Camera | ![CAM 1](image4) |
Sediment samples were collected from ten sites, all being used for the assessment of infanual communities (Figure 9-17). Analysis of particle size distribution and contaminant testing was conducted on samples from seven sites shown in Table 9-16, Table 9-17 and Figure 9-17. As indicated above, the dominant particle size fraction within the sediment samples where those classed as sand, followed by silt. Only Site 2 had higher percentage gravel (28%). This was probably due to this site being the closest to shore than all other samples and very close to the current WAG pipeline, which has resulted in inshore bottom disturbance when it was constructed. Site 8 showed an unusually high % silt fraction in the sample, when compared to the other samples and would require additional investigation in order to explain this anomaly. However the results compared favourably to the four particle size distribution tests conducted by Thales Geosolutions (2003) in the offshore geotechnical assessment for the WAGP. The 2003 results indicated that the samples ranged from well graded sand and silt to well graded Sand with gravel, i.e. a high % of sand, and silts with little fines (clay fraction) and at times gravels.

Table 9-16: Results of the sediment size fraction studies

<table>
<thead>
<tr>
<th>Site</th>
<th>% sediment particle size proportion per sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cobbles &amp; Boulders</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 9-17: Images of sediment composition collected by grab sampling prior to sifting through 500 µm filters

<table>
<thead>
<tr>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Image of sediment composition" /></td>
<td><img src="image2" alt="Image of sediment composition" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Image of sediment composition" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="Image of sediment composition" /></td>
</tr>
</tbody>
</table>
Mean concentrations for metals present in sediments were also analysed and compared to those metals listed in the Australian and New Zealand Environment and Conservation Council.
(ANZECC) guidelines and a comparison based on criteria determined as they appear in ANZECC (2000) and Jackson (2000) (as amended) provided in Table 9-18. These criteria are mostly relevant to dredging activities, as but as the first 1.5 to 2.0 km of the pipeline will be buried. It is envisaged that the sediments in these areas will then be disturbed, and if containing a high proportion of silts and or clays, will become suspended in the water column, carrying with them potentially harmful substances such as metals. For this reason four sediment samples were selected for metals analysis, that occur within the potential area of greatest disturbance (<10 m). One additional sediment sample was selected as a reference (Site 10), which occurs at >30 m depth. Heavy metal concentrations were used a means of determining if the samples were contaminated as shipping traffic within the study area, which is usually the source for other contaminants such as Gasoline and Diesel Range Organics and do contain heavy metals. Furthermore, a large number of land based impacts could also affect the study area, thus conclusive evidence of these sources of pollutants will require a detailed investigation over various seasons and was not the scope of this study.

Should the copper / cadmium / lead levels been higher, possible shipping traffic impacts would have been implicated (antifouling paints and / or fuel additives), but these were not evident in the results.

Table 9-18: Results of the sediment samples analysed (metals) when compared to international guidelines when possible disturbance or dredging is required

<table>
<thead>
<tr>
<th>Element (µg/g)</th>
<th>EL-R</th>
<th>ER-M</th>
<th>Action Level/ Special Care Prohibition</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ANZECC (Long et al 2000)</td>
<td>Jackson (2000)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Arsenic</td>
<td>20</td>
<td>70</td>
<td>30 – 150</td>
<td>&lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001</td>
</tr>
<tr>
<td>Cadmium</td>
<td>1.5</td>
<td>10</td>
<td>1.5 – 10</td>
<td>&lt;0.0001 &lt;0.0001 &lt;0.0005 &lt;0.0001 &lt;0.0001</td>
</tr>
<tr>
<td>Chromium</td>
<td>80</td>
<td>370</td>
<td>50 – 500</td>
<td>&lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001</td>
</tr>
<tr>
<td>Copper</td>
<td>65</td>
<td>270</td>
<td>50 – 500</td>
<td>&lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0005</td>
</tr>
<tr>
<td>Lead</td>
<td>50</td>
<td>220</td>
<td>100 – 500</td>
<td>&lt;0.002  &lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.15</td>
<td>1</td>
<td>0.5 – 5</td>
<td>&lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001</td>
</tr>
<tr>
<td>Nickel</td>
<td>21</td>
<td>52</td>
<td>50 – 500</td>
<td>&lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001</td>
</tr>
<tr>
<td>Silver</td>
<td>1</td>
<td>3.7</td>
<td></td>
<td>&lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001 &lt;0.0001</td>
</tr>
<tr>
<td>Zinc</td>
<td>200</td>
<td>410</td>
<td>150 – 750</td>
<td>&lt;0.0001 &lt;0.01  &lt;0.0001 &lt;0.0001 &lt;0.0001</td>
</tr>
</tbody>
</table>

According to criteria quoted in Long et al. (1995), if an element is below a certain minimum concentration, known as the Screening Level or Effects Low-Range (EL-R), it is deemed uncontaminated. If, however, the concentration level is above a maximum concentration, known as the Maximum Level or Effects Range-Median (ER-M), the material is deemed acutely toxic and not suitable for unconfined sea disposal or disturbance. When mean values lie between the Screening and Maximum Level, material is considered to be moderately contaminated and will require further investigation prior to the decision making process.

Jackson (2000) proposed that specific levels be used to assess the suitability of dredged material for ocean disposal. These levels provide a range of values that act as a guide for management actions depending on levels of contaminants found in dredged material. All substances are assessed at two levels, with Annex I substances having an Action Level (AL) and Prohibition Level (PL), and Annex II substances having a Special Care Level (SCL) and PL. Sediments with Annex I and II substances at levels below AL and SCL values are considered uncontaminated. The PLs speak for themselves, and any substance present at concentrations exceeding these levels is not suitable for unconfined ocean disposal. Material containing
substances at AL or SCL concentrations need to be managed or controlled prior to disposal. Management options include calling for a detailed ESIA, rigorous selection criteria for disposal site, silt screens to prevent spreading of fine particulate matter, isolation using capping techniques and the issuing of special permits.

Based then on the results shown in Table 9-18 none of the samples analysed showed any signs of contamination. Thus, if disturbed, these would not impact on the surrounding marine biota of human life.

9.10 BENTHIC INFAUNA

Phylum Arthropoda dominated the infaunal community composition accounting for 59% by number, with Phylum Annelida comprising 37%, and Nematoda and Mollusca each accounting for 2% (Table 9-19). Malacostracan crustaceans from the Amphipoda accounted for 49% of the composition by number, followed by the polychaeta (Phylum Annelida) which accounted for 33% of the infaunal composition.
Table 9-19: Benthic infaunal community composition from grab sampling within the project area

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Class</th>
<th>Order</th>
<th>Infraorder</th>
<th>Superfamily</th>
<th>Family</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 4</th>
<th>Site 5</th>
<th>Site 8</th>
<th>Site 9</th>
<th>Site 11</th>
<th>Site 12</th>
<th>Site 14</th>
<th>Site 18</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annelida</td>
<td>Polychaeta</td>
<td></td>
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<tr>
<td>Eunicida</td>
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<tr>
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<tr>
<td>Oligochaet</td>
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<td>10</td>
<td>5</td>
<td>3</td>
<td>15</td>
<td>63</td>
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<tr>
<td>Arthropoda</td>
<td>Malacostraca</td>
<td>Tanaidacea</td>
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<tr>
<td>Decapoda</td>
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<tr>
<td>Amphipoda</td>
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<tr>
<td>Isopoda</td>
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<td></td>
</tr>
<tr>
<td>Mollusca</td>
<td>Bivalvia</td>
<td>Veneroidea</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

TOTAL | 30 | 9 | 13 | 7 | 10 | 25 | 2 | 14 | 16 | 0 | 99 |

Nematoda  | No identification possible | | | | | | | | | | | | | | | | | | | 3 |

TOTAL | 30 | 10 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 3 |

Mollusca  | Bivalvia  | Veneroidea     | Tellinidae (?) | | | | | | | | | | | | | | | | | 4 |

TOTAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| OVERALL TOTAL | 5 | 20 | 15 | 10 | 21 | 29 | 12 | 19 | 19 | 19 | 169 |
9.11 PLANKTONIC ENVIRONMENT

Seasonal changes in the phytoplankton at four depths off Tema, Ghana were investigated in the early 1970’s. The physico-chemical factors measured indicated that there were two distinct marine seasons, the first was coupled to upwelling events (July–October), characterized by low water temperatures (< 25°C), high salinity (> 35‰) and high nutrient levels. The second season was non-upwelling related (November–June) when water temperatures were higher and salinity and nutrients were lower. Phytoplankton cell counts were thus high (> 1000 × 10³ cells/1) during the upwelling season and were very low (< 2 × 10³ cells/1) during the non-upwelling period. Dinoflagellates formed the main components of the phytoplankton population during the non-upwelling period, while diatoms were dominant group at other times (Anang, 1979). This phenomenon was again documented, measured in Chlorophyll-a concentrations by, Sevrin-Reyssac (1993), Pezennec et al. (1993) and Djagoua et al. (2011).

These changes in planktonic primary producers, the main source for food for zooplankton results in seasonal changes this zooplanktonic biomass and reflects in seasonal changes to secondary consumers such as fish (Djagoua et al., 2011).

The proposed project will have limited impact on these communities in the long term, with only short term impacts, such as the decrease in available light for phytoplankton during construction when the seabed pipeline is installed and sediments will be disturbed. Accidental spills (ships) also impact on phyto and zooplanktonic production. However when consider the type of activity and the amount of shipping within the area, this project would have a limited impact on the project.

9.12 COASTAL LAGOONS AND MANGROVES

One coastal lagoon occurs within the study area, in close proximity to the proposed landside metering / safety valve site for this project. The lagoon (although not a large systems, does contain both mangrove and salt marsh vegetation units. Both these habitats are sensitive changes to freshwater input, changes to sediment input and physical disturbance. A pipeline to the Sunon Asogli Power station was installed through this system in 2003 and the area has shown little recovery since, with limited the return of any mangroves.

It will be recommended that none of the proposed pipelines cross this system (buried) and that where possible existing infrastructure such as road bridges or elevate crossings must be used thus avoiding any additional / cumulative impacts on this system. This is covered in more detail in Chapter 12 (Assessment of Marine Impacts and Mitigation)

9.13 FISH AND FISHERIES

As previously mentioned the importance of the increase in nutrients, the primary producers (phytoplankton) and secondary consumers (zooplankton / benthos) during upwelling seasons leads to an increase in fish production. Egg and larval stages of important fish species such as sardines, sardinellas and tuna are also represented in zooplankton.

Marine fisheries in Ghana are affected by these seasonal upwelling that result in increased production of fish food and abundance of most marine fish species. Over 300 different species of commercially important fish are caught from marine sources in Ghana. Activities in the marine fisheries sector range from artisanal canoe operations through inshore to industrial operations. Both pelagic and demersal fishery resources are exploited. Canoe fishers use a wide variety of fishing gears to exploit both pelagic and demersal fish species. The inshore fleet
is made up of vessels ranging in size between 8 and 37 m long. They operate from seven centers along the Ghanaian coastline where there are facilities for landing. The industrial/commercial fleet is currently made up of trawlers, pair trawlers, shrimpers; tuna bait boats and purse seiners. The vessels operate from Tema and Takoradi where there are deep waterports. The trawlers and shrimpers exploit demersal and semi-pelagic species. The tuna fishing vessels catch mainly yellowfin, skipjack and big eye tunas. Large steel-hulled industrial vessels from foreign nations also buy licenses to fish in the Economic Exclusion Zone. These vessels include trawlers, shrimpers, tuna pole and line vessels and purse seiners.

### 9.13.1 Regional Context

Ghana is located off the Gulf of Guinea in the Guinea Current Large Marine Ecosystem (GCLME) which extends from Guinea Bissau in the north to Angola in the south encompassing 16 countries (Ukwe et al., 2006). The GCLME is ranked among the top five most productive LMEs in terms of biomass production (Scherman 1993 in Ukwe et al., 2006) and plays a key role in the local economy and food security based on the fisheries it supports. Ghana is situated almost centrally within the GCLME and experiences two annual upwelling events. The major upwelling event occurs between June and September, lasting for approximately three months. A second minor upwelling which lasts for only three or so weeks occurs during January and February (Roy, 1995, in Ukwe et al., 2006; Koranteng, 1995). During upwelling events enrichment occurs leading to increased primary and secondary productivity. It is during this time that the majority of pelagic fish move inshore to spawn and feed thereby taking advantage of the high productivity.

Ghana has a coastline of approximately 550 km with a shelf area of 24,300 km² and an exclusive economic zone (EEZ) of 218,100 km² (Amador, 2006). The continental shelf ranges from 100 to 200 m in depth and varies in width from 20 km in the eastern region to approximately 90 km between Takoradi and Cape Coast (West African Pipeline Company, 2004). The offshore marine habitat to 200 m is estimated at 8,500 km² which is comprised of 6,500 km² of soft substrata and 2,000 km² of hard rocky substrata (West African Pipeline Company, 2004). Fisheries are of major importance in Ghana, accounting for 4.5% of the country’s Gross Domestic Product (GDP) and 12% of the Agricultural Gross Domestic Product in 2010 (Ayivi, 2011). The main fishing season coincides with the major upwelling event, but fishing activities continue year round. The per capita consumption of fish in Ghana is 25 kg per person annum, and fish forms the major source of protein contributing 60% to animal protein intake (FAO 2007). However, most fish stocks in Ghanaian waters are considered overexploited, as evidenced through declining biomass and average fish size (Nunoo & Armah, 2006; Nunoo & Asiedu, 2013).

Tema in the Greater Accra area and Sekondi and Takoradi in the Western Region are the three deep-water ports in Ghana which support the industrial and tuna fishing fleets. The artisanal fleets utilise over 300 landing beaches along the Ghanaian coastline, with each beach being under the leadership of a Chief Fisherman. There are numerous cold stores located along the Ghanaian coastline which receive fish from all sectors, and the three main fish processors and canneries are situated in Tema. In the major ports, ice is produced by cold storage companies and sold to semi-industrial and artisanal canoe operators allowing them to spend longer periods at sea.
9.13.2 Fishery Resources

9.13.2.1 Small pelagics

The main small pelagics targeted by the artisanal and semi-industrial (inshore) fishery include the two sardinellas, the round sardinella (*Sardinella aurita*) and the flat sardinella (*Sardinella maderensis*), the anchovy (*Engraulis encrasicolus*), and the chub mackerel (*Scomber japonicas*). These four species account for over 80% of the small pelagic landings annually (Entsuah-Mensah, 2005). *S. aurita* is the most important fishery species (Korang teng, 1995) and contributes more to the total landings than all other small pelagic species. It is highly seasonal, being captured during the major and minor upwelling seasons. *S. maderensis* on the other hand is captured in small quantities throughout the year (Korang teng, 1995; Entsuah-Mensah, 2005).

Small pelagics are not associated with benthic habitats and are purely reliant on the oceanic productivity. As a result they move freely and migrate long distances in response to oceanic conditions, crossing international boundaries in the process. As a result, stock and fisheries management is difficult as they are targeted by fisheries in numerous countries. As is typical for short-lived pelagic species, inter-annual biomass of the small pelagic resources fluctuates significantly, being influenced by the intensity of upwelling events. However, catch rates are reportedly in decline while fishing effort has remained relatively constant (Entsuah-Mensah, 2005; Fingold, 2010).

The sardinella fishery is one of the most important economic activities in the coastal region of Ghana providing income generating opportunities for a large canoe and semi-industrial purse seine fishery. Furthermore these fisheries support additional business ventures including fish transport and distribution, fish processing and trading (Korang teng, 1995), all of which are typically undertaken by women. Sardinellas also provide a cheap food protein with approximately 75% of total fish production consumed locally (Entsuah-Mensah, 2005).

9.13.2.2 Large pelagics

The main species targeted in Ghanaian waters include the yellowfin (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*) and bigeye (*Thunnus obesus*) tunas. In addition billfish may also be caught including the swordfish (*Xiphias gladius*) and blue marlin (*Makaira nigricans*). These species are highly migratory and belong to stocks which occur throughout the Atlantic Ocean, and are managed through international bodies such as the International Commission for the Conservation of Atlantic Tunas (ICCAT). These species are mainly targeted by bait boats and purse seiners in Ghanaian waters.

9.13.2.3 Demersal species

Demersal species are bottom or substrate associated species and their distribution is heavily dependent on their substrate preferences (rock, sand, gravel etc.). Depth, substrate type, estuarine association/proximity and water temperature are key factors which govern the distribution of demersal species, which are typically less mobile than the pelagic species. Their distributions are also more predictable and their life histories are often complex (slow growing; sex change; long lived) making them more susceptible to over fishing.

Targeted coastal demersal groups include the Sparidae (seabreams – *Pagellus bellottii*, *Pagrus caeruleostictus*, *Dentex canariensis*), Sciaenidae (croakers – *Pseudotolithus spp.*), Lutjanidae (snappers – *Lutjanus fulgens*, *L. agennes*), Haemulidae (grunts – *Brachydeuterus auritus*, *Pomadasys jubelini*, *P. incises*), Mullidae (goatfish – *Pseudupeneus prayensis*), Serranidae
(groupers – *Epinephelus* spp.), Polynemidae (threadfins - *Galeoides* spp.) and Soleidae (soles). These families are targeted by the artisanal, semi-industrial and industrial sectors using hook and line, gillnets and demersal trawling.

Demersal research trawl surveys were conducted during the baseline phase of the West African Gas (WAG) pipeline environmental impact assessment in order to establish the composition and distribution of demersal species within the pipeline servitude. A total of 115 species from 62 families were caught in Ghanaian waters (West African Pipeline Company, 2004). During these trawl surveys the common cuttlefish (*Sepia officinalis*), was the most dominant demersal species, with channel flounder (*Syacium micrurum*), Guinea flathead (*Grammoplites gruveli*), African wide-eye flounder (*Bothuspodas africanus*), West African goatfish (*Pseudupeneus prayensis*), Canary drum (*Umbria canariensis*), streaked gurnard (*Trigloporus lastoviza*) and piper gurnard (*Triglalyra*) being common across all station sampled (West African Pipeline Company 2004). Highest catch rates in the Tema area occurred at depths from 41 to 70 m.

The artisanal sector lands the greatest harvest of demersal species and has accounted for approximately 75% of Sparidae (seabream) harvest over the last decade (Ayivi, 2011). Fisheries independent surveys and catch rates, however, have shown a marked decline in the abundance of demersal fish in the coastal waters (<30 m) indicating possible over-exploitation (Koranteng, 2001; Fingold, 2010; Ayivi, 2011).

### 9.13.2.4 Shrimp

The shrimp fishery in Ghana primarily targets the pink shrimp (*Penaeus nortialis*) and the Guinea shrimp (*Parapeneopsis atlantica*) with an average of 720 tonnes caught annually between 1960 to mid 1970s (Korateng 2002). Caramote prawn (*Penaeus kerathurus*) and the deep-sea rose prawn (*Parapeneaus longirostris*) area also landed. *P. nortialis*, *P. kerathurus* and *P. atlantica* typically occur over sandy and muddy substrata from the coast to approximately 60 to 100 m (Caverivière and Rabarison Andriamirado, 1997), while *P. longirostris* occurs over sandy substrata on the shelf and upper slope in depths from 50 m to 400 m. Shrimps are caught by all fleets (except tuna fishing vessels) in the shallow coastal waters, particularly close to estuaries. Artisanal beach seiners can catch large amounts of juvenile shrimps and the stocks have showed signs of decline in the past (FAO, 2007). In 1995 there were 17 shrimpers based in Tema which were in operation, however, due to the declining stocks and poor economic recovery from the sector the number of licensed vessels decreased to two in 2002 (Nunoo, 1998; Nunoo&Armah, 2006). There are currently two semi-industrial commercial shrimp vessels licensed to fish in the inshore waters, however, the vessels are currently inoperative (M. Quist pers. comm.).

### 9.13.2.5 Lobster

The royal spiny lobster (*Panulirus regius*) is the most important crustacean species found in West Africa, yet little is known of its basic biology (Freitas et al., 2007). It is a tropical eastern Atlantic species occurring from Morocco to Angola which is found on rocky grounds up to 55 m in depth (Freitas et al., 2007).

### 9.13.2.6 Molluscs

The mollusc species captured by the fisheries include the squid (*Loligo vulgaris*) the common cuttlefish (*Sepia officinalis*), the pink cuttlefish (*Sepia orbignyana*) and the common octopus (*Octopus vulgaris*). *L. vulgaris* occurs throughout the eastern Atlantic from shallow coastal waters down to 500 m (Jereb et al., 2010). It is common over coarse sediments and is generally
more abundant at depths less than 100 m (Jereb et al., 2010). Squid undertakes diurnal migrations remaining near the bottom during the day and rising and dispersing in the water column at night (Jereb et al., 2010). Squid is usually landed as bycatch in the demersal and pelagic trawl fisheries. *S. officinalis* is a large (max length 49 cm) demersal coastal species which occurs over soft substrata. It undertakes a seasonal migration moving into the shallow waters during spring/summer where spawning occurs, while during autumn/winter it migrates to deeper waters (100 m) (Reid et al., 2005). *S. orbignyana* on the other hand is smaller (max length 12 cm), free swimming species which occurs over soft substrata on the shelf edge to depths of 570 m, but is most abundant in shallower waters between 50 and 250 m (Reid et al., 2005). *O. vulgaris* is a widespread species which occurs from shallow coastal waters to 250 m. However, in the north-eastern Atlantic it tends to occur in the intertidal and shallow sub tidal zone (Norman et al., 2014). They can attain 1 m in length and a weight of up to 2 kg and they are a popular fishery species and support a large fishery in northwest Africa. (Norman et al., 2014).

### 9.13.3 Fisheries Sectors

Ghanaian fisheries are classified according to four broad categories or sectors which are discussed below.

#### 9.13.3.1 Artisanal / small-scale

The artisanal or small-scale fisheries sector is a multi-gear multi-species fishery, and is the largest in terms of participation and harvest. Vessels used in this sector are hand built wooden canoes which range in length from 4 to 20 m (Akyempon et al., 2014) (Figure 9-18). Traditionally these canoes were propelled by paddle or sail, however, brackets which can hold an outboard motor have been fitted to many canoes increasing their efficiency and operational range. Motorisation began in 1959 (Doyi 1984) with 50% of canoes being powered by outboards in 1992 (Amador 2006) with this having increased to 60% by 2003 (Ayivi 2011) and currently stands at around 73% (Akyempon et al. 2014).

The artisanal sector accounts for 50% of demersal species landed annually and 90% of small pelagics. Overall the sector accounts for between 65 and 80% of total marine fish landings annually (Doyi 1984; Koranteng 2001; Entsuah-Mensah 2005) and plays an important role in local livelihoods of coastal communities and the regional economy. Women play a key role in fish processing (Figure 2b) and trading, which also supports a fish transportation and distribution sector. The artisanal harvest is comprised of 80% pelagics (dominated by small pelagics) with the remaining 20% being demersal species (Ayivi 2011). Crew are remunerated based on the overall catch, the proceeds of which are split with 50% shared amongst the crew and the remaining 50% going to the canoe, net, and outboard owner(s) (Akyempon et al. 2014).

The artisanal canoe fishery has grown considerably from approximately 7,000 canoes in 1981 (Doyi 1984) to 12,728 canoes and 139,155 fishermen who utilise 314 landing sites spread amongst 190 coastal villages (Akyempon et al. 2014). There are various categories of canoes used in the artisanal sector (Doyi 1984):

- **One man canoes** – these are 4-5m in length and are generally propelled by paddle. They are used in inshore waters to set longlines and handlines.
- **Medium canoes** – these are 6-11m long, 70-100cm wide, and propelled by paddle, sail or outboard. They are generally used to set bottom set or floating gillnets, including aifa-anifa.
• Large canoes – these canoes are used in the ali, poli and watsa net fishery and are 12-19.5m long, 1.5-2.8m wide (Akyemponet al. 2014). They are mainly found in Tema and Kpone areas, and for pure seining they are propelled by outboard engines.

• Beach seine canoes – these are usually old ali canoes which have had the bow raised to prevent taking on water in the surf. They are mainly found between Ningo and Keta to the east of Tema Port. They are propelled by paddles, oars or outboard engines and range in length from 8-11m (Akyemponet al. 2014).

The following main gear types are employed in the artisanal marine fishery in Ghana (Doyi 1984):

Gillnets

Various designs of gillnets are used to target demersal species in water depths from 10-80m (Doyi 1984). Bottom set gillnets are widely used in the coastal waters of Ghana. Gillnets range from 230-350m in length and are approximately 2m deep. Mesh size ranges from 30-50mm and they are set by 2-3 fishermen on soft substrata in 10-20m of water. Species captured include the coastal fish, threadfin (Galeoidesdecadactylus), grunts (Pomdasys spp., Brachydeuterusauritus), clupeids (Ilishaafricana) and flagfinmojarra (Ecinostomusmelanopterus). Larger mesh set gillnets are also used in deeper waters 30-50m in depth. These have a 75mm mesh size and range from 180-270m in length and 2-3m in depth. They are usually set on hard bottoms to catch catfish (Arius spp.), southern common seabream (Pagruspagrusafricanus) and croakers (Pseudotolithus spp.), tongue sole (Cynoglossus spp.) and dogfish (Mustelus spp.) as well as certain molluscs. Other similar variations of these types of set gillnets also exist.

Drift nets

These nets are set on the surface or subsurface and drift freely with the current and may be attached to the vessel.

The ali net is a small-mesh driftnet used to target S. aurita. The mesh size ranges from 45-50mm, and net length varies from 450-650 m, with a depth of 30-50 m. They are operated by a crew of 10-12 fishermen at night in depths of up to 50m. Ali nets are most important at the beginning and end of upwelling seasons when the fish are more dispersed. Fishermen usually use a canoe powered by an outboard engine.

Anita-anifa are large mesh (100-200 mm) driftnets ranging in length from 100-450 m, and 15-20 m in depth. Fishing is conducted overnight and they target large pelagic species such as sharks (Carcharhinus spp.), tunas (T. albacares, T. obesus, K. pelamis, E. aletteratus), sailfish (I. albicans) and sword fish (X. gladius). They are set from outboard driven canoes with crews of up to 10 fishermen.

Purse seine

Purse seines in the artisanal sector are used to target small pelagics, primarily Sardinella spp. and Scomber japonicas, when they aggregate inshore during the major (June-September) and minor (January-February) upwelling seasons. Outside of the upwelling seasons these nets are used to target anchovy (E. encrasicolus) and juvenile sardinella spp. which remain inshore. There are numerous types and configurations of pure seine nets used in the artisanal fishery, watsa, poli and beach seine are the most important.
Watsa nets are a type of surround or purse seine net with large mesh 50-60mm with twine thickness of 0.5mm (Doyi 1984). Watsa nets range from 400-500m in length and 35-50m in depth. They are operated by a crew of 8-12 fishermen in 40-50m of water (Doyi 1984).

Poli nets are purse seine nets with smaller mesh sizes (10-13mm) and constructed from finer twine (0.33mm) (Doyi 1984). Poli net lengths range from 450 to 540m, and are 35 to 45m in depth. They are usually operated by a crew of 12-15 fishermen in approximately 30m of water depth. They are used throughout the year and are particularly common and important in the Tema region. The poli net is important for targeting anchovy (*E. encrasicolus*) due to the smaller mesh sizes. The small mesh size has also however led to overfishing of juvenile sardinellas. A poli-watsa net was developed to combine the two mesh sizes.

Beach seines are used to target small pelagic species primarily during the upwelling periods, as well as inshore demersal species and shrimps. Demersal species landed in beach seines include burrito (*Brachydeuterusauritus*), red snapper (*Lutjanusfulgens*), mullet (*Pseudupeneusprayensis* and *Mugil spp.*) and hairtail (*Trichiuruslepturus*) (FAO 2007). Beach seines also exploit shrimps (*Parapeneopsisatlantica; Penaeuskerathrus; Penaeusnotialis*) as they move between the estuaries and nearshore (Entsuah-Mensah 2005). Beach seines range in length from 6m to 1 800m and from 6m to 22m in depth. They are only operated during the day and require a large crew to retrieve the net (Doyi 1984).

Hook and line

Canoes utilising hook and line fish over hard bottoms on water depths between 10 and 200m (Doyi 1984). Canoes are usually operated by a crew of 5-6 fishermen. They are also known as Lagas canoes and have ice boxes enabling them to stay at sea for up to four days and maintain high quality product. The demersal species typically landed (Doyi 1984), substrates they occur on (FAO 1990) and the depths in which they are targeted (Doyi 1984) are listed below.

**Sparidae – Sea breams**

<table>
<thead>
<tr>
<th>Species</th>
<th>Habitat</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dentexgibbosus</em></td>
<td>Rock and sandy bottom</td>
<td>40-85m</td>
</tr>
<tr>
<td><em>Pagruscaeruleostictus</em></td>
<td>Hard bottoms, mud and sand to 150m</td>
<td>10-70m</td>
</tr>
<tr>
<td><em>Pagrusafricanus</em></td>
<td>Hard bottoms, sand and mud to 200m</td>
<td>70-90m</td>
</tr>
<tr>
<td><em>Dentexangolensis</em> 220m</td>
<td>Various substrates, continental shelf and slope</td>
<td>200-</td>
</tr>
<tr>
<td><em>Dentexcanariensis</em></td>
<td>Various substrates, on continental shelf to 150m</td>
<td></td>
</tr>
<tr>
<td><em>Dentexcongoensis</em> 125m</td>
<td>Various substrates, continental shelf and slope</td>
<td>100-</td>
</tr>
<tr>
<td><em>Pagellusbellottii</em></td>
<td>Hard and bottoms to 100m</td>
<td>20-50m</td>
</tr>
</tbody>
</table>

**Lutjanidae - Snappers**

<table>
<thead>
<tr>
<th>Species</th>
<th>Habitat</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Lutjanusfulgens</em> 10-70m</td>
<td>Rocky substrata</td>
<td></td>
</tr>
<tr>
<td><em>Lutjanusgoreensis</em> 40-90m</td>
<td>Rocky and hard bottoms</td>
<td></td>
</tr>
</tbody>
</table>

**Serranidae - Groupers**

<table>
<thead>
<tr>
<th>Species</th>
<th>Habitat</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Epinephalusaeunes</em></td>
<td>Sand and mud in coastal waters to 100m</td>
<td>40-90m</td>
</tr>
</tbody>
</table>
Epinephalus guaza (marginatus) Rock and sandy bottom from coastline to shelf edge 180-220m

**Scombridae and Carangidae – Tunas and jacks**

- **Scomber japonicas**  
  Coastal pelagic  
  125m

- **Caranx rhonchus**  
  Pelagic and near bottom to 60m  
  20-50m

- **Thunnus albacares**  
  Pelagic  
  50m

- **Istiophorus albicans**  
  Pelagic  
  50m

**Elasmobranchs**

- **Carcharinus spp.**  
  Pelagic  
  50m

9.13.3.2 Longlines

Longlines consisting of a main line 380-500m in length with 500-600 snoods and hooks are set in 10-30m of water. They are set from small canoes by canoes 1-2 fishermen. Longlines target rays (Mylobatis spp.) seabream (Pagrus pagrus africanus), threadfin (Galeoides decadactylus), hairtails (Trichurus lepturus) and guitarfish (Rhinobatos sp.) (Doyi 1984).

9.13.3.3 Lobster nets

*Panulirus regius* are targeted over rocky bottoms in depths of 10 to 50m using bottom set gillnets 180m long and 1.5-2m in depth. Mesh sizes ranges from 60-120mm. They are et overnight and used mainly off Nungo-Prampan, Senya, Beraku, Winneba from November to March (Doyi 1984).

**Light fishing**

Light fishing makes use of artificial lights at night to attract small pelagic species into dense shoals in order to improve the ease at which they can be caught. This method was introduced by the Marine Fisheries Research Division to improve catches, particularly outside of the upwelling season. Although this method was initially adopted by the semi-industrial vessels it has been widely adopted by the canoe purse-seiners over the last 10 years with over 80% of canoe fishermen in the Western Region now using this method (Fingold 2010).

9.13.4 Artisanal Fishery in the Tema area

The Tema artisanal fishery has two landing sites in the Tema Port, namely Ashamang and Awudun and all canoes use the canoe basin in Tema Port (Figure 9-18). A third landing site is located to the west of Tema (outside of project area) at Sakumono. The artisanal fishery market is also located in the canoe basin in Tema Port (Figure 9-20). Based on the recent canoe frame survey conducted in 2014 (Akyempon et al., 2014) the following information on the artisanal fishery in the Tema area can be provided. There are three fishing communities which land fish at six sites. A total of 786 canoes operate in this area, with 611 outboard motors and 10 209 fishermen who utilise the resources. Purse seining is by far the most important artisanal fishing activity in the area with 319 nets, followed by 257 line canoes. There are 92 drifting nets, 74 other nets, 35 all nets, five beach seiners and four lobster nets which are utilised in the
immediate Tema surrounds. All beach seiners occur in the Sakumono area to the west of Tema and out of the project area.

Engagement with fishermen during this assessment and previous assessments for the WAG pipeline EIA revealed declining catches by the local artisanal fleets in the Tema area (West African Pipeline Company, 2004). This was attributed to the large number of trawlers operating in the inshore waters.

9.13.5 Semi-industrial (Inshore)

The semi-industrial or inshore fleet is comprised of 397 locally built wooden vessels with inboards up to 400hp (M. Quist pers. comm.). They range in size from 8 to 37m being classed as either small (8-12m) of medium (12-22m) (Figure 9-21). It is a multipurpose fleet which uses both purse seine and demersal trawling gears. Purse seine is conducted during the upwelling seasons when small pelagics are abundant and concentrated. Purse seine nets are comprised of 25 to 40 mm mesh with nets 400 – 800 m in length and 40 – 70 m in depth. When purse seine, they capture the same species as the artisanal canoe sector.

Vessels switch to bottom trawling out of the upwelling seasons to target demersal species. Although they are permitted to purse seine within the 30 m depth or 6 nautical mile limit, they are not permitted to conduct demersal trawling in these waters. Most vessels are small and their demersal trawling abilities are limited. Small vessels target trigger fish (*Balistes capriscus*) (now declined stocks) while medium sized vessels target sparids (*Pagellus bellottii, Pagrus caeruleostictus, Dentex canariensis*) snappers (*Lutjanus fulgens; L. goreensis*) red mullet (*Pseudupeneus prayensis*), cassava fish (*Pseudotolithus senegalensis*), burrito (*Brachydeuterus auritus*) and groupers (*Epinephalus aeneus*). The vessels use ice for chilling the fish, allowing them to stay at sea for up to five days at a time. This sector is in a decline, as most of the vessels are old and in need of repair and the Government instituted a ban on pair trawling in 2008, which was commonly used by the fleet.

9.13.6 Industrial

The industrial fleet consists of large (30 to 60 m) steel hulled vessels (Ayivi, 2011) (Figure 9-22). The fleet comprises approximately 106 trawlers, two shrimpers, one crab vessel and 38 tuna vessel (M. Quist pers. comm.). They operate from the deep water ports at Tema and Takoradi only and have onboard freezer facilities and can stay at sea for extended periods. They are required to operate in offshore waters >30 m in depth and >6 nautical miles from shore (Fisheries Act, 2002), however, with the exception of the tuna fleet many industrial vessels operate in the prohibited inshore waters and hence fish illegally, competing for resources and space with the artisanal and semi-industrial sector (Ayivi, 2011). Due to the legal spatial restrictions, this sector is unlikely to be impacted by the current proposed project activities.
Figure 9-18: Artisanal canoe departing Tema Port at dusk to commence overnight fishing

Figure 9-19: Smoking small pelagic fish prior to distribution and sale
Figure 9-20: Fish market in the Tema canoe basin

Figure 9-21: Semi-industrial vessel departing Tema Port at dusk to commence overnight fishing

Figure 9-22: Industrial fishing vessel in the inner fishing harbour, Tema Port
MARINE MAMMALS, BIRDS AND REPTILES

The West African region supports a diverse marine mammal fauna. Six baleen whale species and 22 toothed whale and dolphin species most likely occur in the region. Three of these whale species are endangered (blue and fin whales), two are vulnerable (i.e. humpback and sperm whales) and several others are in lower-risk categories. Coastal areas offshore West Africa are possible breeding and nursery areas for the humpback whale, which migrates along the coast of Southern Africa to mate, calve, and nurse its young during the austral winter.

There are a few records of dolphins and whales spotted at different places along the coastline of Ghana. In a preliminary survey, Waerbeek and Ofori-Danson (1999) recorded six cetacean species: clymene dolphin (Stenella clymene), rough-toothed dolphin (Steno bredanensis), bottlenose dolphin (Tursiops truncates), dwarf sperm whale (Kogia simus), sperm whale (Physeter macrocephalus), and humpback whale (Megaptera novaeangliae). Small cetaceans were regularly caught in artisanal gillnet fisheries operating from Apam in the Central Region to Kpone in the Greater Accra Region. Annual catches were estimated to be in the low hundreds (WAGP 2004).

The aquatic birds of the Gulf of Guinea comprise two distinct groups: creek birds (waterfowl, waders, and fish-eating birds) and oceanic birds that are rarely seen near the seashore (shearwaters, storm petrels, tropicbirds, frigatebirds, gannets, and boobies). These oceanic birds do not appear to be as abundant in the Gulf as the coastal species. For instance, records dating back to the 1960s reveal only limited sightings of a few species (Elgood et al., 1994). The rarity of oceanic birds may be attributable to the absence of suitable breeding sites (e.g., remote islands and rocky cliffs) in the Gulf of Guinea.

Observations of these species within the Tema LNG study area was assessed during the baseline studies with particular reference to potential impact of shipping collisions with these species, water quality and food resources impacts and the disturbance of any turtle nesting sites within the study area.

The Gulf of Guinea serves as an important migration route, feeding ground, and nesting site for marine turtles. Six species have been identified: loggerhead (Caretta caretta), olive ridley (Lepidochelys olivacea), Kemp’s ridley (Lepidochelys kempi), hawksbill (Eretmochelys imbricata), green (Chelonia mydas), and leatherback ( Dermochelys coriacea ) (Armah et al., 1997 cited in WAGP, 2004). While they all have international protection status, populations have decreased due to poaching and habitat destruction. With the exception of the hawksbill, the rest are known to nest in significant numbers on the eastern beaches in the vicinity of the project site at Tema.

Sea turtles nest on sandy beaches, in the spray zone and grassy areas beyond the high tide mark and since they always return to the same area to nest, it is important that such beaches are protected from human activities. The young turtles hatch from eggs from their nests in the sand, endeavor to reach the water, and begin to swim away into the sea. In Ghana, sandy beaches constitute most of the coastline and much of it could serve as prime turtle nesting sites. The nesting period stretches from July to December, with a peak in November (Armah et al., 1997 cited in WAGP, 2004). The young turtles begin to appear in the sea in April. The gravid female turtles lay their eggs in burrow-nests along the sandy beaches during a particular period of the year, usually starting in the month of August.

Previous works done on the dynamics of the sea turtle on the coastline of Ghana clearly indicate that most of the beaches provide sites suitable for nesting by all the five species of
turtle in Ghana. In general, most of the beaches are known to provide nesting sites for the leatherbacks. Five of the six species (loggerhead, olive ridley, hawksbill, green, and leatherback) are known to use the beaches east of the Tema project site for nesting.

In Ghana, 86.3 percent of nests observed are those of the olive ridley. The prime nesting sites have been identified as the coastline from Prampram (about 10km to 15km East of Tema) to Ada and the areas beyond the Volta estuary to Denu, in the Volta region. It is also evident that moderate nesting occurs from Winneba through Bortianaor and some beaches around Accra such as Gbegbeseh and Sakumono (Amiteye, 2002, Tando 1999).

9.15 ECOLOGICALLY SENSITIVE AREAS

The Gao Lagoon at Tema is fringed with a narrow strip of mangrove forest (Adomako and Armah, 1989 cited in WAGP 2004). It is characterised by the presence of large *Avicennia germinans* and *Rhizophora racemosa*. This also serves as breeding grounds for some marine fishes and as roosts and/or nesting sites for resident and migratory birds. The lagoon and wetland is not expected to be significantly impacted by the Tema LNG project as a result of the proximity of the site to existing industrial facilities, which have had a significant impact on the ecological area. In this regard, the sensitivity of the Tema LNG project area is generally low.